CLIMATE SOLUTIONS LIVING LAB
ALASKA TEAM II

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This Report and Implementation Plan are student work product completed to fulfill requirements of the Climate Solutions Living Lab, a 12-week course offered at Harvard Law School. This report and plan were researched and written under tight time constraints to answer specific questions posed to the students in their course assignment. Any opinions expressed in the report are those of the students and not of Harvard University or Harvard Law School. If you would like to learn more about Harvard Law School's Climate Solutions Living Lab, please contact Professor Wendy Jacobs at wjacobs@law.harvard.edu.

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EXECUTIVE SUMMARY

Many Alaska Native peoples live in rural communities in Western and interior Alaska. Over half of these communities are very small with populations less than 500 residents. They also face some of the highest incidences of poverty in the United States and some of the highest costs for food and fuel in the world. Most communities are situated off the road and accessible only by water or air, while most households lack access to running water.

Climate change exacerbates ongoing economic and public health challenges faced by rural Alaskan communities, who lack access to cash-based economies due to their traditional subsistence-based lifestyles. Communities who face poverty are particularly vulnerable to climate change because they have fewer economic resources to respond to adversity, evacuation or emergency response. It is an unfortunate reality that climate change disproportionately impacts marginalized peoples.

To reduce climate change emissions and produce social benefits in these communities, we propose a weatherization project that encompasses energy reduction and food security while reducing greenhouse gas emissions that an unregulated entity—our hypothetical client—could use to offset its own emissions. One particular challenge for Alaska Native communities has been high and fluctuating costs of heating and energy. A second problem has been increasing food insecurity. Our project thus focuses on (1) increasing energy efficiency to lower energy bills by weatherizing residential homes and (2) creating a hydroponics project at the local school to make fresh produce more available in rural Alaskan villages and reduce the cost of transporting foods.

The project will cost approximately $2 million (mm), of which the client will fund 50%, or $1mm, with the remainder funded via grants. The project will create benefits of approximately $6mm over the course of a 15-year modeled life. All outside capital is incurred in the first 2 years for the initial hydroponics and weatherization interventions and is self-sustaining thereafter. The overall emissions reductions total to 1,563 metric tons of CO_2, at a cost to the client of $630/ton of avoided CO_2.

This project takes a holistic approach to produce an integrated weatherization project with a hydroponics component. In our cost-benefit analysis, this project emphasizes the strong social benefits of our intervention. Our mandates are to reduce costs for home energy and food expenses, improve public health outcomes, and develop education, training, and employment skills. Furthermore, this project aims to be a scalable intervention that can demonstrate its replicability for Alaska Native villages in the Alaskan rural landscape.

IMPLEMENTATION PLAN

Project Goals

Our goal is to design a culturally sensitive project that a community can use to serve their needs. We have defined this sensitivity under our criteria of cultural sustainability, which is based on emphasizing local stakeholder input and processes of participatory development throughout the implementation process. It is not our desire to impose external technocratic solutions on marginalized communities, but to instead conduct research that can be properly mobilized to serve their purposes. Our goal is to facilitate long-lasting solutions designed for community ownership.

Because the demographics and socio-economic characteristics of Native communities are so distinct from those of non-Native communities, we recognize that indigenous communities in rural Alaska have diverse characteristics and needs, and we worked to design a project that could be easily adapted to address local circumstances. We also recognize the legacy of colonialism in Alaska and in the United States more broadly, and, as a result, the importance of historical context in evaluating the social implications and public health dimensions of our work.

We have identified the following list of criteria for our project:

Carbon Reductions

Quantifiable
Additional

Feasibility

Cultural
Financial
Legality
Scalability

Socio-Economic

Public Health
Food Security
Local Employment
Educational Opportunities
Community Capacity Building

Feasibility Analysis Summary

The selection of this project for the implementation plan came through the feasibility analysis stage of our project. The two projects that were carried through the feasibility analysis were: (1) a utility-scale intervention designed to optimize diesel efficiency and recover potential waste heat, and (2) a community-scale intervention intended to reduce energy loss through residential weatherization.

The analysis of the diesel efficiency project included two alternatives: replacing the community's old generators or installing retrofits on the existing generating system to yield higher efficiency. This made the project both feasible and scalable because the exact layout of the chosen community's utility would not have been a barrier to implementation. Further, the choice of the client as the utility and the availability of different grants made for a straightforward project structure. However, the high up-front cost of the project brought about a very high cost-per-avoided-ton of CO_2. This finding along with the implied reliance of the community on diesel as a fuel source for the next decades, and the comparatively low public health benefits, led us to choose the weatherization project.

Given the large number of poorly insulated and low-energy efficiency homes in rural Alaska, the weatherization project provided a way to significantly reduce CO_2 emissions at a much lower cost than the utility-scale intervention. Furthermore, the preliminary Health Impact Assessment indicated that, by different measures of outcomes, the envisioned home improvements and stove replacement would yield more public health benefits to the chosen community. The same was true for social benefits given the strong focus on capacity building and local employment promotion. However, the involvement of multiple stakeholders and actors as well as the different legal considerations for contracting community members resulted in a set of significant, but not insurmountable, challenges. The goal of this implementation plan will be to highlight, caution, and advise our client about these issues.

While the principal goal of these projects is to reduce GHG emissions, the prevalence and ongoing rise of food access challenges in the communities under consideration -as previously described- could not remain unaddressed. Thus, all along, the team considered ways to incorporate a food security element to either project. The recent adaptation of hydroponics technologies to cold climate environments rendered it a viable and sustainable solution.

Community Profile

This project is designed for rural Native communities in Alaska, in particular in Western and Interior Alaska. Alaska Native communities share a common demographic profile: many have small populations between 200-800, above 90% of the population is Indigenous, and 30% - 40% percent of the community lives below the federal poverty line[1]. In many communities, a high child poverty rate (45%+) and most parents have 3 or 4 children on average. These communities are situated off the road and accessible only by barge or plane. Many communities lack access to running water. The cost of living is particularly high due to the prohibitive costs of shipping, and community members may depend on the local school for employment and school feeding programs[2]. Subsistence-based food patterns are the custom but due to climate change and increasing food insecurity, fresh food may be scarce, especially in winter.

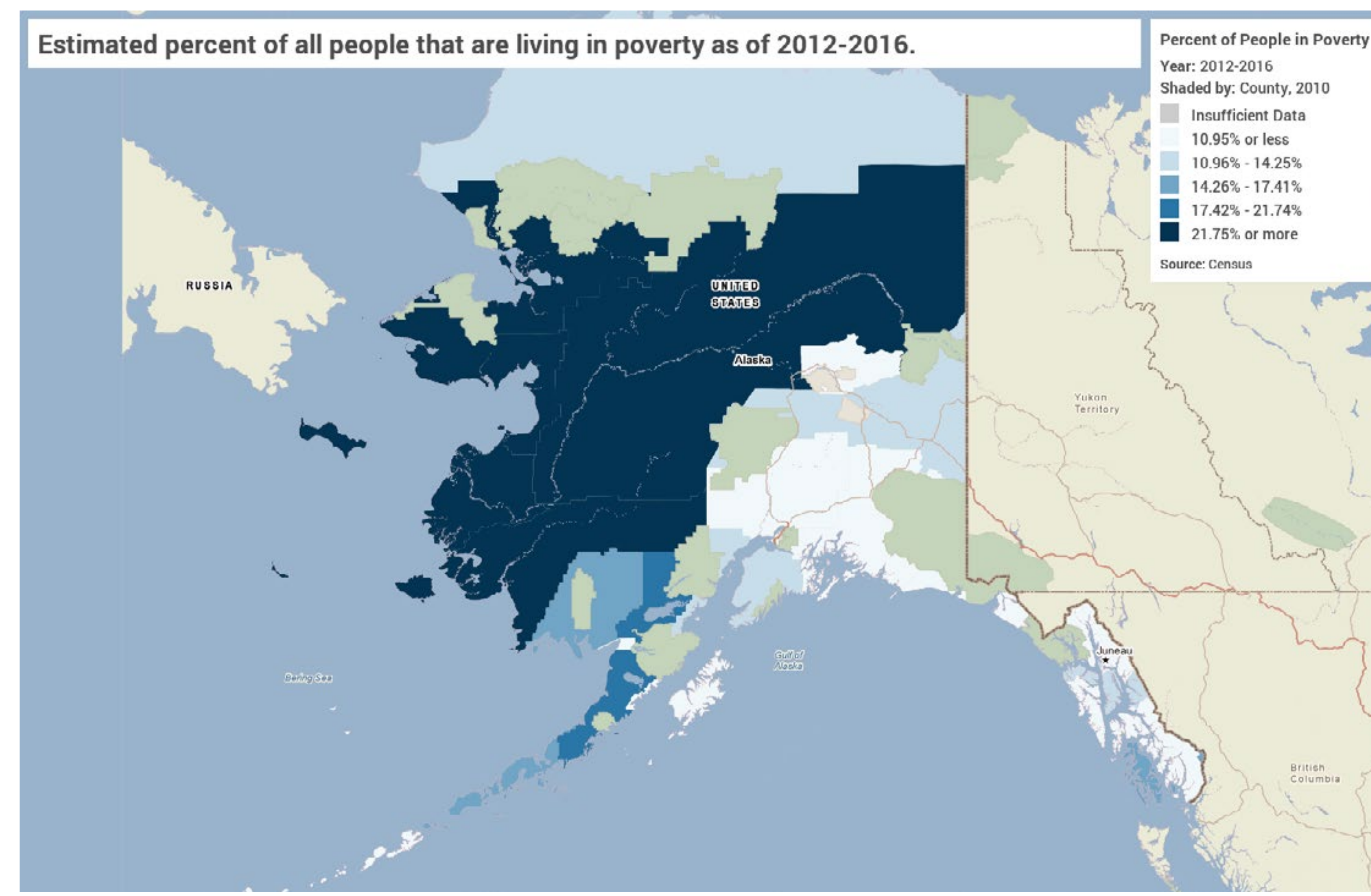
Our selected partner community is Alakanuk. We chose this community by first narrowing in on the Kusilvak Census Region in Western Alaska and after discussion with the Rural Alaska Community Action Program (RuralCAP), a nonprofit organization working in Alaska. It serves in our analysis as a sample community that may benefited from the designed intervention. Similar to many other rural Native villages, 95.4% of the community in Alakanuk is indigenous and the poverty rate is 33.8%[3]. The population of Alakanuk is around 700 based on 2016 census estimates. Half of the population is under the age of 18[4].

Alakanuk is a community that stands to benefit from weatherization but also has the capacity to support a hydroponics project, which would require a source of running water. In Alakanuk, approximately 90% of the homes are connected to a system that has a water and piped sewer system, and a central watering point. Water is derived from the Alakanuk Slough, is treated, stored in a tank, and piped to most of the community. There is a sewage lagoon available for individuals to dump their honey buckets, which are basic dry toilets where a bucket is used to collect waste.

Improving food security is also an important issue in Alakanuk. Alakanuk is off the road system and accessible only by air or water. Transportation of foods is often expensive or unfeasible. Subsistence foods include salmon, beluga whale, seal, moose and rabbit, which provide food sources, but climate change has changed the seasonal availability of many of these resources. There is one school located in the community, attended by 211[5] students. This school is potentially the site of our hydroponics component.

1. Goldsmith, Scott. "Understanding Alaska's Remote Rural Economy." UA Research Summary N.10 by the Institute of Social and Economic Research. University of Alaska Anchorage. Jan 2008.
2. Ibid
3. "Community: Alakanuk." Commerce.alaska.gov. Accessed May 05, 2018. https://www.commerce.alaska.gov/dcra/DCRAExternal/community/Details/ce7e59f5-2ed0-4555-8468-0a18a3a36191.

Federal Census Area	Kusilvak
Municipal Government	City of Alakanuk
Status of Municipality	Second-class city
Federally Recognized Tribe	Village of Alakanuk
Regional Educational Attendance Area (REAA)	Lower Yukon School District
Alaska Native Regional Corporation	Calista Corporation



4. Ibid
5. Ibid

Project Context

Indigenous communities in rural Alaska have diverse characteristics and face unique sets of issues. Nonetheless, communities share some common legal and political history and face similar environmental, public health, and economic challenges.

Legal and Political Context

Alaska is home to 40 percent of federally recognized Native tribes in the United States. Long before contact with White settlers, the Native peoples of Alaska governed themselves through traditional community systems. Today, most of the 229 tribes in Alaska have tribal councils as a governing structure[6]. However, Alaska is unique because tribal representation is not the predominant form of land ownership and economic organization in Alaska. Instead, the 229 tribes are largely enrolled in 13 Alaska Native Regional Corporations, which administer land and financial claims.

1971 Alaska Native Claims Settlement Act (ANCSA)

The federal 1971 Alaska Native Claims Settlement Act (ANCSA) by Congress created the regional corporations and extinguished Native land and resource claims[7]. ANCSA settled land claims by transferring title of land to twelve Alaska Native regional corporations and over 200 village corporations, as well as setting aside a thirteenth regional corporation for Alaska Natives that did not live in Alaska. This settlement is unique because it organized land ownership under for-profit corporations. At the time of the act, around 80000 people of at least one-quarter Alaska Native descent enrolled in the Act as shareholders. Today, approximately 60% of Alaska Natives are shareholders in ANCSA corporations. The corporations[8] are for-profit entities that pay returns to their shareholders. They are subject to Alaska state corporation law as well as federal Indian law.

Native corporations also established a non-profit association as a counterpart to provide cultural and social services. For example, the Regional Bristol Bay Native Corporation serves as the Regional Native Corporation for the area while the Bristol Bay Native Association serves as the non-profit counterpart that endeavors to provide socio-cultural, economic, and educational opportunities. Additional to the Regional Native Corporation, a community in the Bristol Bay area may also have a village corporation (there are 200 in the State) which also endeavors to provide profits and services.

In another example, in the Kotzebue community in Northwestern Alaska, the Regional Native Corporation is the NANA Regional Corporation, but the Kotzebue community also has the Regional Village Kikiktagruk Inupiat Corporation, which is organized to serve the Inupiat people of Kotzebue[9]. This Kikiktagruk Inupiat Corporation founded the subsidiary company Arctic Greens, which is a hydroponics farming company that we identify later in this implementation plan as a possible subcontracting party for the hydroponics portion of our project.

Native corporations have employed people through their industries and helped provide for their shareholders. However, Native Corporations do not pay returns to non-shareholders. Meanwhile, poverty remains an affliction in much of rural Alaska. There has also been debate over whether the corporate structure is the best model for Native governance[10]. In Rural Alaska, Native peoples live in small villages with few economic opportunities where poverty and health concerns remain omnipresent. Furthermore, although ANCSA settled land claims, it did not create legal protections for subsistence hunting and fishing[11], which are central to the Native culture, way of life and economy. Waters for fishing was not included in ANCSA and subsistence hunting for food required more land than was delegated[12].

Local Governance Structure

In addition to Native Corporations, Alaska communities also have complex state, tribal and municipal governance structures. The State of Alaska's Constitution, Article X, Section 2, created two forms of local government: cities and organized boroughs. Within boroughs, the Constitution also further divided the state into organized and unorganized boroughs. There are 19 organized boroughs and one unorganized borough. The organized boroughs were generally formed in areas of the state where economies were better developed. The Constitution created this division based on criteria such as geographic boundaries and economic interests[13]. A large portion of the state is instead designated as the unorganized borough.

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The Unorganized Borough

The unorganized borough is home to a large concentration of the rural Native communities that this project proposal targets. The unorganized borough spans over half of Alaska's land area and includes 13% of the

6. "Alaska Native Claims Settlement Act." Federal Indian Law for Alaska Tribes. Accessed May 05, 2018. http://tribalmgmt.uaf.edu/tm112/Unit-3/Alaska-Native-Claims-Settlement-Act-ANCSA-1971.
7. Alaska Native Claims Settlement Act of 1971. United States. Congress. Senate. Committee on Interior and Insular Affairs.
8. Ibid
9.

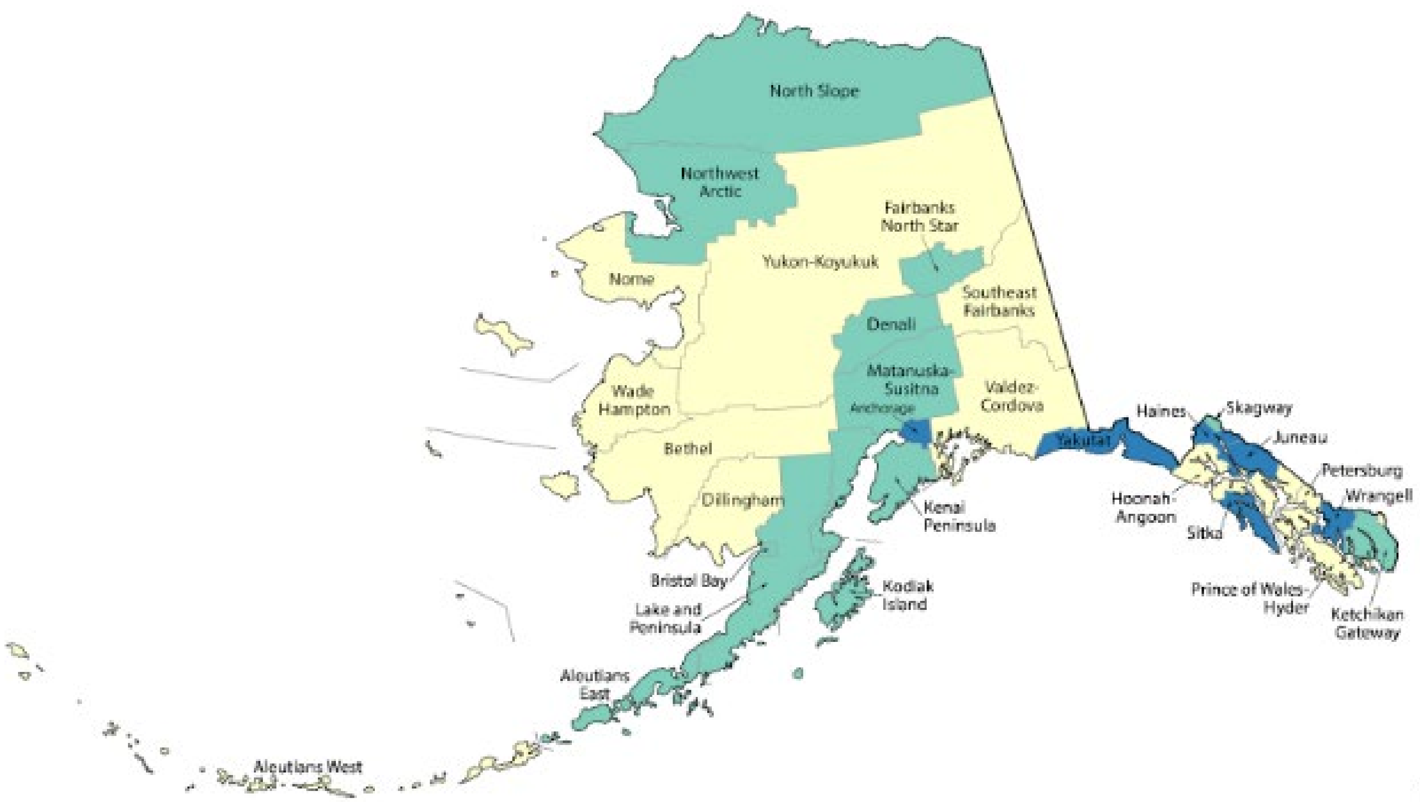
9. "Arctic Greens." Kikiktagruk Inupiat Corporation. Accessed May 05, 2018. http://kikiktagruk.com/shareholders/hydroponics/.
10. "Alaska Native Claims Settlement Act of 1971." Encyclopedia of United States Indian Policy and Law. doi:10.4135/9781604265767.n17.
11. "Alaska Native Claims Settlement Act." Federal Indian Law for Alaska Tribes Unit 3. Accessed May 05, 2018. http://tribalmgmt.uaf.edu/tm112/Unit-3/Alaska-Native-Claims-Settlement-Act-ANCSA-1971.
12.

state population. In the below map, the unorganized borough is shown in yellow. Almost all of rural Western Alaska is located in the unorganized borough. These are the areas where community organization exists in the form of small rural Native villages with populations that are 90% Indigenous. These communities may have around 500 residents that live in a community which is not linked to any road, but only accessible by plane or air. There is typically a "hub" community that is larger (around a population of 5000 or higher) that serves as a local center for commerce[13]. The hub communities typically have a more mixed demographic set and 40% may be the population is non-Native, while the proportion remains above 90% in the more impoverished rural communities.

The United States Census Bureau, a federal agency, does identify ten census areas within the unorganized borough, which is shown in below. The Kusilvak Census Region (formerly known as the Wade Hampton region), which represents an area with many communities within our target profile, has a per capita income that makes it the fourth-poorest county-equivalent in the United States. In 2014, the Kusilvak Census Region had the highest percentage of unemployed people of any county or census area in the United States, at 23.7 percent[14]. The local hub city in the Kusilvak Region is the city of Bethel.

City Planning

Since cities in the unorganized borough do not belong to a regional borough, they do not have a regional government. 145 cities are located in the unorganized borough, including Alakanuk. Among the two forms of local government in Alaska (cities and regional boroughs) rural Alaska villages in the unorganized borough only have one form: the city. Cities are further divided into different types of municipalities, such as home rule cities, first class cities, second class cities.



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13. "Alaska Native Claims Settlement Act." Federal Indian Law for Alaska Tribes Unit 3. Accessed May 05, 2018. http://tribalmgmt.uaf.edu/tm112/Unit-3/Alaska-Native-Claims-Settlement-Act-ANCSA-1971.
14. "U.S. Census Bureau QuickFacts: Kusilvak Census Area, Alaska." United States Census Bureau. Accessed May 05, 2018. https://www.census.gov/quickfacts/fact/table/kusilvakcensusareaalaska/PST045217.

Land use regulation is not required for all municipalities. Only a minority of all municipalities: boroughs, home rule cities, and first class cities, have mandatory land use regulation. The level and character of local community planning is influenced by community size and cultural make-up. Many cities in rural Alaska are classified as second-class cities and have elective planning and zoning policies. Alakanuk, our identified community, is a classified as a second-class city, which means that it does not have mandatory zoning policies.

In Alaska, the majority of municipalities do not regulate land use (81%). They may instead engage in planning for the purpose of improving general quality of life or prioritizing grant funding. One of the major motivations for rural communities in community planning has been fulfilling governments requirements to receive financial and technical assistance for public services and for physical infrastructure projects. Since Alakanuk does not belong to a regional borough, it does not have a regional government. For this reason, our contracting mechanism is with the City of Alakanuk, which is the municipality of this second-class city. Alakanuk also has a federally recognized tribal authority, the Village of Alakanuk, which is one of the 229 tribal councils recognized under federal law.

All organized boroughs as well as certain cities in the unorganized borough must operate municipal school districts, but second-class cities in the unorganized borough, such as Alakanuk, are not authorized to do so. Cities and tribal organizations typically provide community services while education is delivered by the state through Regional Educational Attendance Areas (REAAs). A Regional Educational Attendance Area (REAA) is an educational area that is established in an unorganized borough of the state[15].

Schooling

Due to the prevalence of the Native Corporation, tribal authorities are somewhat more removed from community organization in Alaska than in the Lower 48 states. Similarly, due to the lack of a regional government in the regional borough, local governance structures are more sparse and only concentrated at the city. There may be problems of community coordination and organization at the city level, since by law second-class cities, which are predominant in the unorganized borough, only have elective planning powers and are not mandated under law to act. Furthermore, second-class cities in the unorganized borough do not run their local school, which is instead organized by the REAA, Regional Educational Attendance Area. Thus, local governance can be weak in rural Alaskan communities. This is a concern that we return to throughout this proposal and something that we try to address with our proposals in contracting and project structure. For example, we identify in our contracting mechanism the possibility of contracting with either the municipality or the tribal council, depending on the strengths and organizational capacity in the local city. It is also our purpose that planning and situating such a project in an Alaskan community will help with community coordination and governance, especially since many benefits of the project centre around education and employment, which should enhance human capital in the community.

Economic Context

Native communities in rural Alaska are geographically isolated from much of the state's infrastructure and economy, producing systemic poverty. 86 percent of Alaska's 162 municipalities are not connected to the road system or to other communities. Together with the mountainous and waterway-filled geography of the state, the isolation of the communities prevents most municipalities from connecting to a major electric grid. Communities must therefore import most goods and many services, including fuel for local generation of electricity, resulting in a high cost of living. The high cost of living is exacerbated by the scarcity of employment

15, Regional Educational Attendance Areas. Alaska Statutes. AS 14.08.031.

opportunities and the resulting unemployment and poverty. While Alaska is home to high-cash-flow industries, rural Alaskan Native households have traditionally been excluded both geographically and economically from the financial benefits of such ventures[16]. Hub communities that are racially mixed tend to be more economically successful than Native communities. Moreover, wealthy industries in oil and gas may often threaten the subsistence of these communities by endangering the environment. Isolation and poverty also reduce the ability of Alaskan Native communities to respond to economic or environmental shocks, including natural disasters, oil spills, or spikes in the cost of diesel.

High energy costs can be devastating in Native communities because of their reliance on subsistence-based ways of life. Prices of oil fluctuate based on the market and this can lead to energy insecurity for Native households. Due to their independence from the modern cash economy, Native households are less likely to have disposable cash to address high energy costs and respond to unexpected fluctuations. In some rural areas, the proportion of household income spent on electricity and home heating is almost 50 percent, and that proportion has been growing. In 2000, the poorest 20% of households spent one-sixth of their income on home heating while in 2008, they spent about half. In contrast, the top 20% of households only spent 6% of their household income on heating in 2008[17]. In total, more than 200 remote communities spent approximately $186 million in residential heating costs in Alaska in 2016.

Furthermore, food insecurity is an ongoing problem in Alaska Native villages. Traditionally, Alaska Natives engaged in hunter-gatherer lifestyles to achieve food security through subsistence patterns. However, this traditional way of life faces erosion due to cultural disintegration over centuries of colonization and is exacerbated by climate insecurity. Currently, few legal protections exist to preserve Alaska Natives' access to subsistence-based lifestyles. With changing weather patterns and melting permafrost, traditional hunted game such as moose, seal, and bear is more unpredictable. In the Bristol Bay Region, a late seasonal snowfall prevented locals from being able to hunt because the lack of snow did not allow them to go into the woods on their snowmobiles[18].

In rural Alaska, shipping costs of imported foods are high and prohibitively expensive. A head of lettuce in rural Alaska may cost $8-$10[19], if it available at all. Food must be flown in by plane or transported by barge from Anchorage or Tacoma. This lack of access is exacerbated by the existing poverty. Thus, food insecurity and malnutrition from the lack of access to a steady and balanced diet are endemic problems to living in rural Alaska.

Environmental and Public Health Context

Most communities face significant environmental and public health challenges. Outdoor air quality is often harmful because of varied sources of pollution including solid waste burning, road dust, and diesel exhaust. Indeed, most communities rely on diesel fuel, which produces high levels of nitrogen oxides (NOx), particulate matter (PM), and ground-level ozone.

16. Census data for fisheries district
17. Cold Climate Housing Research Center, "Small-Scale Biomass Combined Heat and Power Demonstration Project," 2012
18. Conversation with Jayne Bennett of the Bristol Bay Native Association. March 26th, 2018.
19. Ibid

These pollutants are known to cause adverse respiratory health effects such as bronchitis, pneumonia and asthma[20]. Particulate matter can also aggravate chronic heart and lung diseases, and is linked to premature deaths in people with these chronic conditions[21]. Further, Alaska Native families experience high levels of indoor air pollution because they primarily use wood-burning stoves for heating and cooking purposes. The cold and moist environment contributes to poor indoor environmental quality in many homes. Dampness increases black mold accumulation and subsequent incidence of respiratory illness and allergic reactions[22]. Climate change is also affecting the incidence of allergies as higher temperatures and changes in precipitation influence the abundance, seasonality, and distribution of aeroallergens.

Many communities also face direct and immediate effects of climate change. Increased erosion affects many coastal communities, often threatening the long-term existence of the village. They are also affected by increasing salt water intrusion, which endangers their water supply. Climate change also leads to decreasing wildlife populations and permafrost, which affects food availability and storage. Given the reliance of Alaska Native communities on subsidence resources, climate change is a direct threat to their food security on both the short and long term scales.

Climate change disproportionately impacts marginalized peoples. Communities who face poverty are particularly vulnerable to climate change because they have fewer resources to respond to adversity, evacuation or emergency response. The environmental and public health challenges faced by many communities are also often exacerbated by the isolation of the communities: many municipalities lack comprehensive medical services and and the technical expertise needed to address increasingly difficult engineering challenges.

20. https://www.epa.gov/indoor-air-quality-iaq/wood-smoke
21. Ibid
22. https://www.cdc.gov/mold/dampness_facts.htm

Project Structure

Our basic project structures involves several key project partners. Additional to the client, the three organizations central to the project include the weatherization contractor (RuralCAP), the hydroponics contractor (Arctic Greens), and the municipality (City of Alakanuk). Other involved actors are the local school and local homeowners. Half of the upfront funding costs would be provided by the client - the other half would come from state and federal grants. After the initial implementation and installation of the weatherization and hydroponics components of the project, which will be completed in the first two years, the municipality will maintain and fund the project in perpetuity. Part of the role of the municipality is to present the residential homeowners and the school in the contracting. For the purposes of the pilot study, our weatherization contractor is RuralCAP, our weatherization contractor is Arctic Greens, and our potential clients are the Regional Alaska Native Corporation, Amazon and Alaska Airlines.

Potential Clients

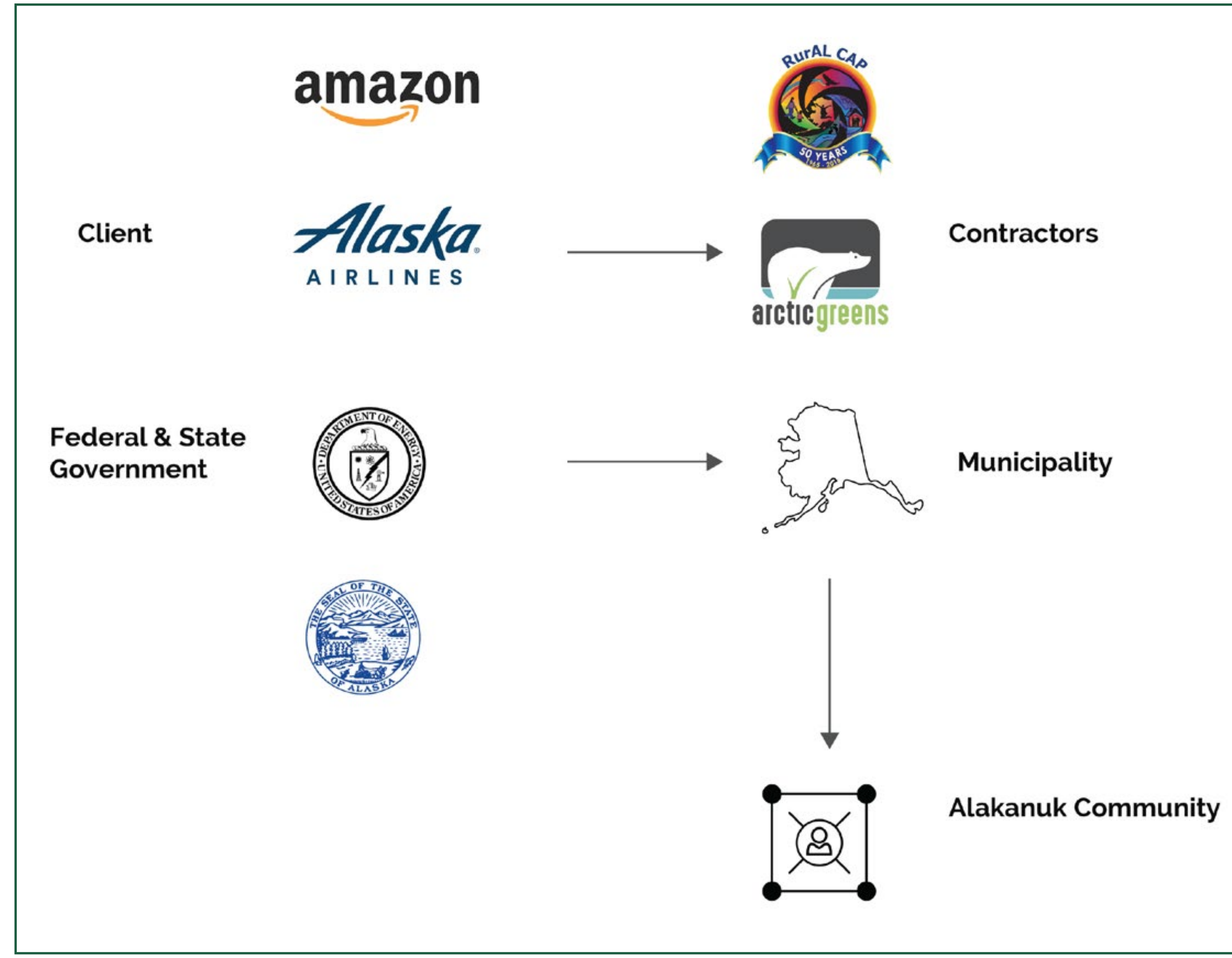
Regional Alaska Native Corporation:

The Regional Calista Native Corporation is one of the twelve Alaska Native regional corporations that provides benefits to its its Native shareholders in Alaska. It includes 48 permanent communities and eight seasonally occupied villages. The federal 1971 Alaska Native Claims Settlement Act (ANCSA) by Congress settled land claims by transferring title of land to twelve Alaska Native regional corporations and over 200 village corporations. The corporations are for-profit entities that pay returns to their shareholders. They are subject to Alaska state corporation law as well as federal Indian law. Most Native corporations also established a non-profit association as a counterpart to provide cultural and social services.

A Native Corporation has a duty to provide financial returns to its shareholders. Furthermore, they have financial assets and can afford to invest in such a project. The Calista Corporation is a unique corporate entity that may be interested in both the carbon offsets of the project but also the many social co-benefits that the project offers. A Native Corporation has an interest in the well-being of its shareholders and would want to pay for increasing food security, providing local employment, and reducing energy costs. For example, the Arctic Greens project is a subsidiary company initiated by the Regional Native Corporation in Kotzebue. The Calista Native Corporation may want to invest to see if it can replicate the model by creating its own hydroponics project. A Native Corporation would be interested in developing its own hydroponics to sell in more of its companies across the region to develop a market share and create jobs.

Amazon:

Communities like Alakanuk rely on Amazon for deliveries of everyday necessities. Due to their inaccessibility, Amazon has very high shipping costs servicing these rural off-road communities. The hydroponics component of our weatherization project helps these communities become more self-sufficient and reduces GHG emissions from avoided air shipments of fresh produce. This would reduce shipping costs for Amazon, as well provide a charismatic opportunity for showcasing the company's values around community investment.



Alaska Airlines:

The communities we are working with in Western Alaska are off the road, meaning the only way to get there is via plane or boat. Alaska Airlines would be an ideal partner, given that in part because of the lack of other access alternatives, traveling to and supplying these communities has a large air travel carbon footprint. By entering into this partnership, Alaska Airlines can offset some of these emissions it creates, while investing in and helping local communities in their home state.

Potential Partners

City of Alakanuk

The project contracts with the City of Alakanuk as the representative of the community. Alakanuk is classified as a second-class city with elective planning powers located in the unorganized borough of Alaska. At the local governance level, since Alakanuk does not belong to a regional borough, it does not have a regional government. Our contracting mechanism is with the City of Alakanuk, which is the municipality of this second-class city. Alakanuk also has a federally recognized tribal authority, the Village of Alakanuk.

Local governance structures in rural Alaska can be complicated and weak because municipalities are not legally mandated to take on many roles. For example, as a classified second-class city, Alakanuk are not legally obligated to use planning powers nor do they run a municipal school district. The governance structure is further complicated because of the existence of both tribal governments and municipal governments. Some communities may have one but not the other, or others may have both. Alakanuk has both, and we have chosen to contract with the local municipality because it has broader elective land use and planning powers, and also because it has connections to the School Board Members of the Regional Educational Attendance Areas, which runs the local schools. For the replicability and scalability of the contracting mechanism, in communities without a municipal government, it would be possible to contract with the local tribal government, which is one of the 229 federally recognized tribe in Alaska.

RuralCAP

RuralCAP stands for Rural Alaska Community Action Program, Inc. It is a non-profit community action program "working to improve the quality of life for low-income Alaskans"[23]. It works on weatherization in Anchorage, Juneau, Northern Alaska, and Western Alaska. Our contacts at RuralCAP include Carla Burkhead, Rural Housing Coordinator, and Shelby Clem, RuralCAP Housing and Weatherization Field Manager. RuralCAP receives funding for weatherization from the Alaska Housing Finance Corporation (AHFC), which receives the funding from the Department of Energy for their Weatherization Assistance Program. RuralCAP is considered by AHFC to be a subcontractor that then executes the programming of the Weatherization Assistance Program. RuralCAP also receives money from HUD. About 80% of RuralCAP money is federal and 20% is state. RuralCAP is currently working on four communities in Western Alaska and they identify that there is much more need in the rural landscape.

Artic Greens

Arctic Greens is a subsidiary company and social enterprise founded and owned by Kikiktagruk Inupiat Corporation (KIC), a village Alaska Native Corporation organized to serve Kotzebue, a community in Northwest Alaska. It operates hydroponics farms in communities where conventional farming is inaccessible and it opened first in 2016 in Kotzebue[24]. The Kikiktagruk Inupiat Corporation partnered with Anchorage company Vertical Harvest to design and build the farm, with long-term plans to expand and sell produce in at least 30 communities. Arctic Greens eventually has aims to have a farm in each community that sells produce, since it only wants to sell local, with goals to be "the largest rural supplier of produce throughout Alaska and Canada[25]." Arctic Greens thus has experience creating and installing successful hydroponics projects. It has Native-led expertise in an agricultural and dietary intervention and experience selling the produce successfully. Its model as a entity of a Village Corporation is also an interesting structure that may be appealing to our third identified potential client: the Regional Calista Native Corporation in the Western Alaska region.

State and federal governments

There are a variety of state and federal sources that could be tapped for grant funding. These include the US Department of Energy's Weatherization Assistance Program (WAP) funding, which is administered through state weatherization agencies - for Alaska, this is the Alaska Housing Finance Corporation (AHFC). RuralCAP is a listed weatherization service provider eligible to use this funding. Additionally, the Native American Housing Assistance and Self Determination Act of 1996 (NAHASDA) created a source of flexible tribal funding for housing, which would potentially be used for weatherization based on the discretion of the tribe. The Alaska Energy Authority also provides funding, at a state level. In addition to the WAP funding, AHFC also channels

23. "About Us." Rural Alaska Community Action Program, Inc. Accessed May 05, 2018. https://ruralcap.com/about-us/.
24. "Arctic Greens." Kikiktagruk Inupiat Corporation. Accessed May 05, 2018. http://kikiktagruk.com/shareholders/hydroponics/.
25. Ibid

US Department of Housing and Urban Development funding. Finally, there is public health funding available for stove replacements.

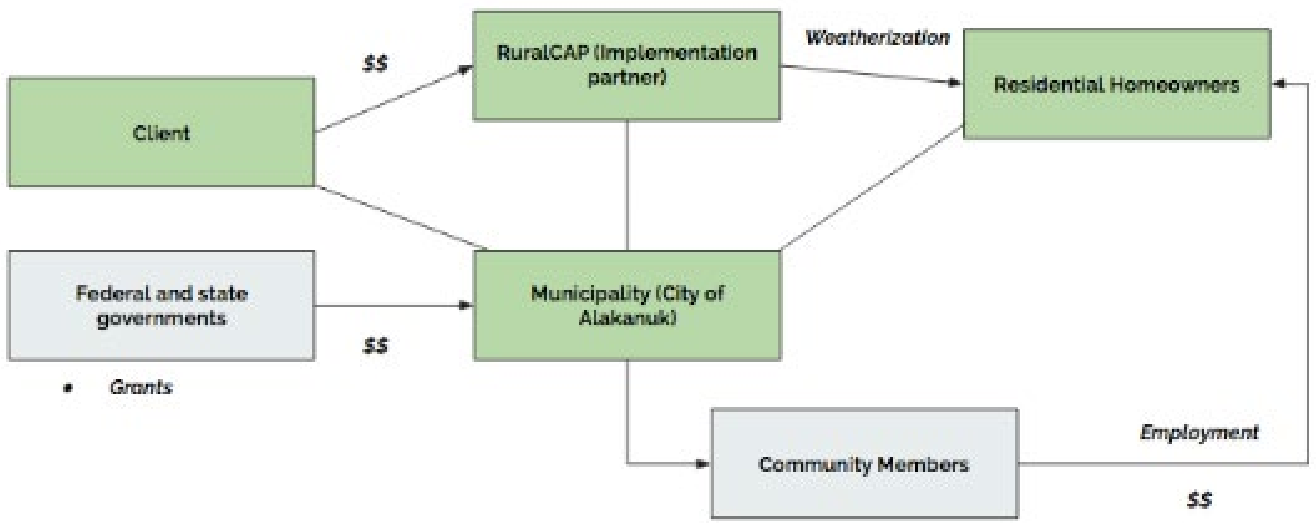
Mechanisms

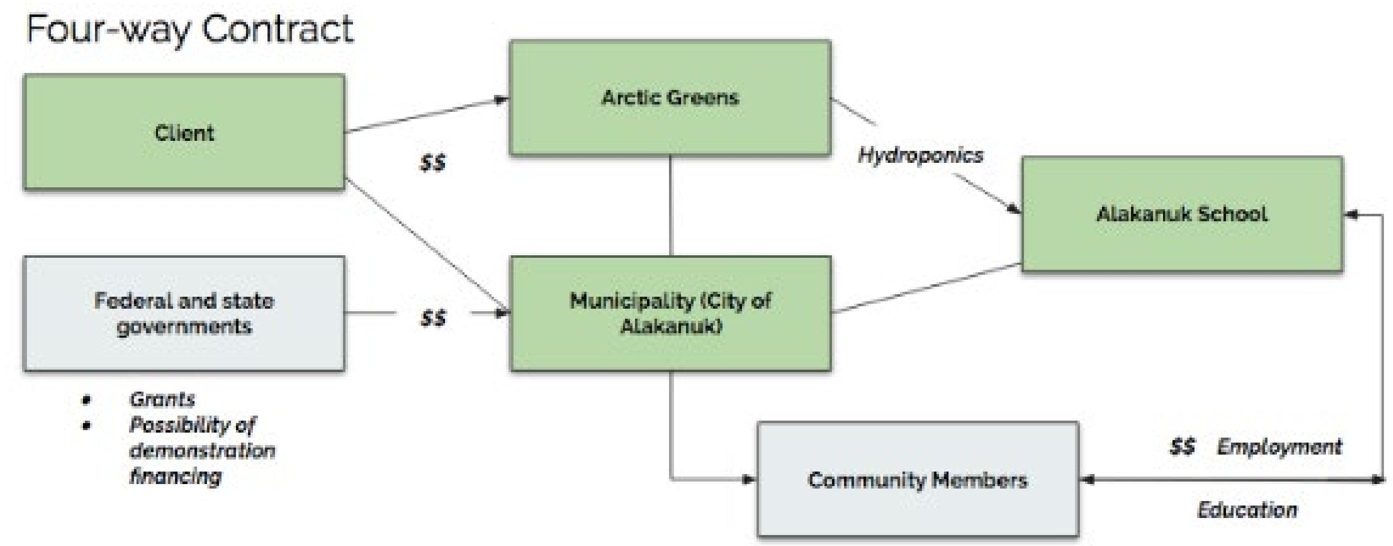
The project aims to create multiple social benefits, including employment. The weatherization contractor will hire and train locals to carry out the weatherization, and the hydroponics project will employ a full-time employee to maintain the farm. There will be an educational component to the project hosted at the local school that will engage local youth in the hydroponics project, teaching them about healthy eating, farming, and botany.

A key component of the project is the long-term maintenance fund, which ensures long-term sustainability and feasibility. Residents will contribute 10% of their energy bill savings to the fund, as will a portion of the profits from the produce sold from the hydroponics farm. In the future, when residents experience appliance breakdowns or other weatherization-related maintenance, they can draw from the maintenance fund.

Contracting Mechanisms

Our project consists of two contracts, one for the appliance upgrades and residential weatherization, and the second for the construction of a hydroponics greenhouse at the local school. The first phase of the contracting involves approaching the community to gain its buy-in and consent, and then the community would aid and serve as a representative cultural broker with the local parties—
the local homeowners for the weatherization component and the school for the hydroponics greenhouse—to gain their interest and cooperation for project implementation. The reason to contract with a community representative is that a representative body is much closer to the interests of the community and would be able to coordinate the two parts of the project (the weatherization and the hydroponics) better over the long-term project life-span.





Weatherization

The weatherization project contracts in two phases. The first step of the project is to approach the municipality of the community and obtain its consent and buy-in. The municipality is in the best position to approach the individual community members along with RuralCAP, which is a trusted organization in Western Alaska, to determine if the community is interested in the project. After obtaining community buy-in with the municipality and determining the interest and direction of the project, the municipality and RuralCAP will apply for eligible federal and state government grants to determine how much funding they will be able to contribute to the pool. At this point, the amount of funding from the client and from grants would be clear, and so would the number of participating home-owners. The municipality, RuralCAP, and the client would then agreeing to the overarching goals and timeline of the project, along with the steps each actor must take to contribute funding. The client would then give its funding to RuralCAP, which has the capacity to create a separate fund specifically for the purposes of the carbon offset project, and is the most experienced project partner to guard against risk and carry out the terms of the project.

Phase Two: Each home-owner would also have to sign a contract that the municipality, RuralCAP, and the client are party to. The contract would specify the length and duration of the project, and a promise that the home-owner would not alter his or her home after the weatherization so to ensure that the offsets are attained.

For the client's risk, the client would be able to enforce remedies against the municipality and RuralCAP if the project were to go amiss. This is preferable to having to contract only separately with each homeowner, which would put both the homeowner, a party with little bargaining power or knowledge, and the client, which is far-removed from the geographic location of the project, in vulnerable positions. The best party to enforce the contract against would be RuralCAP, which is a seasoned weatherization partner with deep expertise in the sector and the region.

Hydroponics

For the hydroponics greenhouse, which would be installed at the local school, the project would require a four-way contract. Once again, the project begins with the client obtaining the buy-in and assent of the municipality to ascertain that there is interest at the local school to develop a greenhouse, as discussed in Phase One of the contracting set-up above. The contract would then involve four entities: the client, the municipality, Arctic Greens (the implementation partner), and the Alakanuk School, which is run by the Regional Educational Attendance Areas (REAA), which is the Lower Yukon School District. The Regional Educational Attendance Area runs the local schools in the area. The Alakanuk municipality does not run the school, but it coordinates with the school board representatives. Thus, there is a representative linkage between the municipality and the school. This would aid in the coordination between the client and the project. Otherwise, to contract only directly with the school would be difficult because the school is organized by a larger school board that is not headquartered in the community. Furthermore, if there is employee turnover at the school, the institutional knowledge would be lost with employee turnover.

The municipality and the implementation partner, a social enterprise such as Arctic Greens, would also apply for relevant grants. A potential source of innovative financing would be for the school and the municipality to appeal to relevant agencies that fund school feeding and child feeding programs in rural Alaska. For example, the US Department of Agriculture funds the Summer Food Service Program (SFSP) administered by the State of Alaska Department of Education & Early Development to provide that low-income children, predominantly in rural areas, nutritious meals when school is in session[26]. Government agencies might be interested in providing demonstration funding to invest in hydroponics to see if growing local food would offset their costs, provide healthier meal options, and also reduce their carbon footprint in shipping to these remote regions.

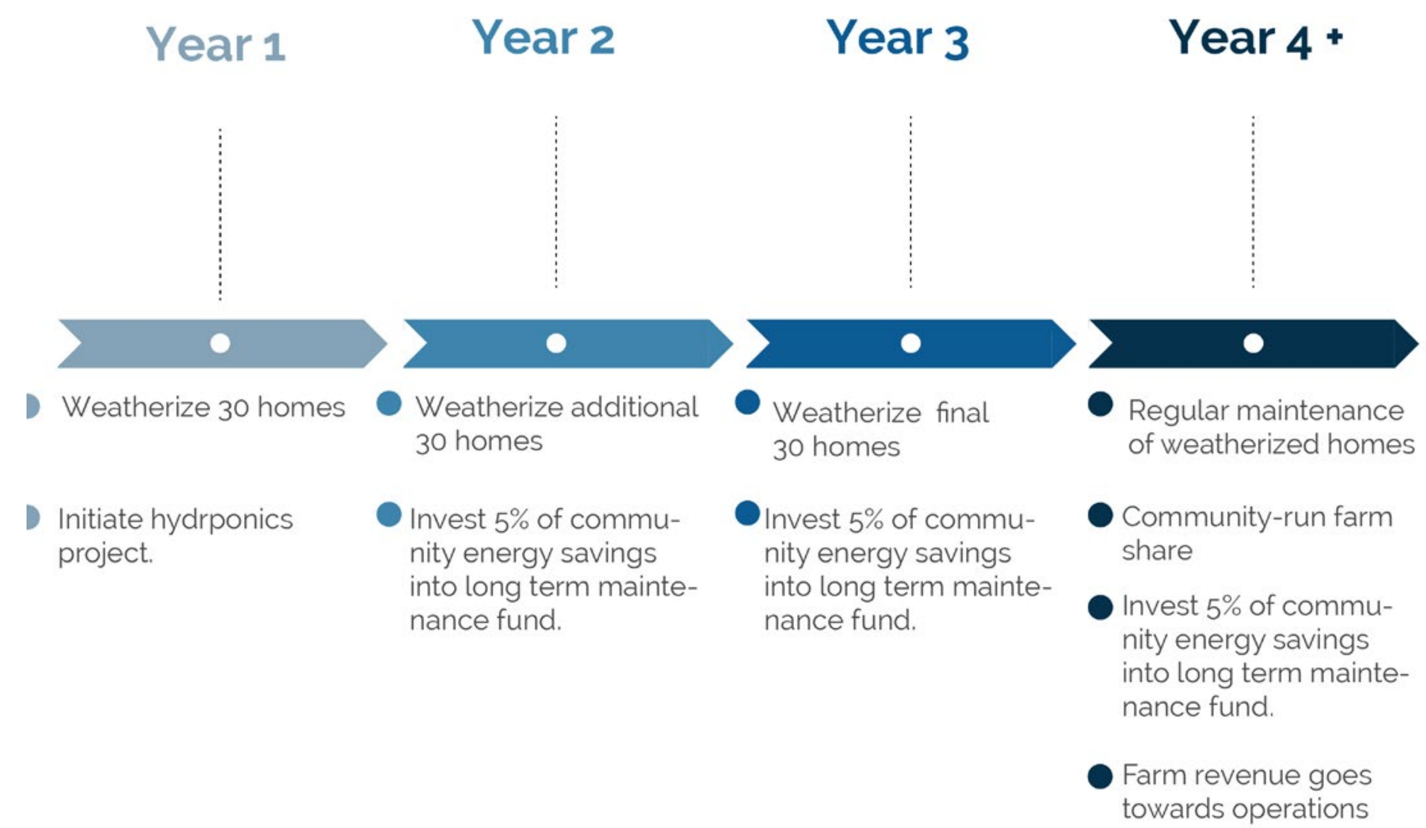
The client would give the funding directly to the implementation partner, Arctic Greens, which would combine the grant funding with the client funding to create the project at the local school. Arctic Greens is also responsible for initial training and set up with local community participants, which is a role that it has experience in. The school and the community would likely appoint and hire a committee of responsible persons to oversee the project and to ensure it runs smoothly. Arctic Greens would participate in the process and provide adequate tools for training to prepare the project for its departure.

26. "Federal Programs." Mission & Financials | Food Bank of Alaska. Accessed May 05, 2018. http://www.foodbankofalaska.org/programs/federal-programs.

Project Timeline

The weatherization component of the project will occur over the first 2 years, with 30 homes weatherized per year. The hydroponics component will be installed at the beginning of the first year. The project requires outside funding for these first two years, only - thereafter, all operating and maintenance costs can be self-funded from the profits from selling the hydroponics produce, and the project becomes self-sustaining.

The weatherization process generally takes 6-8 months to complete, from beginning to end. After the eligible houses are identified and scheduled for weatherization, RuralCAP will take over. First, RuralCAP needs to run an assessment on the house. Then, they order the materials to be delivered to the community. An accounting administrator oversees this process to ensure accuracy. RuralCAP will engage 4 employees within RuralCAP, and hires and trains 4-6 locals on weatherization. There will likely be economies of scale and learning curves on this training, given that locals can complete multiple weatherization jobs in the community. After weatherization is complete, the homes require monitoring and evaluation of public health impacts.



Weatherization

Alakanuk produced 793,216 kWh that were sold to 163 residential customers from 2015 to 2016, for an average annual residential electricity use per home of 4,866 kWh[27]. Weatherization and energy efficiency measures can reduce residential electricity consumption. The Cold Climate Housing Research Center reports that the Alaska Housing Finance Corporation's Weatherization Assistance Program has produced an average energy use savings of 32 percent for space heating interventions and 3 percent for appliance upgrades. We assume that the energy savings are not additive but instead are relative to the initial energy use; if a household completes both interventions, it will reduce its energy use by 34 percent. In Alakanuk, these interventions would produce an annual savings of approximately 1,600 kWh per home and 150 kWh per home for space heating and appliance upgrades, respectively. If two interventions are implemented in concert, the annual savings would be 1,648 kWh per home [Table 1].

Alakanuk is serviced by the Alaska Village Electric Coop (AVEC), which is eligible for the state's Power Cost Equalization (PCE) program, a subsidy that provides reduces the effective electricity rate for eligible customers. As a result, Alakanuk has two residential electricity rates: a standard rate of $0.57 per kWh and a PCE effective rate of $0.22 per kWh. For an average PCE-eligible household, a space heating intervention could save the family $340 per year, and appliance upgrades could save $32 per year. Combining the two interventions could save a household $360 per year. For a household paying the standard electricity rate, a space heating intervention could save a family almost $900 per year and appliance upgrades $83 per year. Combining the upgrades could save a family almost $950 per year [Table 1]. These estimates should be treated as an underestimate. RuralCAP, an Alaskan organization that has conducted many weatherization upgrades in the region, estimates that the average annual cost savings for a weatherized household are closer to $2,000.

Regardless of the exact financial savings associated with weatherization, the cost reduction is significant: the underestimate calculated here represents half of the annual electricity cost for a weatherized household, and up to 2 percent of annual income of a household earning the region's median income. For a family of five at the federal poverty line, the RuralCAP estimated savings represent up to 7 percent of annual income.

Given the financial benefits of weatherization and the budgetary constraints of the project, it is important to identify those households who will benefit the most from the intervention and who have the greatest need of the benefit. The Alaska Housing Finance Corporation reported in their 2017 Alaska Housing Assessment that 35 percent of occupied homes in the Kusilvak census area were built before 1980 and have not had retrofits installed[28]. These homes represent those that are likely to benefit the most from weatherization interventions. This subset of households is also likely to intersect with the neediest households. Assuming that the regional average holds true in Alakanuk, and that this threshold correctly identifies the homes in the greatest need of assistance, approximately 60 homes in the community are suitable for retrofitting.

If space heating interventions are implemented in all 60 homes, the total electricity reduction would be approximately 88,300 kWh per year. If appliances are upgrad-

26. "Federal Programs." Mission & Financials | Food Bank of Alaska. Accessed May 05, 2018. http://www.foodbankofalaska.org/programs/federal-programs.
27. This is the most recent period for which data is available. Within the Kusilvak census area (formerly the Wade Hampton census area), annual residential electricity consumption per home has increased an average of 2.4 kWh per year from 2002 to 2013. Projecting forward, this would suggest that average annual residential electricity use in Alakanuk increased by 4.8 kWh from the 2015 to 2016 period to the present. This is a an insignificant increase relative to current per capita energy use, and given the uncertainties associated with the trend, we opt to use the 2015 to 2016 data.

28.An estimated 36 percent of occupied homes in the region have been retrofit through the Weatherization Assitance Program, an initiative of the federal Department of Energy that is administered through state agencies and organizations.

Intervention	Per Home Electricity Reduction (kWh per year)	Per Home Cost Savings $ per year	NON PCE	Total Electricity Reduction (kWh per year)	Total Diesel Reduction (gal per year)
Space Heating	1,557	343	888	93,427	6,741
Appliance Replacement	146	32	83	8,759	632
All Interventions	1,656	364	944	99,383	7,171

Table 1: Electricity and disel reductions associated with weatherization interventions, on a per-home and village-wide basis.

Intervention	Total Diesel Reduction (gal per year)	Total CO2 Reduction (metric tons per year	Total PM2.5 Reduction (kg per year)
Space Heating	6,741	69.0	2.5
Appliance Replacement	632	6.5	0.24
All Interventions	7,171	73.3	2.7

Table 2: Carbon dioxide equivalent and particulate matter reductions associated with reductions in diesel emissions.

29. These are given by the 2014 "Emission Factors for Greenhouse Gas Inventories" from the EPA, which cites the IPCC. While there are more recent numbers available, this was the most complete compilation of emission factors relevant to the project.
30. Here we consider the emissions of carbon dioxide (CO2), nitrous oxide (N2O), and methane (CH4) weighted by their 100-year global warming potential (GWP), which considers the different effects of the gases on global radiative forcing. The emission factors used were 10.20 kg CO2 per gallon, 0.08 g N2O per gallon, and 0.42 g CH4 per gallon. Emissions were weighted by 100-year GWP values of 1, 298, and 25, respectively.

ed, the total electricity reduction would be approximately 8,300 kWh per year. If the two interventions are combined, the reduction would be 94,000 kWh per year [Table 1].

AVEC reports that the fuel efficiency in Alakanuk is 13.86 kWh per gallon of diesel. Thus, the diesel savings for 60 space heating intervention are approximately 6,400 gallons per year. For appliance upgrades, the diesel savings are approximately 600 gallons per year. For two interventions, the diesel savings are 6,800 gallons per year [Table 1].

Based on these diesel reductions and EPA emission factors[29] for carbon dioxide and other greenhouse gases[30] emitted from diesel[31], it is possible to estimate the reduction in greenhouse gases associated with the weatherization of 60 homes in Alakanuk. This reduction is expressed in carbon dioxide equivalents (CO2-e), which considers the different contributions of different greenhouse gases to global radiative forcing. This method suggests that the project would initially produce savings of 70 metric tons of CO2-e per year [Table 2].

Following the same procedure, it is possible to estimate the reduction in particulate matter (PM2.5) associated with a decrease in diesel consumption[32]. According to this calculation, space heating interventions would reduce PM2.5 by 2.5 kg per year, appliance upgrades by 0.25 kg per year, and both by 2.7 kg per year. These reductions represent between a 2.7 and 2.9 percent decrease in particulate matter emissions associated with electricity generation[33]. This calculation does not consider the decrease in indoor particulate associated with replacing wood-burning cookstoves with high-efficiency alternatives. As such, this reduction should be treated as an underestimate [Table 2].

There are several important caveats to this analysis:

First, weatherization interventions are likely to become less effective over time as insulation degrades and appliances age. The cost, fuel, and pollution reductions will therefore also decrease over time. The values calculated here should thus be treated as an upper estimate with respect to time.
Second, community-level calculations assume the weatherization of 60 homes. As noted above, this number was determined from regional values for the percentage of homes built before 1980 that have not yet been weatherized. However, it is possible that the available housing stock in Alakanuk may differ from this regional average. Moreover, even if 60 homes are suitable for weatherization interventions, it is possible that some households may prefer to abstain from project participation. In the event that 60 homes are not available under the proposed eligibility criteria, the project will lower the criteria as needed. The project could allow any home built before 1985 that has not been weatherized to be eligible, or it could identify an income threshold for eligibility.

Third, the calculations assume that all homes achieve equal relative efficiency improvements. It is likely that there would be some variability in the relative and absolute efficiency improvements associated with weatherization interventions. This analysis assumes that the

31. We use the average of the values given for distillate fuel oil no. 1 and no. 2, both of which are commonly used in rural Alaskan communities. No specific information on the fuel used by Alakanuk was available. The emission factors for both fuels are very similar, so using the average does not skew the result unnecessarily.
32. We use an emission factor of 0.83 pounds PM2.5 per 1,000 gallons.
33. The effects of particulate matter depend on its atmospheric concentration (mass per volume). As such, the calculated total reduction is useful only if it can be compared to baseline concentrations and be used to calculate the associated decrease in PM2.5 concentration. However, in the absence of air quality monitoring stations near Alakanuk, we offer the percentage decrease as an alternative metric.

regional average efficiency improvements given by the Cold Climate Housing Research Center reflect a representative subset of the available housing stock, and that the housing stock selected in Alakanuk is also representative. If this assumption holds true, the average efficiency improvement across the 60 weatherization projects would be approximately 34 percent, even given variability in the improvements for each home. Thus, the per home values calculated here should be treated as an average reduction across all weatherized homes.

Fourth, the analysis assumes that there are no additional costs to the homeowner associated with the weatherization interventions. However, it is possible that weatherization measures may degrade over time or break. To avoid incurring this cost on the homeowners, who may not be able to afford the maintenance fees and who may therefore experience decreasing project benefits over time, the project requires that participating homeowners pay 10 percent of the electricity savings into a long-term maintenance fund. Thus, the calculated cost savings should be reduced by 10 percent, but no additional calculation need be done to include long-term maintenance costs.

Finally, the calculations assume that the selected homes would not be weatherized without project intervention and that all reductions can be attributed to the project. While it is possible that some of the housing stock considered may be weatherized without the project, it is unlikely that these projects could occur without incurring debt. In the past, the Weatherization Assistance Program, a federal Department of Energy program administered through state agencies and organizations, funded many weatherization projects in the region. However, recent appropriations bills attempted to eliminate the program. While the government has opted to pass continuing resolutions in lieu of a full appropriations package, the risk that the program will be eliminated increases the financial risk associated with weatherization projects. Thus, the project assumes financial additionality and accepts the reductions associated with the weatherization of all 60 homes. However, the calculated values should be seen as an upper limit on possible reductions to account for the chance that homes would be weatherized even absent the project.

Hydroponics

The hydroponics component of the project also has the potential to produce cost, fuel, and pollution reductions. However, because this component requires construction and maintenance of new systems rather than improving the efficiency of existing components, there are also positive costs associated with it. The financial costs associated with construction and maintenance and the benefits associated with the decreased food costs will be described in the financial analysis. The net fuel use and resulting pollution emissions are described below.

A hydroponics system that produces approximately 900 pounds of produce per week requires 300 kWh per day or 110 MWh per year to provide adequate light, heating, and water supply to the plants. At a fuel efficiency of 13.86 kWh per gallon of diesel, as in Alakanuk, this electricity demand would be met by the consumption of 7,900 gallons of diesel per year. Using the same emission factors as in the previous section, this fuel consumption would produce 80.8 metric tons of CO2-e and 3.0 kg of PM2.5 per year.

However, the hydroponics project also generates produce that would otherwise be shipped by barge or plane, displacing emissions. Because Alakanuk is accessible by sea for only a portion of the year, consider first the displaced emissions associated with airplanes.

Assuming the hydroponics project produces 900 pounds of produce each week, for 90 percent of weeks in the year, the project will produce 42,120 pounds (19.1 metric tons) of produce each week. Assume also that food would otherwise travel from Sacramento, California, an agricultural hub located relatively close to Alaska, via Tacoma, Washington. This transport path requires that the food travel approximately 3,000 km. The IPCC estimates that direct CO2 emissions per distance travelled and mass of cargo for long-haul cargo aircraft is between 375 and 975 g CO2 per metric ton-km. Using the median of 675 g CO2 per metric ton-km, the hydroponics project would prevent the emission of 51.6 metric tons of CO2:

4,000 km19.1 metric tons 675 g CO2metric ton- km1 metric ton1106g=51.6 metric tons CO2

If the displaced food were transported from farther away, the prevented emissions would increase. Consider a scenario in which food is transported first from Mexico City to Sacramento, adding an additional 3,000 km to the journey. In this case, the emissions prevented by the hydroponics project would almost double to 90.2 metric tons CO2:

7,000 km19.1 metric tons 675 g CO2metric ton- km1 metric ton1106g=90.2 metric tons CO2

Both of the above scenarios assume that food is transported by only long-haul cargo flights. If the displaced food would normally complete any short-haul trips (fewer than 800 km) by plane, the prevented emissions would increase dramatically. Consider a scenario in which food would be transported from Sacramento to Alakanuk via Anchorage, with the second leg requiring a short-haul flight. The IPCC estimates that short-haul cargo aircraft have direct CO2 emissions of between 1,200 and 2,900 g CO2 per metric ton-km. Short-haul aircraft that transport both passengers and cargo have direct CO2 emissions of between 800 and 2,000 g CO2 per metric ton-km. Using 1,700 g CO2 per metric ton-km as an intermediary value that exists in

both ranges[34], the hydroponics project would prevent the emission of 59.8 metric tons of CO2:

Sacramento to Anchorage: 3,000 km19.1 metric tons 675 g CO2metric ton- km1 metric ton1106g=38.7 metric tons CO2
Anchorage to Alakanuk: 650 km19.1 metric tons 1,700 g CO2metric ton- km1 metric ton1106g=21.1 metric tons CO2
Total: 59.8 metric tons CO2

If food were transported first from Mexico City, avoided emissions would again increase:

Mexico City to Anchorage: 6,000 km19.1 metric tons 675 g CO2metric ton- km1 metric ton1106g=77.4 metric tons CO2
Anchorage to Alakanuk: 650 km19.1 metric tons 1,700 g CO2metric ton- km1 metric ton1106g=21.1 metric tons CO2
Total: 98.5 metric tons CO2

By contrast, if food were flown to Tacoma before being transported by barge to Alakanuk, the avoided emissions would decrease since the carbon footprint of a barge is lower despite the need to transport the food over longer distances:

Sacramento to Tacoma: 1,000 km19.1 metric tons 675 g CO2metric ton- km1 metric ton1106g=12.9 metric tons CO2
Tacoma to Alakanuk: 4,000 km19.1 metric tons 40 g CO2metric ton- km1 metric ton1106g=3.1 metric tons CO2
Total: 16.0 metric tons CO2

Hydroponics Component	Total CO2 Reduction (metric tons per year)
Energy Use	-80.8
Energy Savings	51.6
Total	-29.2

Table 3: Net carbon footprint of the hydroponics project.

The variability of emissions avoided under these four scenarios demonstrates the dependency of emissions on both the origin of the food and the transport path taken. Because Alakanuk is inaccessible by barge for a portion of the year, we use the estimate of avoided emissions associated with transport of food by plane from Sacramento. This provides what is likely an underestimate of the emissions avoided if all food were transported by plane, thus balancing any reductions in the total footprint associated with any barge transport. The net carbon footprint of the hydroponics project is therefore estimated to be -29.2 metric tons CO2 [Table 3]. However, the magnitude and sign of this estimate is highly uncertain.

Note that the analysis of avoided emissions was conducted only for CO2 and not for PM2.5. The quantity of particulate matter emitted from aircraft is highly uncertain, due in part to the fact that the pollutants are released in the upper troposphere or lower stratosphere, where atmospheric chemistry, transport, and radiative transport are different than in the lower troposphere. As a result, any available estimates for particulate matter emission factors for aircraft are highly uncertain. This calculation is therefore excluded from this analysis[35].

Complete Project

The total carbon reduction associated with the Alakanuk project is summarized in Table 4.

34. This value is the average of the mean direct CO2 emissions from short-haul cargo flights and the mean direct CO2 emissions from short-haul mixed passenger-cargo flights. Thus, this value represents the average emissions produced if half of produce was transported by cargo flights and half by mixed passenger-cargo flights.
35. This uncertainty is also responsible for the use of direct CO2 emissions rather than CO2-e emissions in the analysis of avoided emissions. The climate effect of many gases emitted high in the troposphere or low in the stratosphere is highly uncertain both in magnitude and in sign.

The proposed project is highly replicable within western Alaska. At a population of approximately 700, Alakanuk has a slightly larger population than the region average of 460, but it has a similar number of households (163 compared to the region average of 121) that use similar amounts of energy per year (4,866 kWh compared to the non-hub community average of 5,068 kWh and the PCE community average of 4,405 kWh) at similar fuel efficiency values (13.86 kWh per gallon compared to the region average of 13.1 kWh). The communities in the region also experience similar climatic conditions. As a result, the project could be replicated to similar effect throughout the region. Using the same methods used above, the emissions reduction associated with expanding the project to the 33 PCE-eligible communities in the region with populations less than 1,000 would be 1,060 metric tons CO2-e per year and 63.6 kg PM2.5 per year. Moreover, many other communities have higher annual electricity costs and so would experience increased cost savings from a weatherization project relative to those estimated for Alakanuk.

Project Component	Total CO2 Reduction (metric tons per year)	Total PM2.5 Reduction (kg per year)
Whole Weatherization	73.3	2.7
Hydroponics	-29.2	-
Total	44.1	2.7

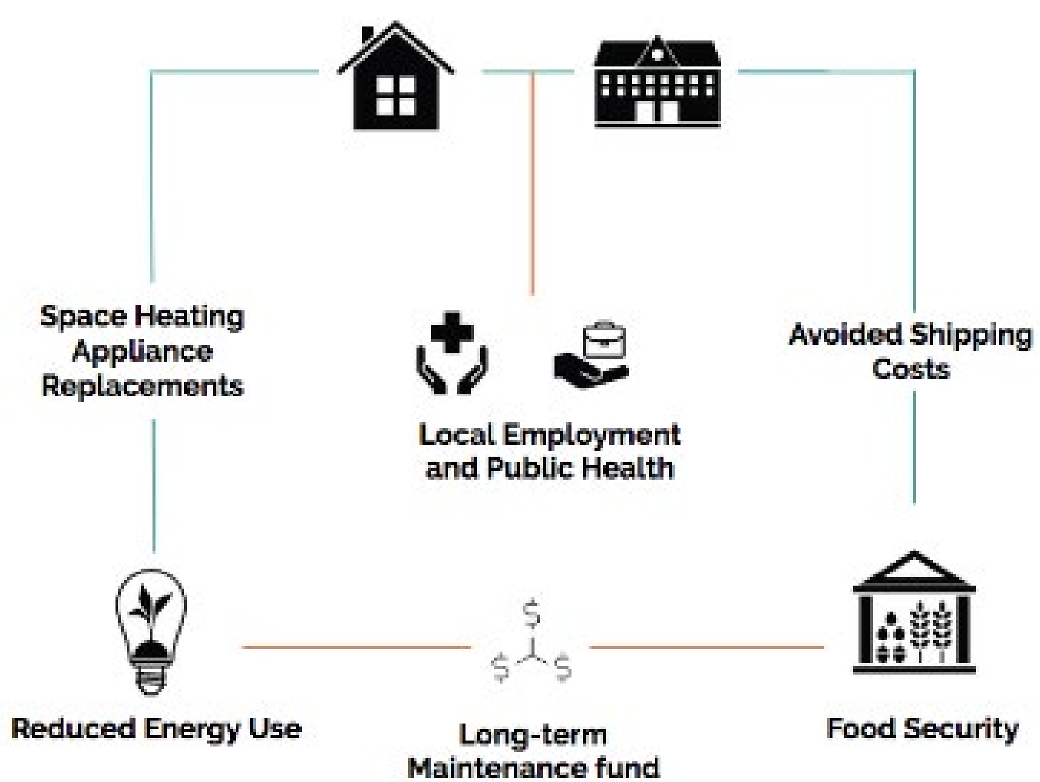
Table 4: Carbon dioxide equivalent and particulate matter reductions associated with the project.

Project Scale	Total CO2 Reduction (metric tons per year)	Total PM2.5 Reduction (kg per year)
Alakanuk	44.1	2.7
Region	1,065	63.6

Table 5: Carbon dioxide equivalent and particulate matter reductions associated with expanding the project throughout the Lower Yukon-Kuskokwim region.

Project Finances

The project has been modeled over various cases, to map out a range of possible outcomes. Our base case uses weatherization cost savings and avoided CO2 numbers provided by RuralCAP, and will be the default figures referred to for the project. Our project will cost $1.97mm, and will avoid 108.8 metric tons/year of CO2 after full installation, or a total of 1,563 metric tons of CO2 over the project. Total monetary benefits from weatherization and hydroponics come to almost $6mm, over the 15-year life of the project, not including job creation, public health, and other social co-benefits. The project also creates a long-term maintenance fund that will be endowed with $1.47mm, after 15 years. The $/avoided ton to the client is $630/ton of CO2.



Assumptions

For illustrative purposes, the project's finances have been modeled over a 15-year period. Out of the existing housing stock in Alakanuk, 60 homes qualify for weatherization. According to conversations with RuralCAP, given labor and funding conditions, 30 homes/year is a reasonable rate of completion. With the hydroponics installation occurring at the beginning of Year 1, the first 30 homes weatherized in Year 1, and the remaining homes weatherized in Year 2, the project will be self-sustaining after the first 2 years and will no longer need outside capital.

The client will assume 50% of project equity, but 100% of project offsets. This means that of the headline capital costs of $1.97mm, the client will assume 50%, or approximately $1mm of the capital expenditures. However, all 108.8 metric tons of CO2 avoided each year will go to the client as offsets.

Costs

The initial capital expenditures associated with the weatherization and hydroponics installation is $1.97mm, incurred in the first 2 years of the project. At a 5% discount rate, this comes out to $1.88mm, and at a 10% discount rate, $1.80mm.

We have modeled the space heating component of weatherization at $30,000/home, as per figures given by RuralCAP. This breaks down to $6,500 for the cost of raw materials, $14,000 in labor costs, and $9,500 in shipping costs. RuralCAP typically staffs 4 internal RuralCAP supervisors, and hires 4-6 locals from the community to work on the weatherization project. For shipping, it costs $14,000 to ship one 40-ft Conex container to Nome, Alaska. Containers are typically shipped from both Tacoma, Washington and Anchorage, Alaska, with shipping costs from the two cities intentionally kept at parity. According to RuralCAP, the typical rule of thumb is $1/pound for shipping. We have modeled $1,000/home for appliance upgrades, which would include upgrading to high-efficiency boilers, and replacing fridges, stove, and lights.

The initial costs for hydroponics is $110,000, a one-time installation cost, per estimates from Bright Agrotech, an indoor farming and greenhouse newsletter for farmers. The cost estimate is based off a 500 sq ft hydroponics farm, the exact specifications of our project, and includes towers, racks, lighting, lighting racks, nutrient reservoir and automated dosing, and a CO2 injection.

The operating and maintenance costs are covered by selling the produce grown in the hydroponics farm at cost, or approximately $4/pound. This includes $62,000/year in electricity costs, and $20,000/year in labor, which pays for a full-time employee to oversee, run, and maintain the farm. The remaining profits from selling the produce goes into the long-term maintenance fund.

The long-term maintenance fund is set up in the initial year of the project, with 10% of homeowner energy savings re-invested into the fund, and remaining profits from selling hydroponics produce. Over the 15-year life of the project, the maintenance fund will accumulate $1.47mm. If the produce is sold at $2/pound instead, the maintenance fund will still have accumulated $0.21mm by the end of the 15th year.

Benefits

Alakanuk homeowners accumulate $1.57mm in energy bill savings over the life of the project. Using RuralCAP's in-field estimates, weatherization realizes $2,000 in energy bill savings per home per year, and homeowners keep 90% of those savings, reinvesting the remaining 10% into the long-term maintenance fund. At a 5% discount rate, total weatherization energy bill savings come out to $1.10mm, and at 10% discounting, to $0.81mm. If we used a more conservative estimate of $944 in energy bill savings per home per year (the estimated savings from a non-PCE household, see Table 1), then total savings over the life of the project are $0.74mm ($0.52mm at 5% discounting, $0.38mm at 10% discounting).

Alakanuk residents collectively save $4.42mm over the 15-year life of the project from the hydroponics project. This is calculated via the avoided costs, namely, how much was saved by residents by growing produce locally versus purchasing and shipping the produce in from afar. At a 5% discount rate, the savings come to $3.14mm, and at 10%, savings come to $2.35mm.

In terms of avoided CO2, the weatherization project avoids 2,001 metric tons of CO2, over the 15-year life of the project. This is based off RuralCAP calculations of weatherization and appliance upgrades avoiding 2.3 metric tons/home/year. Using a more conservative calculation (see Table 2) of 1.2 metric tons/home/year leads to 1,063 metric tons of total CO2 avoided. The hydroponics portion of the project has a positive CO2 footprint of 438 metric tons, or 29.2 metric tons/year. But over the life of the project, the combined impacts of weatherization and hydroponics avoids 1,563 metric tons of CO2 over the 15 year project. The more conservative weatherization estimate, when combined with hydroponics, avoids 625 metric tons of CO2.

Overall, the community receives monetary benefits, in either energy bill savings or avoided cost of purchasing produce, of $5.99mm over the course of the 15-year life of the project, with $1.57mm from weatherization and $4.42mm from hydroponics. At a 5% discount rate, overall benefits come to $4.23mm, and at 10%, benefits come to $3.16mm. This does not include the job creation, public health, and social co-benefits created from the project. For example, the hydroponics project employs a full-time worker who will make a $20,000 annual salary. The project's stove replacements alone is estimated to save 0.45 lives over 15 years, and the hydroponics project doubles the percentage of residents who can meet daily nutritional requirements, from 9% to 18%.

Project Costs and Benefits (15-year life)	Amount (USD, undiscounted)
Total Costs	$2 million
Total Costs Paid by Client	$1 million
Total CO2 Avoided	1,563 metric tons of CO2
Weatherization CO2 Avoided	2,001 metric tons of CO2
Hydroponics CO2 Avoided	-438 metric tons of CO2
Cost / Avoided CO2 (to Client)	$630 / metric ton of CO2
Total Benefits	$6 million
Weatherization Benefits	$1.6 million
Hydroponics Benefits	$4.4 million
Maintenance Fund	$1.5 million

Table 6: Key financial statistics. Base case assumptions.

Public Health

Overall Impact

A preliminary public health impact assessment was conducted using statistics specific to Alaska Native communities and is presented in greater detail in the feasibility analysis. The assessment of the baseline health of Alaska Natives revealed that their health status is largely affected by key factors: 1) respiratory diseases are the second leading cause of hospitalizations, 2) cardiovascular and heart diseases are the leading cause of mortality, and 3) the suicide rate among Alaska Natives is twice as high as that of Alaska Non-Natives. These findings greatly influenced the structure and direction of the project as we actively sought out opportunities to address these challenges even when these opportunities might have competed with other considerations. For instance, while the installation of a hydroponics greenhouse significantly reduces the amount of achievable carbon offsets, it remains a necessity for the community from a public health perspective.

With this prioritization of public health improvement in mind, different considerations need to be taken into account so that the project implementation maximizes the anticipated community health benefits. A summary of the health outcomes expected to ensue from this intervention, and their relation to the baseline health characteristics discussed, are illustrated in Table 7 below. The detailed mechanisms leading to these outcomes are represented in the Appendix.

Weatherization Impact

The US Department of Energy Weatherization Assistance program conducted a nationwide survey to assess the health benefits associated with the program[36]. The results of this survey are used as an indication of the health benefits that our project would provide to

	Energy efficient retrofits and air sealing	Stove replacement	Hydroponics farm	Employment opportunities
Improved respiratory health outcomes	↓ outdoor air pollution	↓ indoor air pollution		
Improved cardiovascular health outcomes			↑ access to healthy food options	
Improved mental health outcomes	↓ financial chronic stress	↑ time available for other activities	↓ stress related to loss of subsidence resources	
Overall physical health		↓ injury risk		↑ disposable income available for health expenses

Table 7 Overview of health impacts associated with proposed intervention.

36. Health and Household-Related Benefits Attributable to the Weatherization Assistance Program. Oak Ridge National Laboratory. 2014.

Cold-related Illnesses	Frequency
# of Occurrences, Treatment (Pre-weatherization)	3.2%
# of Occurrences, Treatment (Post-weatherization)	1.5%
# of Occurrences, Comparison 1	2.1%
Decreased Rate of Occurrence	1.4%

Table 8. Reduction in Medical Care Needs due to Cold-related Illnesses Post-Weatherization

Alakanuk residents. Survey results revealed that the number of times that occupants were required to seek medical attention due to exposure to extreme temperatures inside their home was reduced from the first administration of the survey (pre-weatherization) to the second (post-weatherization). Table 8 indicates the reduction by percentages for both the treatment and comparison groups. The average change in the treatment group pre- and post weatherization plus the average change in treatment group pre-weatherization and the comparison group 1 (one year post-weatherization) (See Equation 1) yielded a decreased rate of seeking medical attention of 1.4% for cold-related illnesses.

One could argue that regardless of the incremental drop in rates of occurrence within this particular sample, these results have major implications. It should be noted that these results could be underestimated because it was assumed that only one person per household is impacted by extreme temperatures and results for any one year could be quite sensitive to extreme winter events.

Equation 1. [(Pre-treatment – Post-treatment) + (Pre-treatment – Comparison group one year post-weatherization)] / 2

Stove Replacement Impact

The stove replacement initiative is a major component of this intervention in terms of its potential to reduce PM2.5 emissions. Using the EPA guidelines for quantifying emission reduction from woodstove change-out programs, we estimate a net reduction of 4,008 PM2.5/year from the pre-change out conditions.

The EPA recommends using the following equation to determine emissions:

E = A * EF * (NEold/NEnew), where
E = emissions
A = activity rate = cord use * cord-to-mass conversion
EF = emission factor of the stove
NEx = net efficiency of the stove

The assumptions that we make based on the EPA guidelines are as follows:
There are 60 uncertified wood stoves to be replaced by 60 certified pellet stoves
The PM2.5 emission factors of the uncertified wood and certified pellet stoves are 34.6lb/ton and 4.2lb/ton respectively
The annual cordwood usage value for this region is 1.75 cords/stove/year, which is the national annual average
The mass conversion factor is 1.4 tons/cord
Thus, the activity rate (A) for this region is:
A = 1.75 cords/stove/year * 1.4 tons/cord = 2.45 tons/stove/year

Therefore, the pre- and post-changeout PM2.5 emissions can be estimated as follows:
Pre-changeout emissions:
E = (2.45 tons/stove/year) * (30.6 lb PM2.5/stove) * 60 stoves = 4,498 lb PM2.5/year
Post-changeout emissions:
E = (2.45 tons/stove/year) * (4.2 lb PM2.5/stove) * (54%/68%) * 60 stoves = 490 lb PM2.5/year

This leads to a net reduction of 4,008 lb PM2.5/year or 1.82 metric tons/ year from the pre-change out conditions. Using the social cost of carbon methodology[37] and using $3.05 million as the average value of a statistical life, this emission reduction can be translated into 0.45 lives saved over the 15 year course of this project. Considering the project's high potential for scalability and replicability, the number of lives saved would significantly increase upon project adoption by other communities.

In addition, it is important to consider that Alakanuk is home to a large proportion of children who, because of their developing biological systems, are particularly vulnerable to the impact of air pollution. Specifically, Alaska Native children experience high rates of lower respiratory tract infections (LRTIs) and lung conditions, which are associated with substandard indoor air quality (IAQ)[39]. A recent evaluation of the impact of leaky wood stoves replacement and ventilation improvement in Alaska's rural southwest indicates a decreased proportion of children with respiratory symptoms according to parents' reports. For instance, the post-intervention odds ratio for cold symptoms was 0.53 with a p-value of 0.003, indicating a statistically significant decrease in cold incidence. Given that these results cannot solely be attributed to woodstove changeouts, they further corroborate the importance of including ventilation improvements as well. These could include passive vents, range hoods, and/or bathroom fans.

Hydroponics Impact

In 2015, only 9% of Alaska Natives reported meeting the nutritional recommendation of five fruit and vegetables per day. As previously described, cardiovascular and heart diseases are the leading cause of death among Alaska Natives. Given the preponderant role that diet plays in the development of such diseases, the hydroponics farm has the potential to positively and significantly impact this risk factor. The yearly yield of the farm is estimated to be 42,120lb/year or 19,200,000 grams/year. This corresponds to 132 people being able to have 5 serving of fruit and vegetables on a daily basis. Given that the Alakanuk population is approximately 700 people, the hydroponics farm would help increase the proportion of people who can meet the nutritional recommendation from 9% to 18%. This has important implications for their cardiovascular health because it has recently been demonstrated that the risk of premature death by any cause is reduced by 29% if one eats three to five fruits and vegetables per day.[40]

37. EPA. Guidance for Quantifying and Using Emission Reductions from Voluntary Woodstove Changeout Programs in State Implementation Plans. 2006.
38. Shindell, D. The Social Cost of Atmospheric Release. Economics Discussion Papers, No 2013-56, Kiel Institute for the World Economy. 2013.
39. Singleton et al. Impact of Home Remediation and Household Education on Indoor Air Quality, Respiratory Visits and Symptoms in Alaska Native Children. Int J Circumpolar Health. 2018.
40. Dagfinn et al. Fruit and Vegetable Intake and the Risk of Cardiovascular Disease. Int J Epidemiol. 2017.

Social Impact

This project will provide social benefits on both the individual and community levels. First, skill training is a strong focus of RuralCAP's approach to community weatherization. This will provide community members with the opportunity to develop "green" skills, for which demand has and will continue to increase. Second, employment opportunities will be provided to complete the weatherization jobs as well as operating the hydroponics farm. The hydroponics farm will require that a community member works there full time, earning an annual salary of $20,000 annual. This will significantly change the living conditions of this resident and family, given that most families in Alaska Native communities do not have access to disposable income.

On a community level, this project presents a true educational component with the capacity to change dietary habits on a large scale. Indeed, there is only one school in Alakanuk, which is attended by over 200 students. As nutrition and sustainability issues become integral components of their curriculum and as they are increasingly exposed to fresh produce grown in-house, they will have the knowledge and opportunity to make healthier choices regarding their diets. Finally, the hydroponics farm will bring the community together and strengthen community ties as everyone will have a vested interest in the outcome.

Evaluation and Monitoring

The success of the project relies on its ability to achieve long-lasting improvements in public health, household costs, greenhouse gas emissions, and community welfare. To ensure that the project continues to achieve these goals following the implementation period, it is critical to establish proper evaluation and monitoring procedures and to pre-empt any potential unintended consequences of the project.

Ensuring Equitable Distribution of Project Benefits

The project weatherizes 60 of the 160 occupied homes in Alakanuk. Another 60 homes are assumed to have already been weatherized by external programs. As a result, approximately 40 homes remain un-weatherized. While some portion of these homes may be newer and therefore energy efficient, it is likely that some portion of the community would benefit from weatherization interventions but would not receive retrofits under the project. It is important to address this fundamental imbalance in the distribution of project benefits by ensuring (1) that these homes are prioritized for weatherization projects if any of the selected homes opt out of the project and (2) that these homes have access to the benefits of the hydroponics project. In particular, these homes do not have to contribute to the long-term maintenance fund, a cost of between $100 and $200 per year for non-PCE homes, in order to have access to the hydroponics facility.

Ensuring that Project Participants Don't Experience an Undue Cost Burden

The proposed project is additional and necessary because most households in Alakanuk and the region cannot afford to implement weatherization retrofits on their own. As a result, if the project's weatherization retrofits fail before the end of the project lifetime, it is likely that many families will be unable to afford to repair the damage or replace the equipment. To ensure that families neither have to sacrifice the benefits of the weatherization project for financial security nor have to accept undue cost burden to continue to receive the project benefits, the project requires that participating households pay 10 percent of their cost savings into a long-term maintenance fund. This fund can be used in the event of a system failure to pay for repair and replacement. It can also be used to perform routine maintenance on the installed systems so as to reduce the risk of system failure.

Ensuring Public Health Outcomes

The project is motivated largely by its ability to achieve meaningful public health outcomes. As a result, it is critical to monitor public health in Alakanuk throughout the lifetime of the project. This allows the project to quantify its public health benefits, to observe and address any unintended public health consequences, and to provide a data set that could be used to estimate the potential benefits of future weatherization projects.

In particular, it is important to consider the possibility that weatherization may cause adverse health effects. Insulating homes may decrease the flow of air between the outdoor and indoor environments, increasing exposure to indoor air pollutants. To reduce the risk of this exposure, the project will address any existing indoor air pollution problems, including black mold, before installing the weatherization retrofits. The project will also select weatherization retrofits that incorporate appropriate ventilation so as to reduce the risk of exposure if any indoor air pollutants recur following project implementation. Finally, as a part of the public health monitoring plan, the project will measure indoor air quality at regular intervals in participating homes.

The project must also ensure that it does not inadvertently harm public health (for example, by increasing exposure to hazardous pollutants as insulation degrades). The project must consider the direct health effects of the materials and chemicals used in any weatherization interventions throughout the planning and implementation phase, and select materials and interventions that minimize risk. Installing appropriate ventilation will also reduce the risk that any of the installed weatherization interventions could increase exposure to indoor air pollution and cause adverse health effects. The project must also ensure that all materials are appropriately disposed of at the end of their useful lifetime with assistance from the maintenance fund.

Finally, to the extent that some of the public health benefits rely on increased produce consumption, the project must ensure that the produce generated by the hydroponics facility is consumed by the community. Produce may not currently be a part of local diets, so the project must facilitate, to the extent possible, the integration of produce into the community. This can be done by involving the community in seed selection, allowing the community to grow plants that can more easily be incorporated into local diets. The project will also include an education component, both for children at the school and for other community members, to help families and individuals develop meal plans and recipes incorporating the produce grown by the facility.

Ensuring Greenhouse Gas Reductions

Given the importance of greenhouse gas reductions to both the success and finance of the project, it is critical to ensure that the project achieves these reductions. The project must therefore monitor the greenhouse gas emissions associated with both its weatherization and hydroponics components.

Direct changes in greenhouse gas emission associated with the whole project can be measured in two ways. First, because the local utility, the Alaska Village Electric Cooperative (AVEC), is PCE eligible, it reports Alakanuk's annual fuel consumption, electricity production, and residential electricity sales to the Alaska Energy Authority (AEA). These records can be used to identify the baseline residential electricity use. This baseline should include any trends in per household residential electricity consumption and should, to the extent possible, remove the effect of year-to-year climate variability. Given this baseline, any changes in Alakanuk's residential electricity consumption can be identified and attributed to the project.

Second, the project could require that any participating households and the hydroponics facility submit past and future utility bills. Past bills could be used to identify baseline electricity use on a per-building basis as described above. The changes in electricity consumption associated with the project could then be measured against this baseline based on future utility bills.

Quantifying the indirect changes associated with avoided emissions poses a different challenge. The avoided emissions depend both on the mass of produce grown by the hydroponics facility and on the displaced food. To address the former, the project will track the mass of produce sold. The project will also employ a full-time employee at the hydroponics facility to help ensure its proper functioning and maximal growth.

To quantify emissions from displaced food, the project will attempt to obtain records of past produce shipments to Alakanuk to determine the average food-miles traveled. If these records are not available, the project can either work with a nearby community to obtain information on average food-miles traveled from ongoing food shipment records, which would then be scaled by population, or the project can use the average food-miles traveled of all future food shipments to Alakanuk to model the avoided food-miles. Based on the measured mass of produce and the estimated avoided food-miles, the greenhouse gas emissions associated with the hydroponics project can be determined. The the total greenhouse gas reductions associated with the entire project can then be calculated.

Ensuring that the Project does not Reproduce Overcrowding

Overcrowding is a significant problem in rural Alaska. In the Kusilvak Census area, 53 percent of occupied housing units are either overcrowded (more than one person per room) or severely overcrowded (more than 1.5 persons per room), according to the 2017 Alaska Housing Assessment. This rate of overcrowding is 16 times the national average and the worst in the state. Conducting weatherization retrofits will increase the value of the existing housing stock, decreasing the chance that such overcrowding issues are addressed. As such, the project should work with the community and the project partner to identify long-term strategies to address overcrowding while improving current housing stock.

Conclusion

This project has the potential to produce significant social co-benefits and address some of the most important public health challenges that Alakanuk residents -and other Alaska Native communities- face. As long as recommendations to mitigate unintended consequences are taken into account, the residential weatherization component will significantly improve indoor environmental quality while also reducing diesel-related outdoor air pollution. Decreased energy bills and associated stress will allow for better mental health outcomes. The hydroponics farm, in combination with increased awareness of the benefits associated with consuming fresh produce, will allow the community to deal with the loss of subsidence resources in a healthy manner. As climate change progresses and worsen current challenges faced by Alaska Native communities, projects aimed at offsetting carbon emissions need to create resilience from a public health perspective as well.

Overall, this project costs $2 million in upfront capital expenditures, but generates $6 million in benefits, not including the public health, job creation, and other associated social benefits. The cost to the client is $630/ton of avoided metric ton of CO_2. While we recognize this is a hefty price tag for a carbon offset, particularly compared to the carbon offset markets, we believe that the value proposition of our project doesn't lie in cost-competitiveness. The right client for our project will be attracted to the social benefits and value for the community, more so than a cost-effective way to offset carbon emissions.

Financial Appendix
Financial Appendix

We ran four different cases, using different assumptions and scenarios. All cases are run over a 15-year life of the project.

Case 1: Base Case. Assumptions from RuralCAP.

Assumptions:
Homes eligible for weatherization: 60 homes
Produce price: $4/pound
% of Homeowner energy bill savings paid into maintenance fund: 10%
Project equity held by client: 50%
Weatherization cost savings / home / year: $2,000
Weatherization CO2 avoided / home / year: 2.3 metric tons

Project Costs and Benefits (15-year life)	Amount (USD, undiscounted)
Total Costs	$2 million
Total Costs Paid by Client	$1 million
Total CO2 Avoided	1,563 metric tons of CO2
Weatherization CO2 Avoided	2,001 metric tons of CO2
Hydroponics CO2 Avoided	-438 metric tons of CO2
Cost / Avoided CO2 (to Client)	**$630 / metric ton of CO2**
Total Benefits	$6 million
Weatherization Benefits	$1.6 million
Hydroponics Benefits	$4.4 million
Maintenance Fund	$1.5 million

Case 2: RuralCAP assumptions, $2/pound produce prices.

Assumptions:
Homes eligible for weatherization: 60 homes
Produce price: $4/pound
% of Homeowner energy bill savings paid into maintenance fund: 10%
Project equity held by client: 50%
Weatherization cost savings / home / year: $2,000
Weatherization CO2 avoided / home / year: 2.3 metric tons

Project Costs and Benefits (15-year life)	Amount (USD, undiscounted)
Total Costs	$2 million
Total Costs Paid by Client	$1 million
Total CO2 Avoided	1,563 metric tons of CO2
Weatherization CO2 Avoided	2,001 metric tons of CO2
Hydroponics CO2 Avoided	-438 metric tons of CO2
Cost / Avoided CO2 (to Client)	**$630 / metric ton of CO2**
Total Benefits	$7.3 million
Weatherization Benefits	$1.6 million
Hydroponics Benefits	$5.7 million
Maintenance Fund	$0.2 million

Case 3: Conservative assumptions, non-PCE

Assumptions:
Homes eligible for weatherization: 60 homes
Produce price: $4/pound
% of Homeowner energy bill savings paid into maintenance fund: 10%
Project equity held by client: 50%
Weatherization cost savings / home / year: $944
Weatherization CO_2 avoided / home / year: 1.2 metric tons

Project Costs and Benefits (15-year life)	Amount (USD, undiscounted)
Total Costs	$2 million
Total Costs Paid by Client	$1 million
Total CO2 Avoided	625 metric tons of CO2
Weatherization CO2 Avoided	1,063 metric tons of CO2
Hydroponics CO2 Avoided	-438 metric tons of CO2
Cost / Avoided CO2 (to Client)	**$1,576 / metric ton of CO2**
Total Benefits	$5.2 million
Weatherization Benefits	$0.7 million
Hydroponics Benefits	$4.4 million
Maintenance Fund	$1.4 million

Case 4: Conservative assumptions, PCE

Homes eligible for weatherization: 60 homes
Produce price: $4/pound
% of Homeowner energy bill savings paid into maintenance fund: 10%
Project equity held by client: 50%
Weatherization cost savings / home / year: $364
Weatherization CO_2 avoided / home / year: 1.2 metric tons

Project Costs and Benefits (15-year life)	Amount (USD, undiscounted)
Total Costs	$2 million
Total Costs Paid by Client	$1 million
Total CO2 Avoided	625 metric tons of CO2
Weatherization CO2 Avoided	1,063 metric tons of CO2
Hydroponics CO2 Avoided	-438 metric tons of CO2
Cost / Avoided CO2 (to Client)	**$1,576 / metric ton of CO2**
Total Benefits	$4.7 million
Weatherization Benefits	$0.3 million
Hydroponics Benefits	$4.4 million
Maintenance Fund	$1.3 million

Legal Appendix

Protections for Subsistence

Protection for subsistence is an ongoing concern for Native communities. The State of Alaska enacted its first subsistence law in 1978 recognizing that subsistence use of land has a priority over sport and commercial uses. However, Native people objected to the law because it defined all Alaskans to be subsistence users and urban Alaskans could still complete with Native villagers for the food supply. After Congress extinguished hunting and fishing protections through ANCSA, it sought to pass Title VIII of the Alaska National Interest Lands Conservation Act in 1980, which gave a preference for subsistence hunting and fishing to rural residents of Alaska on federal lands. Congress also asked the State of Alaska to pass similar laws. However, the State's preference for rural subsistence was later declared in violation of the Alaska Constitution in McDowell v. State of Alaska. The result is that the federal government manages subsistence on federal lands and waters, while the State manages it on State and private lands, including ANCSA lands. Thus, subsistence for Alaska Native people is inadequately protected as resources dwindle due to climate change while competition increases from urban migration, leaving Native food security in a precarious state.

Indian Self-Determination and Education Assistance Act (ISDEAA) 1975

Lastly, many social services are administered by Native organizations themselves. The Indian Self-Determination and Education Assistance Act (ISDEAA) in 1975 delegated authority to Native tribes to run programs that deliver services created through the federal trust responsibility such as health and housing. These are primarily services administered by the Bureau of Indian Affairs and by the Indian Health Service. Tribes negotiate contracts directly with the federal government. Most tribes in Alaska run their own programs such as health clinics, housing corporations, and social services, or form Native owned and operated non-profit tribal organizations. The status of Indian tribes was clarified in 1993 to not include the Native Corporations, but only the 229 federally recognized tribes. However, Native land and financial claims are still based on the Corporation structure.

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FEASIBILITY STUDY

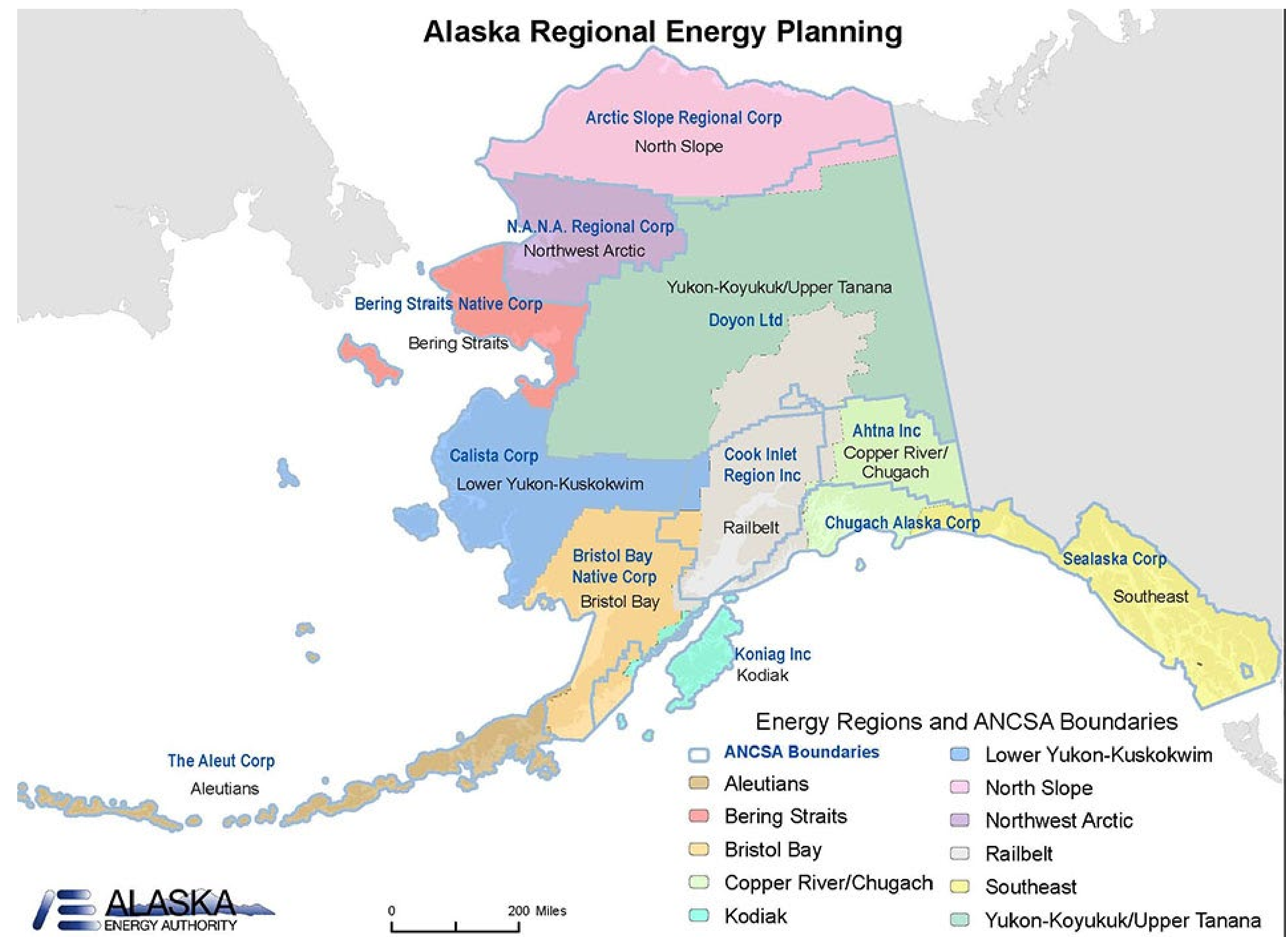
Summary

This feasibility study evaluates and compares several climate change mitigation projects that address the challenges facing Native rural communities. The projects all aim to improve energy efficiency and reduce GHG emissions while providing important public health and community co-benefits. The two major projects for analysis are a diesel efficiency/waste heat recovery project and a residential weatherization project. This report also examine heat pumps and hydroponics.The study is structured with an introduction to the two major projects and possible community partners before moving onto comparative analyses between the two to make a final recommendation.

Based on the findings in the analysis, this feasibility study recommends the residential weatherization project incorporated with a hydroponics component for the implementation study. Out of the projects that we analyzed, the residential weatherization project has the greatest potential to provide co-benefits to the community. It is a holistic response that addresses various challenges facing Alaskan Indigenous peoples today. In addition, the hydroponics component will address the important issue of food security in rural Alaska.

Projects

To address the economic, environmental, and public health challenges faced by these communities, we propose a project to reduce fuel consumption by improving utility or community efficiency. In what follows, we describe the technical, legal, finance, and public health components of each of two proposals. The first proposal recommends several utility-scale interventions to improve the efficiency of diesel efficiency. The second suggests several residential- and commercial-scale weatherization interventions to reduce energy use in the community. In the case of the first proposal, we describe interventions applicable to Scammon Bay in the Kusilvak Census Region because we were able to retrieve data on this community. In the case of the second proposal, we consider communities in the Lower Yukon-Kuskoswim where Scammon Bay is located since many have potential for the project, as long as they have a need for weatherization and have access to water.



Energy regions of Alaska. We design a project for a community on the western coast of the Lower Yukon-Kuskokwim region, shown in light blue.

Community Selection

The Kusilvak Census Region was chosen for three reasons. First, the community and regions met the criteria developed for project selection: the communities are predominantly indigenous, have high poverty rates, experience high food and energy costs and insecurity, and lack access to many needed technical, health, and finance resources.

Second, data were available for these communities, allowing quantification of the greenhouse gas reductions, energy cost savings, and public health benefits.
Third, for the first project of diesel efficiency several communities in these regions had prior project proposals that had been rejected. Thus, our project could address a known need in an appropriate and proven way while also providing additionality of carbon reductions.

The identification of specific communities and regions permits the quantification of the energy cost reduction, public health benefits, and carbon savings of each proposed projects. However, the shared characteristics of predominantly-indigenous communities in rural Alaska allow the new proposals to be easily extended to other communities

Scammon Bay

Scammon Bay is a community of approximately 500 people located in the Lower Yukon-Kuskokwim region on the coast of Scammon Bay off of the Bering Sea. Scammon Bay, serviced by the Alaska Village Electric Coop (AVEC), imports diesel by barge and stores it in fuel farms, particularly during the winter months, when the Bering Sea may ice over. The community generated over 1,600 MWh of energy from 120,600 gallons of fuel during the 2015 to 2016 reporting period. The fuel cost amounted to over $370,000, or $0.24 per kWh sold. This cost represents almost half of the expense of producing and distributing energy; the total cost per kWh sold in Scammon Bay was $0.52 during the same period.

At this rate of energy production, AVEC achieved fuel efficiency of 13.62 kWh per gallon of diesel in Scammon Bay. This is consistent with fuel efficiency in other communities in the Lower Yukon-Kuskokwim; the average fuel efficiency in the region is 13.1 kWh per gallon. As a result, any on-site diesel efficiency measures proposed for Scammon Bay are likely to produce similar fuel savings if implemented in other communities.

Following electricity generation, AVEC distributes the energy to the community. While fuel efficiency in Scammon Bay is consistent with that of other communities, Scammon Bay has relatively low line losses. The community loses 3.5% of produced energy during distribution, while the average for the region is over 11%. 75 percent of communities have line losses higher than those experienced by Scammon Bay.

AVEC distributes energy to residential, community, commercial, and industrial customers. Of the 1,600 MWh sold, 40% went to residential customers, 13% to community customers, and the remaining 47% to other customers. Thus, interventions to improve energy efficiency at the use-point could further reduce fuel demand, particularly when implemented in residential or industrial buildings. The weatherization project proposed below could be one way of achieving these reductions; the diesel efficiency and weatherization projects could therefore be seen as complementary interventions.

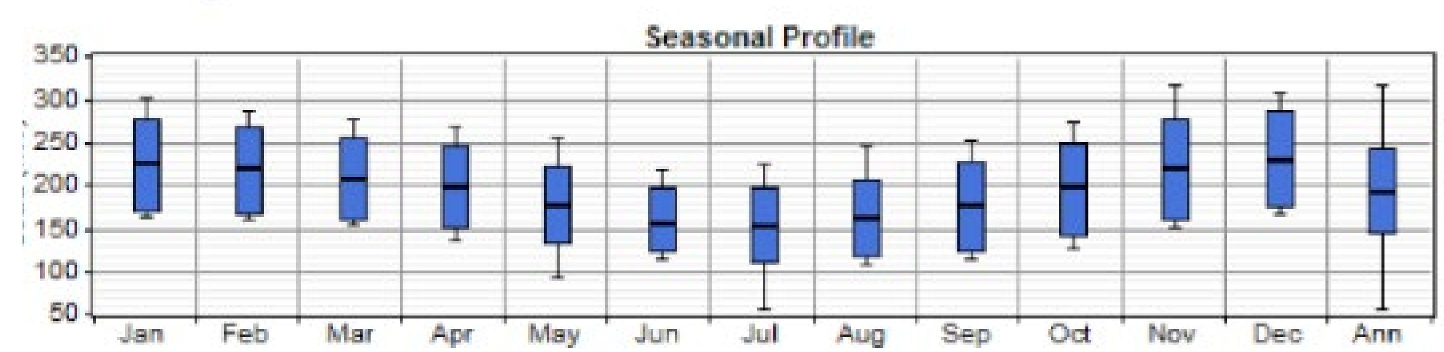
Utility-Scale Interventions: Diesel Efficiency and Waste Heat

Technical Description

Diesel efficiency may be improved at the utility-scale by either (1) replacing old generators with high-efficiency alternatives or (2) retrofitting existing generating systems. In the first case, efficiency may be further improved by relocating the generator to reduce the total distance that electricity must travel to reach customers, thereby decreasing line losses. If the generator is not replaced, two types of retrofits may be considered: a generator can be insulated to reduce heat loss, or lost heat can be captured and used by a waste heat recovery system. In both cases, a community can consider the possibility of installing "third party aftertreatment" systems to reduce the pollutants contained in diesel exhaust. This option will be discussed later on.

Base Electricity Load

For a population of between 100 and 800 people, a community in the Lower Yukon-Kuskokwim region requires 2.80 MWh per person per year. This is equivalent to 0.32 kW per person, or between 32 kW and 255 kW for the population range considered. This load is not distributed equally over the course of the year; a generating system must be able to respond to maximum energy demand. In Scammon Bay, a representative community in the Lower Yukon-Kuskokwim region with a population of 528, monthly load varies from 60 kW to 320 kW with an average value of 190 kW (Figure). If we assume that electricity demand varies from the mean by 68%, as in Scammon Bay, a community of 100 will require up to 54 kW, while a community of 800 will require up to 430 kW. Any utility-scale interventions



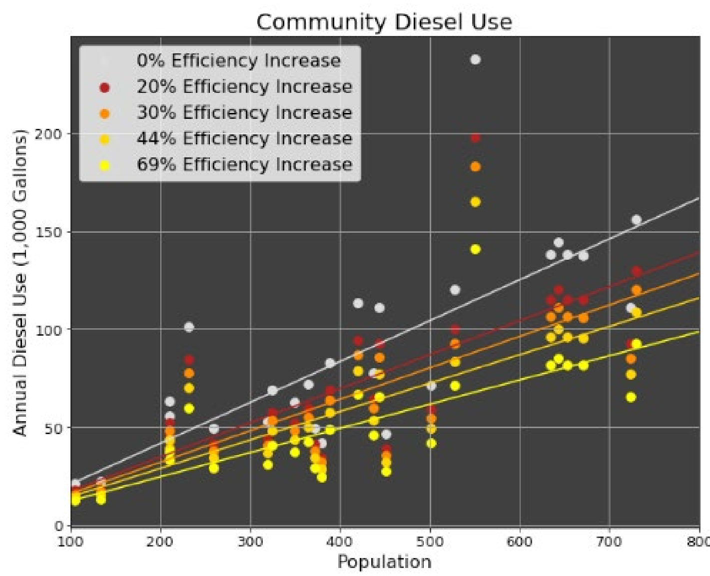
Seasonal profile of electric load in Scammon Bay Alaska. We use the deviation from the average to determine the maximum electric load experienced by a community must maintain this maximum generating capacity.

For a population of between 100 and 800 people, a community in the Lower Yukon-Kuskokwim region requires 2.80 MWh per person per year. This is equivalent to 0.32 kW per person, or between 32 kW and 255 kW for the population range considered. This load is not distributed equally over the course of the year; a generating system must be able to respond to maximum energy demand. In Scammon Bay, a representative community in the Lower Yukon-Kuskokwim region with a population of 528, monthly load varies from 60 kW to 320 kW with an average value of 190 kW (Figure). If we assume that electricity demand varies from the mean by 68%, as in Scammon Bay, a community of 100 will require up to 54 kW, while a community of 800 will require up to 430 kW. Any utility-scale interventions must maintain this maximum generating capacity.

The project must also maintain the reliability of the generating system, particularly during extreme weather, when electric load is likely to be highest. In Scammon Bay, electricity is provided by three diesel generators with capacities between 350 and 499 kW. This generating capacity is significantly larger than the maximum load; the excess capacity provides backup in the event of a system failure. Any utility-scale intervention must consider the importance of excess capacity to off-grid, off-road communities.

Efficiency Measures

Improving utility-scale efficiency would allow a community to provide electricity using less fuel. We consider the effects of replacing old generators with high-efficiency alternatives or retrofitting existing generating systems with insulation or waste-heat systems. We also consider the combined effect of both projects. Assuming that both interventions increase efficiency by between 20 and 30 percent, the combined measures will produce an efficiency increase of between 44 and 69 percent. The results are summarized in the Figure below, which shows the effect of various efficiency increases on annual diesel use, and in the preceding tables, which predict the effect of decreasing diesel consumption on diesel expenses and pollutant emissions.



Effect of efficiency measures on annual diesel consumption. This plot shows the potential reduction in diesel use associated with increases in diesel efficiency. The gray points represent diesel use in individual communities in the Lower Yukon-Kuskokwim from July 2015 to July 2016, as reported by the Alaska Energy Authority. The red, orange, gold, and yellow dots reflect the diesel use in those communities were they to increase diesel efficiency by 20, 30, 44, or 69 percent, respectively. And, the lines represent the best-fit of the points; they model diesel use, within a certain error, for a community with a given population and given efficiency improvement over standard technology.

	Community Results: Diesel Reduction (1,000 gal)			Modeled Results: Diesel Reduction (1,000 gal)		
Efficiency Increase	Average	Minimum	Maximum	Average	Minimum	Maximum
20%	15.1	3.5	39.7	15.7	3.5	27.8
30%	20.9	4.9	54.9	21.7	4.8	38.5
44%	27.6	6.5	72.8	28.7	6.4	51.0
69%	36.9	8.7	97.2	38.4	8.5	68.2

Diesel Volume Reduction Associated with Utility-Scale Efficiency Measures

	Community Results: Cost Reduction ($1,000)			Modeled Results: Cost Reduction ($1,000)		
Efficiency Increase	Average	Minimum	Maximum	Average	Minimum	Maximum
20%	47.46	13.72	103.33	51.39	11.42	91.35
30%	65.72	19.00	143.09	71.15	15.81	126.48
44%	87.01	25.17	189.48	94.20	20.93	167.47
69%	116.26	33.63	253.20	125.87	27.97	223.77

Short-Term Cost Reduction Associated with Utility-Scale Efficiency Measures

	Community Results: CO_2 Reduction (metric tons)			Modeled Results: CO_2 Reduction (metric tons)		
Efficiency Increase	Average	Minimum	Maximum	Average	Minimum	Maximum
20%	151.63	35.59	398.98	157.47	34.99	279.94
30%	209.94	49.29	552.50	218.02	48.45	387.60
44%	277.96	65.27	731.61	288.67	64.15	513.19
69%	371.40	87.23	977.63	385.72	85.71	685.72

CO2 Reduction Associated with Utility-Scale Efficiency Measures

	Community Results: $PM_{2.5}$ Reduction (metric tons)			Modeled Results: $PM_{2.5}$ Reduction (metric tons)		
Efficiency Increase	Average	Minimum	Maximum	Average	Minimum	Maximum
20%	5.68	1.33	14.94	5.90	1.31	10.48
30%	7.86	1.85	20.69	8.16	1.81	14.51
44%	10.41	2.44	27.39	10.81	2.40	19.22
69%	13.91	3.27	36.61	14.44	3.21	25.68

PM2.5 Reduction Associated with Utility-Scale Efficiency Measures

Deployment of high-efficiency diesel technology in rural diesel powerhouses has increased the usable electricity generated from a gallon of diesel by 20 to 30 percent. Assuming conservatively that installing a high-efficiency diesel energy does not change the ratio of energy consumed to generated, and assuming that line losses remain constant, installing high-efficiency diesel engines would reduce annual fuel consumption by between 15,100 and 20,900 gallons on average, representing a direct annual fuel savings of between $47.5 and $65.7 million on average in the Lower Yukon-Kuskokwim region. Moreover, a reduction of this volume decreases annual emissions of carbon dioxide by between 150 and 210 metric tons, of fine particulate matter (PM2.5) by between 5.7 and 7.9 metric tons, and of NOx by between 137 and 189 metric tons. Reducing line losses by installing the generator closer to consumers would further reduce costs and emissions. Moreover, this analysis reflects current energy use in communities; it does not assume the implementation of community-level energy efficiency measures (i.e. weatherization).

If replacing diesel generators with high-efficiency alternatives is not feasible, retrofitting existing generating systems may also improve efficiency and reduce fuel demand. Heat recovery systems collect the heat generated by power plants that would otherwise dissipate, increasing power plant efficiency and providing a valuable heat resource to communities. The collected heat, stored in water or air, can be used for space heating, to provide domestic hot water, or to prevent municipal water supplies from freezing. Waste heat systems can also be combined with community development projects to provide heating or hot water to common spaces.

Heat recovery systems from both traditional water jacket systems and from the newer exhaust stack waste heat recovery systems can increase the efficiency of diesel power by an additional 20 to 35 percent. This would lead to a similar decrease in annual fuel consumption and emissions of CO2, PM2.5, and NOx. If combined with a generator upgrade, annual fuel consumption could decrease by between 27,600 and 36,900 gallons and produce between $87.0 and $116.3 million in annual savings, both on average. Annual carbon dioxide emissions would decrease by between 278 and 371 metric tons, annual PM2.5 by between 10.4 and 13.9 metric tons, and annual NOx by between 251 and 352 metric tons.

A final option to reduce exposure to harmful pollutants without implementing energy efficiency measures is to install systems that filter diesel exhaust. Diesel generators are available that incorporate these filtration systems; these Tier 4 engines are available from John Deere in capacities ranging from 30 kW to 369 kW. CAT and Detroit Diesel, the other two dominant companies serving rural Alaska, do not offer Tier 4 engines. However, they do offer Tier 2 and Tier 3 engines with third party aftertreatment systems. In all cases, filtration systems use physical or chemical mechanisms to reduce the emission of particulate matter, hydrocarbons, carbon monoxide, and/or NOx. A typical NOx reduction mechanism, a selective catalytic reduction (SCR) system, can reduce NOx emissions by up to 90 percent. Diesel particulate filters (DPF) often have efficiencies greater than 90 percent for the removal of fine particulate matter.

Despite the potential benefits of diesel filtration systems, there are no Tier 4 engines or third party aftertreatment systems installed in remote power houses for rural prime power. The maintenance requirements of such systems are uncertain, and many rural communities may lack the technical assets necessary to make repairs in the event of system failure. Because of the severe climate, generator reliability is critical in rural Alaska, and being able to repair failed systems quickly is critical to community safety and health. These systems are also likely to be expensive: in addition to the standard maintenance costs, any repairs to a generator with third party aftertreatment may cost more because of the need to entirely remove and reinstall all exhaust components. Finally, filtration systems may reduce generator efficiency. Many systems heat exhaust, requiring additional energy and reducing fuel efficiency. Filtration systems may also impede the installation of heat recovery systems. Therefore, we identified the incorporation of these systems as infeasible.

Case Study: Adak's Diesel Efficiency Projects

Adak is a small rural community with a population of 300 located on the Kuluk Bay of Adak Island in the Aleutian Islands. It is the southernmost community in Alaska. We chose Adak as a case study because it is a example of an Alaskan rural community that has a significant diesel efficiency project already underway, and we believe there are valuable lessons to be learned from Adak's project and planning.

Adak is a former Navy base, and therefore has considerable legacy infrastructure, including a power generation and distribution system that is sized for a population of 7,000 individuals. The system is now owned and operated by the local utility, TDX Power. Layton Lockett, the Adak City Manager, said that Adak experiences some of the highest energy costs in the state, in part because of the oversized generation infrastructure.

To reduce energy costs, the city is proposing a suite of renewable energy and energy efficiency projects. The power plant at Adak currently uses two 3516 Caterpillar generators. The proposed project would replace the oversized diesel generators with three smaller 500 kW units. The project will also relocate the generators closer to town to reduce line losses. Currently, the power system is experiencing 30 to 40 percent line loss, and TDX predicts that relocating the generating system will improve line losses to less than 10 percent.

Even with these efficiency improvements, the cost of energy is likely to remain high. In general, the cost of energy in rural Alaska is 3 to 5 times that in urban areas. In an attempt to equalize electricity costs, the state administers the Power Cost Equalization (PCE) program, which subsidizes fuel costs for rural Alaska villages to the level of the averaged fuel price of Anchorage, Juneau, and Fairbanks. As of February 2018, electricity in Adak was $1.41 per kWh prior to PCE, but near $0.70 per kWh after PCE.

However, heating is not eligible for Power Cost Equalization subsidies. As a result, heating upgrades can produce large cost savings. The proposed waste heat recovery system in Adak will use heat from the water jacket and exhaust to heat the local school, a 75,000 square foot facility. 80% of the school building is unused because it extremely expensive to power and heat. With the new proposal, the waste heat will be stored in the school's large indoor pool. Many stakeholders emphasize the importance of waste heat recovery for community revitalization, as the facility will provide space for city offices, public events, and emergency management in the event of disaster.

Adak is also considering renewable energy interconnections, including a short-term wind energy project and a long-term hydro project. Wind turbines were purchased several years ago, weatherized and rewired for the weather and grid conditions, and held in storage. The city is planning to conduct a baseline demand study and erect wind meteorological evaluation towers (MET) in the coming year. The city also recently concluded a hydro project feasibility study.

Uniqueness of Adak

Adak is ultimately a relatively unique community, given its military history, infrastructure buildout, and oversized generating system. These aspects make straightforward replicability of an project based on Adak demographics and site specifications challenging. Cady Lister, the lead economist from the Alaska Energy Authority, says that a project sited at Adak may not be transferable to other communities, given its unique history and characteristics. Because the Adak project is not broadly scalable to other communities, the feasibility study will look at diesel efficiency projects in a more typical rural Alaskan Native community like Scammon Bay in the Lower Yukon-Kuskokwim Region.

Legal Analysis in Adak

The are legal considerations for the location of renewable energy projects such as wind turbines when combined with diesel efficiency projects. On the Aleutian Islands, the considerations include:

- Airport airspace considerations and FAA permitting
FAA control of airport airspace provides criteria which are defined in FAR (Federal Acquisition Regulation) Part 77.
- Proximity to existing roads
- Proximity to existing electrical distribution
- Acceptable zoning and/or landowner permission
- Environmental and avian impact
- Archaeological constraints, flicker shadow and noise considerations

Funding and Policy Analysis

In the past, energy-related projects have been funded through oil and gas royalties, which supplied over 80% of the state's discretionary budget. With the crash of oil prices and the state of Alaska's finances, communities working on energy projects have been struggling to find alternative sources of funding.

The majority of options available are federal and state grant funds. Federal funding is available through the EPA's Diesel Emissions Reduction Act (DERA), the DOE's $11.5mm competitive grant for Energy Infrastructure Deployment on Tribal Lands, and USDA's $280mm Rural Energy for America Program and Rural Utilities Service, and CoBank's $3mm Sharing Success fund. One of the major considerations in going after federal grants is having a very well-outlined timeline and plan for obtaining the balance of required funding. From our meetings with Adak stakeholders, we gained insight into the DOE grant and funding process. If a community is to ask for $1mm from the DOE for a $20mm project, DOE generally wants to know how the community is planning to secure the remaining $19mm. One strategy is to break the project down into phases, to ensure that incremental grant funding has a concrete and defined real impact on a segment of the project.

The Alaska Energy Authority administers several grant sources, including the Alternative Energy and Energy Efficiency and Rural Power System Upgrade funds. Funding for these programs come from a mixture of sources, including Alaska legislative appropriations, the Denali Commission, and other matching funds. AEA manages Alaska's allocation of DERA funding, approximately $0.33mm. AEA also administers affordable loan programs, like the Power Project Loan Fund, which has nearly $20mm in loan commitments and $10mm in uncommitted cash balance. With the increasingly challenging fiscal grant situation, AEA cautions that many projects will have to turn to cheap public debt to finance. AEA recommends that communities avoid private finance, which have more aggressive interest rates and may require collateralizing land or homes in communities that already have very little.

Municipal bonds are also an option for small communities looking to bridge capital. These communities have the ability to have debt offerings of a significant size packaged and sold by the state, affording them the state's bond ratings and allowing small communities to avoid the costs of administering the bonds themselves. For example in Adak, according to Layton Lockett, Adak's city manager, rates are currently between 3-4.5%. The community would put an infrastructure development and repair bond proposition in front of voters, who would vote to authorize spending for a certain amount. This headline number does not have to be offered all at once, but authorizing a higher amount gives the community the freedom to make bond offerings in the future off that authority, based on market rates and need.

Client

The client for the diesel efficiency project is the local utility. For example, in Adak, our client would be TDX Power. From our conversations with TDX Power and various othe Adak stakeholders, we realized how important it is to have overall stakeholder buy-in from the utility, the city government, and the local native corporation. Without this "three-legged stool" of support, a diesel efficiency project cannot get off the ground. Thus, the choice of the utility as our client is fundamental to the feasibility of the diesel efficiency project. The local utility will have a vested interest in upgrading the community's failing and outdated infrastructure, in order to avoid future operating and maintenance costs, and to invest in its community.

Illustrative Benefit-Cost Analysis

We used numbers from Adak as a rough approximation of what costs we will incur in our project, with the understanding there there could be upside, given that part of Adak's costs are from fixing overbuilt systems, as well as downside, as Adak has considerably more established infrastructure than Scammon Bay. Our assumed cost requirements for diesel efficiency upgrade projects run approximately as follows:

Distribution system costs of $9mm
Generation costs of $2.5mm, assuming 3 x 500 kW gensets
Fuel storage costs of $0.5mm

Our assumed benefits run approximately as follows:
Avoided diesel fuel in gallons per year, multiplied by pro-

jected fuel prices
Avoided self-generating costs from local entities that now join a more efficient grid
Avoided maintenance costs from necessary annual repairs to aging infrastructure
Public health co-benefits
Community revitalization co-benefits
Carbon offset market sales of reduced carbon

Assumptions:

Diesel price forecast starts at average price of $3.28, and grows at 2% a year.
Avoided diesel fuel each year decreases 1%, due to wear and tear of machinery.
Heating costs of $20,000/year avoided.
Operational and maintenance costs of $30,000/year avoided.
Carbon offset price of $10/ton.
Assumes the client owns 80% of the equity of the project having funded 80% of capital expenditures (and no portion of following annual O&M costs), and receives 80% of the savings, and 80% of the value of carbon offsets. We assume the balance of the funding comes from one-time upfront grants, to avoid making additional assumptions around interest payment schedules.
Sensitivity of discount rates from 5.0%, 7.5%, 10.0%, and 12.5%.

Cost/Ton Calculations

The benefit-cost analysis ultimately shows that there is a very high cost-per-avoided-ton of CO_2e from the diesel efficiency project, of $7,014.7/ton for the project-level benefit-cost, and $5,515.8/ton for the client's stream of benefits and costs. This is due to the high capital intensity of investing $11.2mm into the project. However, this cost metric does not incorporate the social and public-health co-benefits, and is merely a financial metric.

Public Health Impact Assessment

Assessing the impact of the utility-scale intervention that we are proposing requires an understanding of the baseline health of the communities being targeted. We chose to focus on the health characteristics that Alaska Native rural villages have in common, although community-specific factors will certainly come into play as we move forward with the selection of one community for the implementation plan.

Sociodemographics

Young people make up a large portion of the Alaska Native population. One in five (20.5%) Alaska Native persons are aged 9 years and younger compared with 12.6% of the U.S. population. Our conversation with Sally Cox from the Department of Community and Regional Affairs provided an insight into family dynamics in these communities as most parents have 3 or 4 children on average. Given the subsidence lifestyle of Alaskan Natives, when these children reach teenagehood, they usually do not seek employment. Further, during 2011-2015, approximately 1 of every 4 (28%) Alaska Native children under the age of 18 years were living in poverty. Poverty increases the chances of poor health and poor health in turns traps people in poverty.

Environmental & behavioral health in the context of climate change

Native Alaskan communities face shared challenges that shape and impact their health status. Access to in-home water and sewer service, either through piped connections or closed haul systems, has a positive impact on public health and can help stop the spread of diseases and illnesses. In rural Alaska, only 83.5% of households have access to water and sewer service, meaning that many families still have to resort to options such as honey buckets. A study led by Dr. Thomas Hennessy, CDC Director of the Arctic Investigations Programs, indicates that in-home water service is an important determinant of health in rural Alaska communities. Lower levels of water services were associated with a higher burden of hospitalizations for pneumonia and influenza, skin infections, and lower respiratory tract infections. In addition, more recently, extreme weather events have destroyed water treatment infrastructures and led to inundations, which have both threatened villages' water security.

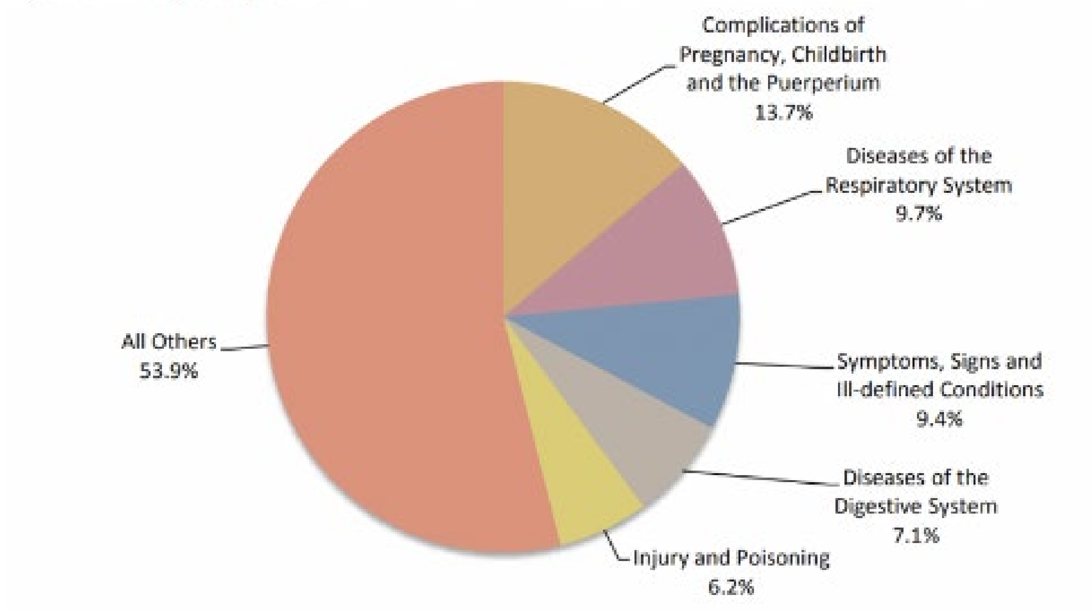
Rising food prices, challenges to food quality and quantity, and changing food distribution patterns are all factors that could be impacted by climate change. Due to the specialized dietary patterns in Alaska with a heavy reliance on subsistence resources, changes to key food sources could lead to food insecurity and associated health consequences. Many Alaska communities have already reported various changes to subsistence harvest, highlighting the need for improvement of their food security prospects. Danny Consenstein, Executive Director of USDA's Farm, corroborated the idea that poor access to healthy food options leads many of these communities to rely on unhealthy alternatives. Such a diet, high in saturated and trans fats can raise cholesterol blood levels, a major risk factor for heart disease and stroke.

Baseline health characteristics relevant to this intervention

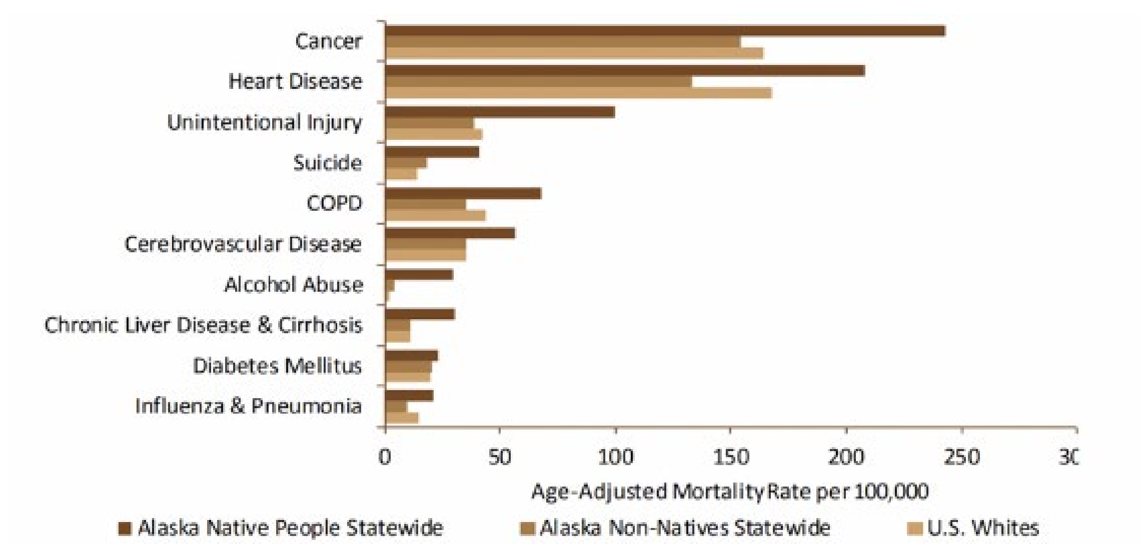
Respiratory health is a determining factor of morbidity and mortality among Alaskan Native People. As shown in Figure 1, diseases of the respiratory system represented the second leading cause of hospitalizations in 2015, after pregnancy complications, childbirth, and the puerperium.

Similarly, cardiovascular or heart diseases are leading causes of mortality in Native Alaskan communities.

Heart diseases accounted for approximately 225 per 100,000 deaths in 2015, after adjusting for age (Figure 2). Heart diseases describes a range of conditions, such as conditions that involve narrowed or blocked blood vessels that can lead to a heart attack, chest pain (angina) or stroke. Other heart conditions, such as those that affect the heart's muscle, valves or rhythm, also are considered forms of heart disease.



Leading Causes of Hospitalizations by Diagnosis Groupings, Alaska Tribal Health System, Alaska Native People, FY15. (Data Source: Indian Health Service National Data Warehouse)



Leading Causes of Death, Alaska Native and Non-Native People and U.S. Whites, 2012-2015. (Data Source: Alaska Division of Public Health, Alaska Health Analytics and Vital Records Section; Alaska Department of Labor and Workforce Development)

Improved outdoor air quality

The diesel efficiency upgrade previously described would significantly reduce the consumption of diesel for electricity generation, and thus, reduce the emissions of pollutants currently impacting outdoor air quality in these rural communities. Indeed, representatives of the Alaska Native Tribal Health Consortium and the Alaska Department of Environmental Conservation confirmed that diesel generators are a common source of petroleum emissions in rural Alaska. In particular, decreased emissions of nitrogen oxide (NOx) and volatile organic compounds (VOCs) will impede the formation of ground-level or "bad" ozone. Ozone occurs naturally at low concentrations throughout the Earth's atmosphere. In the stratosphere, which extends from about 10 to 50 km above the Earth's surface, ozone is 'good' as it protects life on Earth from the sun's ultraviolet rays. In the troposphere, near the Earth's surface, ozone becomes a powerful oxidant and lung irritant. Ground-level ozone is associated with adverse health outcomes, such as decreased lung function, increased premature deaths, and aggravated respiratory conditions (e.g., asthma, chronic bronchitis, and emphysema).

In addition to ozone, air particulate matter concentrations will also be reduced. Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets that get into the air. Particle pollution can be divided in two categories; PM10 are inhalable particles with diameters that are generally 10 micrometers and smaller while PM2.5 are fine inhalable particles with diameters that are generally 2.5 micrometers and smaller. Once inhaled, these particles can affect the heart and lungs and cause serious health effects.4 PM2.5 is of greater concern because these particles are small enough to deposit deep into the alveoli and trigger inflammation and even enter the bloodstream. Numerous scientific studies have linked particle pollution exposure to a variety of detrimental health effects,24 including:

- premature death in people with heart or lung disease
- nonfatal heart attacks
- irregular heartbeat
- aggravated asthma
- decreased lung function
- increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing

Vulnerable populations

Children are especially at risk from diesel emissions because their lungs are still developing and their faster breathing rate increases the amount of exhaust they inhale. Children are also at greatest risk from exposure to ozone because their lungs are still developing and they are more likely to be active outdoors when ozone levels are high, which increases their exposure. In addition, they breathe twice as quickly as adults, taking in more air relative to their body weight, and their respiratory tracts are more permeable.25 Children are also more likely than adults to have asthma. Finally, children have little control over their environment. Unlike adults, they may be both unaware of risks and unable to make choices to protect their health.

In addition to children, people with heart or lung disease, the elderly, and pregnant women are also at greater risk from ambient air pollution than other people. People with heart or lung diseases -such as coronary artery disease, congestive heart failure, and asthma- are at an increased risk because particles can aggravate these diseases. Older adults are at increased risk possibly because they may have undiagnosed heart or lung disease or diabetes.27 The heightened vulnerability of pregnant women is due to the recent evidence for an association between air pollution and adverse birth outcomes, including preterm birth and low birth weight.

Quantification

Once the amount of diesel saved by this intervention is determined, an estimate of the adverse health outcomes avoided will be determined. To do so, published exposure-risk relationships, such as the integrated exposure-response (IER) function, will be used.

Reduction of PM2.5 by between 5.7 and 7.9 metric tons
Reduction of NOx by between 137 and 189 metric tons

Finally, it is important to note that although diesel emissions significantly contribute to air pollution, other sources of pollution are prevalent in rural Alaskan communities. These include:

- Forest fire
- Road dust
- Solid waste burning
- Vehicle emissions

Takeaways / Recommendations

A few key takeaways resulted from our analysis. Studying the Adak case helped guide our thinking towards what type of community and project we wanted to undertake. Our main conclusions are as follows:

Technical: while the resizing of the generators is unique, the challenge of getting old diesel generating infrastructure up-to-date and generating more efficiently is not. Nor is the desperate need for affordable energy and heating security.
Heat recovery: many communities are exploring ways to incorporate a waste heat recovery project into their electricity generating systems. Colocating the power plant also allows a community to reduce distribution costs.
Community revitalization: the Adak project focused heavily on how the diesel efficiency project could create co-benefits beyond just public health, including mixed-use development and emergency situation protocols.
Project approach: the AEA cautioned that projects attempting to layer in a renewable energy component on existing aging infrastructure will need to address the challenges of the underlying infrastructure first. Putting renewables on top of an older system won't work. In order for wind to be interconnected, the underlying system requires updated switchgears and some form of automated control.

The ultimate finding of our feasibility study shows that diesel efficiency has a very high cost per avoided ton at both a project-level and a client-level, due to the capital-intensive nature of the retrofit project. The technical aspects of the project are relatively straightforward and few legal obstacles were identified at this stage, although working with the This project would only have moderate public health benefits.

Community-Scale Interventions: Weatherization

Technical Description

According to the Aleutian Regional Energy Plan, if all homes in the Aleutian and Pribilof Islands region were weatherized, it would save 295,198 gallons of diesel fuel annually. This would translate into 3,303 tons of CO2 emission reductions. Weatherization addresses the energy burden experienced by low-income rural Alaskan communities. There has been little new development in Alaskan villages.The intent of Alaska's weatherization programs is to address quality of life issues, improve the condition of existing housing stock and to maximize energy reduction in Alaskan residential buildings thereby reducing energy costs.

Much of the existing housing in Alaska was constructed before the 1990s and was not built for a northern climate, resulting in thousands of homes that are poorly insulated, expensive to heat and susceptible to leakage. The average housing unit in Alaska uses twice as much energy per year as the average house in cold climate regions of the Lower 48. Nearly 20,000 homes in the state are rated 1 Star, the lowest energy rating possible.

The Cold Climate Housing Research Center has tested the following common weatherization retrofit techniques to residential and commercial buildings in Fairbanks.

Exterior Insulation Retrofits

Above-grade walls are insulated with foam to reduce heating demand. Structures in sub-arctic environments typically have an air/vapor retarder on the interior framing surface, therefore the addition of relatively water vapor impermeable exterior foam insulation on the exterior has the potential to significantly reduce the drying ability of wall systems. The reduced drying ability is problematic if the retrofit does not adequately prevent condensation within the wall framing. These retrofits may induce mold growth, thereby increasing susceptibility to indoor air quality problems and reduced service life of retrofitted structures.

Air Sealing

Air leakage is a leading cause of energy waste in residential buildings. Air leakage contributes to high energy costs, less comfortable surroundings and may have health risks. Reducing leakages through air sealing may reduce utility costs as much as 40%.
Reducing the amount of air that leakage in buildings can reduce building heating costs. Caulking and weatherstripping are two simple and effective air-sealing techniques being used in Alaskan homes that offer quick returns on investment. Caulking and weatherstripping of door and is used to seal components that require movement. Because of the potential for reduced air exchange, there have been concerns raised regarding the potential for negative impacts on health and safety of residents when air sealing occurs.Air sealing interventions could result in small but statistically significant increases in some indoor contaminants such as radon and humidity, while also reducing exposures to elevated carbon monoxide in some homes.

Ventilation improvements

An evaluation of the village housing stock would determine whether mechanical ventilation would be an appropriate weatherization technique.Mechanical ventilation improves indoor air quality in newer, airtight buildings that are designed to minimize energy use. However, introducing cold, dry outdoor air into a space increases heating costs and can over-dry the indoor air. Heat and Energy Recovery Ventilators (HRV/ERVs) can mitigate the heating costs somewhat by recovering heat from the exiting air.Energy Recovery Ventilators (ERVs) exchange stale indoor air with fresh outdoor air, recovering heat and moisture from the exhaust air and transferring it to supply air. Heat Recovery Ventilators (HRVs), only recover heat from exhaust air and thus dry out the indoor air. In a cold dry climate like Interior Alaska, ERVs could help improve indoor air quality by adding moisture to the air.CCHRC is testing how an air source heat pump will work with a combined heating and ventilation system used in high-efficiency homes in Alaska. The system uses an HRV to deliver heat from an oil-fired boiler to ensure homes receive adequate fresh air. CanmetENERGY-Ottawa funded the initial research in 2016 and is supporting this new round of lab testing, which will take place at CCHRC's Research and Testing Facility.

Appliance upgrade/replacement

Refrigerators and freezers consume about 10% of the electricity of a typical home in the United States. Older units consume more electricity than newer units. In the past 20 years refrigerators have gotten 60% more efficient , which reflects stricter energy efficiency standards from the U.S. Department of Energy and Energy Star. Newer Energy Star refrigerators are required to consume 20% less energy than the maximum electricity consumption allowed under the Department of Energy standards (e.g. about 500kWh/yr for a 19 cubic-foot unit).

Woodstove change-out programs help lower fine particle emissions by reducing the number of high polluting solid fuel-fired heating devices in an area.
By focusing on the most polluting devices including wood- or coal-fired stoves, inserts, fireplaces, hydronic heaters, and furnaces that are not EPA-certified, air quality and public health benefits of weatherization can be maximized. Existing programs prioritize change-outs in localized areas that experience poor area quality and are more densely populated to produce the most emission reduction benefit. All newly installed wood- and pellet-fired heating devices are required to meet the 2020 EPA standards for solid fuel heating devices. For example - in Fairbanks, An estimated 11,333 wood-burning devices are used in the borough and approximately 1,260 residences use solid fuel-fired heating devices as a sole source of heat.

A pilot project of in Nightmute upgraded existing lighting with energy efficiency lighting and and also included weatherization upgrades in 13 community buildings and 4 teacher-housing units in Nightmute, Alaska. These energy retrofits took place as part of a "Whole Village" energy efficiency retrofit project spearheaded by The Alaska Energy Authority, with the Alaska Building Science Network (ABSN) completing community building upgrades. This project was an effort to maximize energy savings to the community in the wake of the highest oil price spike in world history - with a barrel of oil topping $150 during the summer of 2008. At the beginning of this project heating fuel in Nightmute cost residents and most community building owners $7.90 / gallon. In June, 2010 heating fuel in Nightmute cost $6.60 /gallon with an expected price increase later that summer. The FY 2009 full cost of electricity rate was .53 cents/kWh.

By replacing 72 light fixtures with with electronic ballasts & T8 lamps, installing 148 compact fluorescent light bulbs, 8 T5 linear fluorescent fixtures in the school gym, the following savings were quantified:

- Pre-retrofit energy use for all lighting: 17.054 Kilowatts
- Post-retrofit energy use for all lighting: 7.009 Kilowatts
- Energy savings projection: 10.045 Kilowatts
- Pre-retrofit to post retrofit energy reduction: 59%

In the Lower Yukon-Kuskokwim region, residential energy sales average 1.02 MWh per person, with a baseline of 5 MWh. (ie residential energy sales = 4.99 + 1.02*population). On average, residential energy sales constitute 44% of a village's energy sales, and community sales average 13% (figure). Weatherization in either of these types of buildings would therefore reduce the energy burden in those sectors and have a commensurate effect on total diesel usage.

Legal, Funding and Policy Analysis

The funding landscape for weatherization projects in rural Alaska is best described as "patchwork." There are two major avenues of funding for residential housing projects in rural Alaskan communities. The first is through the Department of Energy's weatherization assistance programs as supplemented by Alaska state funds. The distributor of these DOE and state funds is the Alaska Housing Finance Corporation (AHFC), which is at the centre of this first avenue. The AHFC is a public corporation with a "mission to provide Alaskans access to safe, quality, affordable housing". The Alaska weatherization assistance program as run by AHFC is a more generous version of the generic DOE model. The program uses state funds to raise the income limits to allow more households to be be eligible for this program, and this has doubled participation.

AHFC works with subcontractors which provide services and perform the weatherization. Its main partners are the fourteen regional Housing Authorities, which correspond roughly to the regions of the Native Corporations. The Alaska Housing Finance Corporation provides the funding to the Housing Authorities for weatherization projects, and the regional Housing Authority uses their region-specific technical designs to implement the services as they desire. The AHFC also runs a supplemental housing development program with state funds that is specific to each regional housing authority.

This supplemental program is based 20% off of HUD dollars and supplemented by state dollars. Most of these projects are for energy efficiency.

AHFC also provides funding to other non-tribal community organizations like Rural CAP which are are sub-grantees. Rural CAP is a non-profit community action program working on weatherization in Anchorage, Juneau, Western, and Northern Alaska. Their most cost-effective weatherization project, what they call a "housewrap," costs on average $30,000 and can save homeowners close to $2,000 in energy costs and 5,000 pounds of CO_2 each year, or 2.5 tons.

The second major avenue of funding comes directly from the U.S. Department of Housing and Urban Development and goes to the 229 federally recognized tribal authorities directly. This source was established by NAHASDA, the Native American Housing Assistance and Self Determination Act of 1996. The money goes directly to federally recognized Indian tribes or their tribally designated housing entity (TDHE). It is important to note that this money does not go to the Native Corporation. Instead, it goes to one of the 229 federally recognized tribal associations, which do not own land under ANCSA. The tribes may have decided to either set up a housing authority, or contract with other groups to manage the funds.

It seems that most of the tribes have directed their money to the regional Housing Authority, which is their tribally designated housing authority (TDHE). For example, the Aleutian Housing Authority is the tribally designated housing entity for all 12 federally recognized Tribes within the region. This is the same for the Bristol Bay Authority. The regional Housing Authority cannot spend the money designated through NAHASDA for one tribe on behalf of the other unless the first tribe has agreed to it. This has led to commentary that the money is patchwork and inefficiently dispatched because it can take a community multiple year to save up for a project, at which point the context and momentum may have changed.

Regulatory approval for this second avenue of funding is vetted based on income eligibility. Federal funding and state funding have different income eligibility thresholds, with applicants placed on a 6-tier priority list. The elderly, disabled, and families with children have enhanced priority. There are also Indian Housing Block grants, as part of NAHASDA.

There are regulatory challenges to implementing a community-based weatherization program that involves the community youth in weatherizing homes. Under the first avenue of funding under the DOE, federal money may have strict investment thresholds, health and safety spending quotas, and stringent quality control, such as requiring certified inspectors and certified managers overseeing the job. These certification challenges may present barriers to enabling locals from taking more ownership of these projects and processes. However, this is not the case for the funding distributed under NAHASDA, since the purpose of the Act was to provide greater self-determination and less oversight over Native communities. However, the funding distributed through NAHASDA may be more patchwork and isolated by region, since it is only provided to individual tribes which may provide for various communities in different regions. It is more difficult to combine the offsets achieved through NAHASDA funded weatherization projects since these are more likely to be multi-year single-family renovations.

Nonetheless, although the landscape is complicated, there are no insurmountable legal obstacles and both the regulatory and contracting pieces of the project are a go from a legal perspective.

he structure of the weatherization project is to sell offsets to an unregulated entity (our client) that would be willing to purchase offsets to fund a regional Housing Authority or tribally designated housing authority (TDHE) that performs weatherization projects. The money would fund weatherization of public housing developments, which are then aggregated into a bulk offset calculation.

Working with public housing authorities has two benefits:
First, working with affordable housing maximizes distributional equity and environmental justice because the beneficiaries will be in a low income bracket
Secondly, working with public housing allows the project to aggregate offsets achieved into a marketable package rather than having to negotiate with individual home owners or renovation projects, which would be difficult to achieve.

This funding would supplement the grant scheme currently available through NAHASDA and AHFC. The project would also then ideally have a community engagement aspect to train and employ local youth.

Addendum

This addendum was written after the feasibility study but before the implementation plan. It explains the change of choice from the Regional Housing Authority partnership model to RuralCAP as the project implementation partner.

At the feasibility stage, we were focusing on the Native Corporation's Regional Housing Authority as the best locus of partnership. Regional Public Housing Authorities such as the Bristol Bay Housing Authority conduct weatherization projects in their regional territories, and our aim was to incorporate all the reductions from one housing authority to create an offset package. The goal of this was to work with public housing to both weatherize public housing stock that benefit low-income peoples and focus the project geographically. However, as of March 26th, we moved away from that model after our call with the Bristol Bay Housing Authority, which informed us that housing authorities do not weatherize their own properties and are not allowed to do so based on their internal regulations.

After our call, we settled instead on directly funding RuralCAP, the community action partner that performed weatherization projects on our area of focus: Western Alaska. Operating in the legal context of an independent non-tribal non-profit subcontractor like RuralCAP—which is not tied to the Native Corporation system—is much more simple. We are now contracting three ways with the community (the tribal authority of Alakanuk), our client (the unregulated entity), and RuralCAP, a non-profit organization that does not operate within the tribal legal landscape. Based our conversation with RuralCAP, they also have the capacity to set up a separate grant program based solely on the funding from the offset project, and the money would only be subject to the terms agreed upon in this program, without stipulations that bleed in from other funding strings.

Client

The client for the weatherization project is Alaska Airlines and/or Amazon. The client would ideally fund the upfront capital-intensive costs of the weatherization project, while claiming the carbon offset benefits and other social co-benefits created from the project. We have chosen these two potential clients because rural Alaska communities that are inaccessible by road are heavily reliant on both Alaska Airlines and Amazon for transportation, access, and shipping of everyday necessiities. Thus, we believe both clients would have a strong interest in investing in and developing such communities.

Illustrative Benefit-Cost Analysis

The estimated costs are as follows:
The number of homes in the community, with $30,000 average cost (inclusive of $6,400 of material costs, as well as labor and freight)

The estimated benefits are as follows:
The number of homes in the community, with $2,000/year saved in energy costs
Public health co-benefits
Carbon offset sales from tons/year of avoided carbon

Assumptions:
Multiple cases of community size (500 people community below)
5 individuals per family, on average
100 homes
15 homes weatherized / year
Client funds 80% of the costs of weatherization throughout life of the project, and receives 80% of the total savings and carbon offset value.
Carbon offset price of $10/ton

Cost/Ton
The cost-per-avoided-ton of CO2e is $1,472.4/ton over the modeled 10-year life of the project. The cost/ton to the client's stream of benefits and costs is $176.7/ton. Similar to the diesel efficiency project, this reflects purely a financial inflow and outflow of cash, and does not incorporate co-benefits.

Community engagement

This weatherization project will require the deployment of a skilled workforce across the community. While contracting trained weatherization workers through a local company would prove more economical, we are considering the possibility to train and employ young Native Alaskans. The idea is to offer them an opportunity to earn much-needed monetized income while providing them with "green" design and construction skills that will prove beneficial in the future.

The model under consideration is that of YouthBuild USA. The mission of YouthBuild USA and YouthBuild International is to "unleash the intelligence and positive energy of low-income young people to rebuild their communities and their lives".

Structure overview

Each year about 10,000 low-income young people who have left high school without a diploma enroll full-time in YouthBuild USA Programs for about 10 months. They spend at least 50% of their time, usually alternate weeks, in caring academic classrooms, and at least 40% in hands-on job training building affordable housing or other community assets.

In the course of their full-time enrollment, they:
Achieve their high school equivalency credentials or high school diplomas in a caring individualized context
Obtain job skills and earn a stipend, wage, or living allowance for building affordable, increasingly green housing for homeless and low-income people in their communities
Gain industry-recognized certifications in preparation for productive careers
Give back and lead through participation in community service and advocating for their communities on the local and national levels.
Transition into post-program placements, in college, registered apprenticeships, other postsecondary opportunities, and employment, with support of a transition coordinator and mentors

The integration of this model in our weatherization project will require some modifications. As the high school dropout rates of the candidate communities are still unknown and may well vary from one community to another, the emphasis will not be on academic training but on providing young Alaskan natives with marketable green building skills. A partnership with local public high schools could be established so that completion of the program counts as a credit bearing internship that would be synchronized with an academic year.

Financing mechanism of community engagement project

The US Department of Labor receives an annual appropriation from Congress for the federal YouthBuild program, which it operates effectively with close attention to quality, performance outcomes, and community need. The federal YouthBuild appropriation for FY15 is 79.7 million dollars.

Each YouthBuild program in the United States is operated by an autonomous non-profit or public entity that secures its own funding – a mix of public and private support. The US Department of Labor is the primary public funding source. YouthBuild USA does not directly run any local programs nor does it participate in the selection of DOL YouthBuild grantees.

Roughly half of the current funding for local YouthBuild programs in the United States comes from the US Department of Labor (DOL) under the federal YouthBuild program which was reauthorized within the Workforce Innovation and Opportunity Act passed in 2014. DOL grants funds directly to the local YouthBuild program through an annual competitive process that rewards performance and prioritizes low-income communities.

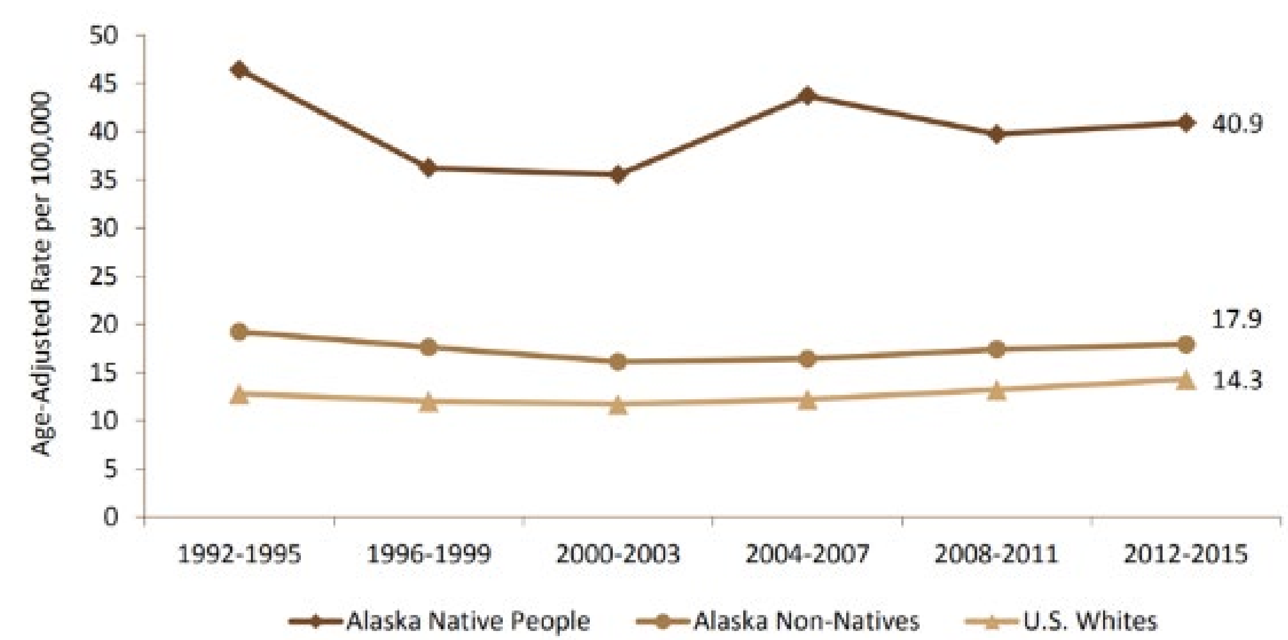
The fact that the YouthBuild program is largely federally funded and has some precedence in Juneau, Alaska suggests that the implementation of a variant of it would be feasible in Alaskan villages. A legal analysis of specific regulations pertaining to Native communities will be conducted.

Public Health Impact Assessment

Although weatherization will help decrease CO2 emissions and outdoor pollution, this health impact assessment will focus on indoor environmental quality. The air inside a home is often more seriously polluted than outside air. Because people may spend up to 90 percent of their time indoors, the risks to health can also be greater from poor indoor air quality than from outside air (EPA). Indoor air quality particularly matters for Alaskans because in cold climates, people tend to spend even more time indoors, in homes and buildings made air tight to save heat and keep out the cold (EPA). However, without fresh air and adequate ventilation, indoor pollutants and humidity can rise to unhealthy levels.

Given that this weatherization project is also designed to be implemented in a Native Alaskan rural village, the baseline demographics and health characteristics used throughout are identical to those used for the utility-scale project. However, additional health outcomes that are relevant to this intervention are described below.

The mental health status of Native Alaskans is fairly poor. According to Dr. Jay Butler -Chief Medical Officer and Director of the Division of Public Health at the Alaska Department of Health- suicide rates are significantly higher in Alaska than they are in the rest of the United States, and they are twice as high among Native Alaskans as they are among non-native residents. The results presented in Figure 1 provide historical evidence for this trend and testify to the poor mental health of Alaska Native People in general. Climate change threats further degrade mental health outcomes as issues such as solastalgia become more prominent. In Alaska, many residents have expressed concern and a feeling of depression related to the uncertainty of the



Age-Adjusted Suicide Mortality Rate per 100,000 Population, 1992-2015. Data Source: Alaska Health Analytics and Vital Records Section; Centers for Disease Control and Prevention, National Center for Health Statistics.

scope and magnitude of potential climate change.

Exterior insulation retrofits

The principal benefit of weatherization is that it prevents energy loss through the addition of insulation retrofits. A study conducted by the Department of Energy Weatherization Assistance Program indicates that weatherization has a significant impact on mental health and well-being of low income communities through the reduction of energy bills and associated poverty-related chronic stress. Chronic stress as it relates to exposure to psychosocial stress is recognized as a symptom of poverty. Psychosocial stress is experienced when individuals face complex and stressful living conditions and can be expressed through feelings of anxiety, depression, high blood pressure and insomnia.

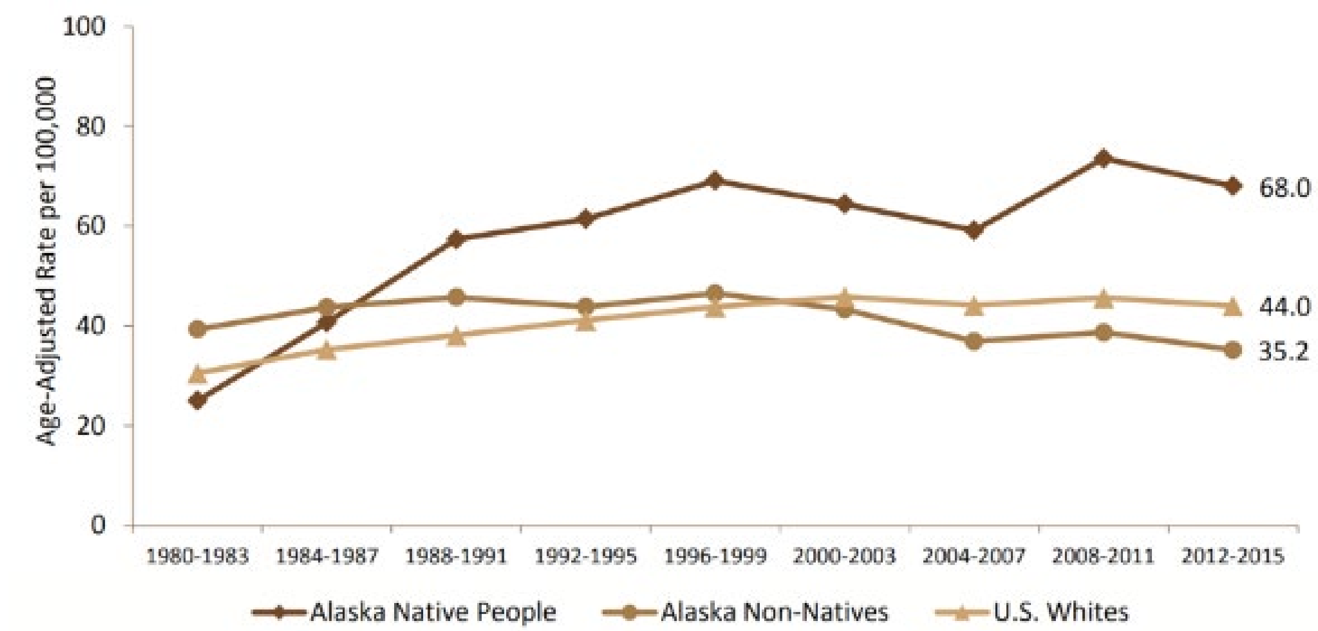
In addition to mental health, chronic stress also affects physical health. Chronic stress is an evidence-based risk factor for adverse health implications associated with the release of stress hormones, in particular, cortisol. High doses of cortisol released as a result of chronic stress correlates with a variety of health problems including cardiovascular disease, asthma, obesity, and anxiety disorders.

In Alaska, best practices recommend the house-wrap technique which is supposed to create a balance between weather protection, moisture management and durability behind residential facades. However, mold formation due to condensation might still be an issue. Molds are usually not a problem indoors, unless mold spores land on a wet or damp spot and begin growing. Molds have the potential to cause health problems as they produce allergens and irritants. Inhaling or touching mold or mold spores may cause allergic reactions in sensitive individuals. These allergic responses include hay fever-type symptoms, such as sneezing, runny nose, red eyes, and skin rash. Molds can also cause asthma attacks in people with asthma who are allergic to mold. Thus, air sealing will participate in the reduction of allergic responses and asthma attacks.

Air sealing

Air sealing participates in sequestering heat inside the homes, but it also means that the houses are made airtight. As a consequence of this decrease in air exchange rates, indoor air pollutants are trapped inside the home, thereby increasing the inhabitants' exposure factor. In particular, smoke from cigarettes and other tobacco products become more concentrated in the confined air of air sealed houses. This is particularly relevant in rural Alaska because smoking is a prevalent habit among Alaskan natives. Long-term exposure to tobacco smoke is the most significant risk factor for COPD or chronic obstructive pulmonary disease. The Alaska Native Tribal Health Consortium reports that during 2012-2015, COPD, at a rate of 68.0 per 100,000 population, was the fifth leading cause of death among Alaska Native people.

In an attempt to address this issue, we will include ventilation improvements to our weatherization plan. Depending on the village housing stock, heat or energy recovery ventilators might be used. These ventilators might also help mitigate the effect of insulation on mold formation. Air cleaners are also under consideration.



Age-adjusted COPD Mortality Rate, per 100,000 Population, 1980-2015. Data Source: Alaska Health Analytics and Vital Records Section; Centers for Disease Control and Prevention, National Center for Health Statistics.

Stove replacement

Smoke from woodstoves and fireplaces significantly contribute to indoor air pollution. Since the air sealing intervention will make the houses air tight and increase the concentration of indoor air pollutants, mitigating this detrimental effect is absolutely necessary. To do so, traditional wood stoves will be replaced by cleaner alternatives. An investigation of the different stove replacement options is undergoing and will be informed by the causal chain depicted below. Many health impact assessments have provided evidence for this causal chain.

Reduced use of wood for heating □ Less time and labor dedicated to wood gathering and preparation □ More time available for other activities □ Improved mental health□ Reduced injury risk

Vulnerable populations

Vulnerable populations to be considered are the same as the ones under consideration in the first HIA.

Youth involvement

A description of the model for youth involvement can be found in the general description of the project's structure. A potential causal chain between this intervention and health and well-being is modeled below:

Gain in employable skills □ Increased job opportunities □ Access to monetized income □ Ability to cover health expenses □ Improved physical and mental health outcomes

Heat Pumps

Heat pumps were another innovation that we considered in our screening exercise. The original design was for heat pumps to be included in a weatherization upgrade. However, based on the results of our feasibility study after discussion with local experts in Alaska working in the interested regions of Bristol Bay and rural Alaska, heat pumps are considered not yet technologically feasible or scalable for most regions. At this point in time, both air-source and ground-source heat pumps still remain important research topics rather than readily implementable technologies in Alaska. Although heat pumps are not a technologically viable addition to the weatherization project at this point in time, this feasibility analysis makes two recommendations:
Heat pumps may be appropriate and widely scalable in Southeast Alaska.
The financing of a ground-use heat pumps may be interesting for a demonstration financing project.

Heat pumps are a space-conditioning technology that move heat using a refrigeration cycle to provide both heating and cooling of indoor areas. Heat pumps provide low-cost heat at a similar cost to wood heating and emit no CO2 emissions. Their use is proven in many American states in the Lower 48 and the performance of cold-climate heat pumps continues to improve at rapid rates of technological advancement. The Tlingit Haida Regional Housing Authority applied to the Alaska Energy Authority Fund to renovate the Saxman Multifamily Low Rent building to include an air-to-water heat pump system that replaces existing oil boilers and offsets 100% of oil use in the mechanical room. From this emerged the idea of incorporating the heat pump installations in our weatherization project of public housing units in Alaska.

There are two types of heat pumps: air-source heat pumps and ground-source heat pumps. Air source heat pumps have a much lower initial cost than ground source heat pumps and are used in many other states in the US. They use ambient air from the outside space to heat the indoors. The problem is that besides the attractive element of their cost, their efficiency decreases as ambient temp decreases. Based on conversation in February 2018, Alaskan heat-pump expert Professor Tom Marsik of the University of Alaska Fairbanks was not aware of any air source heat pumps that would be broadly beneficial for a rural community in Alaska outside of the southeastern region. The amount of diesel that a participant burns to run the heat pump is greater than using to oil directly to heat the house. Air-source heat pumps may be effective in very efficient homes due to price cost equalization, but at this point, they would not be effective in rural Alaskan homes, which already suffer from problems of energy inefficiency.

Ground-source heat pumps have higher technical efficiency because the ground stays warmer than the air does, but their capital costs are significant. At this point, they have not been used or tested in rural Alaska due to the prohibitive cost. Their use could be potentially powerful in the future in a school, but the Cold Climate Research Centre was not aware of heat pumps being used anywhere in rural Alaska. Furthermore, the Centre does not have conclusive data yet about the long-term performance of ground-source heat pumps in Alaska. Thus, ground-source heat pumps are promising but more data is needed before implementation.

Ultimately, the economic efficiency of heat pump use is ultimately dependent on the cost of electricity and the alternate fuel source such as oil. Heat pumps are recommendable in locations with inexpensive electricity, expensive alternative fuel sources such as expensive fuel oil, and warmer climate conditions that would maximize their performance. This scenario is common in Southeast Alaska where inexpensive hydropower and expensive imported heating oil can make heat pumps a cost effective option.

Recommendations/takeaways:

Heat pumps would work well in the Alaskan panhandle, which consists of coastal Southeastern Alaska down to the coast of Canada. The Aleutian Islands may be another possibility because they are southern. The impact of heat pumps would be community specific, but Southeastern Alaska has hydro power installations and cheaper renewable electricity from hydro. If air source is fed with renewable energy and heat pumps are used to replace oil fired heating systems, then significant carbon reductions can be achieved.

Ground-source heat pumps could also benefit from demonstration funding. Because there has not been a lot of research into ground-source heat pumps as implemented technologies, demonstration financing is a way to obtain results about their effectiveness. Some potential sites that would benefit from ground-source air pumps include schools and hospitals. Potential clients for a demonstration finance project include governmental agencies, the Department of Energy, and the Office of Indian Energy. These organizations may be interested in the outcome of the analysis and want a more readily monitorable project to learn from.

Hydroponics

According to the World Health Organization, food security means that "all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". It includes both physical and economic access to food that will meet a person's daily dietary needs. In Alaska, 14.6% of the population is food insecure. Of this demographic, a disproportionate percentage are single women and children.

As previously described in the baseline health assessment of Native Alaskans:
"Rising food prices, challenges to food quality and quantity, and changing food distribution patterns are all factors that could be impacted by climate change. Due to the specialized dietary patterns in Alaska with a heavy reliance on subsistence resources, changes to key food sources could lead to food insecurity and associated health consequences. Many Alaska communities have already reported various changes to subsistence harvest, highlighting the need for improvement of their food security prospects. Danny Consenstein, Executive Director of USDA's Farm, corroborated the idea that poor access to healthy food options leads many of these communities to rely on unhealthy fast food chains. Such a diet, high in saturated and trans fats can raise cholesterol blood levels, a major risk factor for heart disease and stroke."

Technical Description

The conventionally-grown produce that makes its way to grocery stores across Alaska often travels thousands of miles, and often by diesel truck. This increases greenhouse gas emissions and places a burden on the already fragile and expensive regional transportation network, not to mention the depletion of the fossil fuels on which this system depends.Increased vehicle miles travelled means that food is often sold after it has passed its peak freshness and nutritional value. Rural Alaskan villages that do not have easy access to fresh fruit and vegetables year-round can be classified as food deserts.

The goals and priorities of cold climate hydroponic farms will influence the structure, design, and size of the greenhouse, the planting schedule, number of people required to maintain the hydroponic farm, and the way in which it will fit into existing infrastructure. Ideally, these goals would be high profit, low carbon footprint, educational milestones with children and community members,and importantly,and adding to the community's year-round food stocks. Keeping utility bills low is the key to the viability of a cold climate hydroponic farm as the operating cost to maintain optimal temperatures in the Alaskan climate would surpass profits. In these greenhouses, there are typically two different reasons for heating: one for the plants, which tends to manifest as heat storage and recovery methods, focused on heating the soil; and a heating system such as a wood stove or forced air heater that is used for the comfort of people working inside of the greenhouse during the cold winter months.

Hydroponic systems include the deep flow technique, nutrient film technique, or aeroponic systems For adequate management of water and nutrients in the hydroponic system, the electrical conductivity (EC), pH, dissolved oxygen, and temperature should be measured. For stable crop production, disinfection systems using filters, heat, ozone, and ultraviolet radiation are required in hydroponic systems. Hydroponic production systems can operate across different scales to fulfill different uses: household scale, market scale and retail/wholesale scale.

At the household scale, containerized growing systems (CGS), plug-in function similar to regular household appliances. A single CGS has the capacity to grow 66 plants and has a power requirement of 120V. Currently, demo units by Vertical Hydroponics are under study at the University of Anchorage. At the market/neighborhood scale, Alaska Seeds of Change uses space and energy maximizing advanced vertical farming systems from Zipgrow Trower. The simple technology allows to control the design of the project. No machinery or complex technology is required for the operations. Proven crop yields range from 4 to 12 pounds of produce per tower, depending on the crop, and high crop yields allude to potential profitability.At the retail scale, Arctic Greens, a new subsidiary company founded and wholly owned by Kikiktagruk Inupiat Corporation that establishes and operates highly scientific and self-contained hydroponic "farms" in communities where conventional farming is not possible. proved by relocating the generator to reduce the total distance that electricity must travel to reach customers, thereby decreasing line losses. If the generator is not replaced, two types of retrofits may be considered: a generator can be insulated to reduce heat loss, or lost heat can be captured and used by a waste heat recovery system. In both cases, a community can consider the possibility of installing "third party aftertreatment" systems to reduce the pollutants contained in diesel exhaust. This option will be discussed later on.

Structure of Project

Current technology employed by local hydroponic farmers such as Arctic Greens and Seeds of Change is using is a VHH designed and built 4th generation Containerized Growing System (CGS Gen IV). This specific model is an industrial-grade hydroponic fresh vegetable production system housed inside a 40' insulated shipping container, specifically designed for the arctic. The benefit of using shipping containers if that producers can select their growing locations with flexibility

The system is therefore scalable and can be used on any site with access to potable water and electricity, and provides a streamlined path from the point of production to the table. The system is professionally engineered and designed to work functionally between -60F and 85F and has been optimized for high yield, year round production. Each CGS can supply anywhere from 23,400 pieces of produce per year, which is nearly equivalent to 1 acre of farmland.

Conclusion

Technical

Two general diesel efficiency projects were considered: upgrading generators to high-efficiency models and retrofitting existing generators. The feasibility of upgrading generators is limited only by cost; because the distribution system already exists, the new generator would simply replace the existing system. The feasibility of retrofitting existing generators is dependent on the retrofit installed. Insulating the generator should always be feasible. The potential of waste heat depends on the distance that the heat travels; if the waste heat is used to heat a space far from the generation source, it is likely not economically feasible. Finally, third-party after generation systems are never feasible given current technology.

Weatherization is also being widely explored in rural Alaska. An impactful project would entail numerous of small to large scale interventions for quantifiable goals to be met, as opposed to the current piecemeal approach. Constant While the CCHRC has explored many innovative weatherization techniques, high transportation costs of materials pose a challenge. The success of the projects will rely on creative financing.

Public Health

Both the power plant retrofitting and the weatherization project would lead to significant beneficial health outcomes in Native communities. The former would reduce ambient outdoor air pollution levels by decreasing diesel consumption and associated pollutant emissions. Given the prevalence of respiratory and cardiovascular diseases in these populations, this would serve as an important preventive intervention. On the other hand, the weatherization project would address indoor air pollution issues as well as overall indoor environmental quality. The considerable reduction in energy bills would help mitigate the health effects of poverty-related chronic stress, and so would the financial gains that the youth involvement component would offer. Depending on the type of stove chosen, the stove replacement initiative would not only contribute to the improvement of indoor air quality, but also allow for crucial time and energy resources to be dedicated to other activities. This has well-documented mental and physical health implications. Quantification of decreased risk and averted cases remains to be done for both projects, but the multifaceted nature of the weatherization project grants it the ability to tackle more health issues than the utility-scale project could.

Regulatory and Finance

Both projects require a significant contribution from the client. Both projects can be equally compelling, but in terms of cost per avoided ton, the weatherization project is clearly less costly, by an order of magnitude. For the diesel efficiency project, a combination of grants, public loans, and municipal bonds can fund the costs. For the weatherization project, funding can either come through either federal grants or tribal grants. Given a choice, tribal grant money gives projects a bit more flexibility. Ultimately, the financing prospects and regulatory environment for both projects have challenges. Cost-per-avoided-ton is a purely financial metric and benefit-cost analysis should not be the sole decision-making criterion.

Legality

Neither project in the feasibility study presents insurmountable legal challenges. At this point, Alaska does not have carbon emission standards or weatherization requirements. Although the legal and regulatory landscape in Alaska is complex, complex contracting issues can be solved with more information about how local actors interact. Our team will continue conducting research with local actors. For the diesel efficiency project, we have not identified any legal obstacles. Contracting considerations may arise when we evaluate the integration of waste heat into a local social services provider. At that point, we may evaluate what entity runs the local services provider and their relationship to the entity that owns the land.

For weatherization, the legal multi-actor landscape is more complex. Although the general landscape is somewhat clear, we still have more questions to resolve about the relationships between different local actors such as the Housing Authorities and the tribes. However, there are no legal issues that would present an insurmountable red flag.

For the community engagement aspect of weatherization, there are some contracting and legal issues to consider which may be complex. For example, funding that is tied to DOE and state grants may be more restrictive in their application of subcontractors. Local procurement and municipal tribal laws may also restrict the choice of service provider. Lastly, as a general note, subcontracting to an organization that hires local youth creates employment benefits, but may also create inefficiency if the contract is too "hard" and inflexible. Because the communities are so small, if there are few youth available to work at the time, mandating their engagement would be overly prescriptive. At this point, we are considering a soft contract that provides for youth employment as a benefit that a funding source would consider when deciding what subcontractor to choose.

SCREENING EXERCISE

Introduction

Alaska is home to 40 percent of federally recognized tribes in the United States. Many of the 229 indigenous groups live in isolated communities disconnected from the state's road system and electrical grid. These villages rely on imported food, fuel, and other goods and services. Alaska was the third most expensive state in 2017, a ranking that considered only the most populous cities in the state (Council for Community and Economic Research). Rural communities experience higher costs-of-living still, a situation that is worsened by high unemployment. The average unemployment rate in the state is 7.3 percent and rural communities often have higher rates.

Fuel is a significant component of the high cost-of-living in rural Alaskan communities. Most communities depend on imported diesel fuel to provide heating and other needed energy. Reliance on diesel exposes local economies to global fluctuations in energy costs. Diesel also emits large amounts of particulate matter and other harmful air pollutants when burned, resulting in adverse public health effects.

Climate change exacerbates the ongoing economic and public health challenges faced by rural Alaskan communities. Alaska warmed twice as fast as the rest of the United States over the past 60 years. The state average annual air temperature increased by 3 degrees Fahrenheit between the 1950s and the present, while the average winter temperature increased by 6 degrees. While the shorter, warmer winters may decrease heating needs, communities must address increases in coastal erosion, flooding, and saltwater intrusion. They also face decreasing wildlife populations and permafrost that affect food availability and storage.

Our team will work to identify, evaluate, and plan a carbon offset project located in a rural Alaska community.

The offset project will reduce community carbon emissions by addressing energy sources, energy efficiency, or energy needs. The project will also address economic and public health concerns faced by the community, including energy costs, indoor and outdoor air quality, black mold, and food insecurity. The project will target a community that is not facing imminent displacement, but which may have to relocate over the long-term. It will also identify a client and propose a financing scheme.

This memo will discuss the process by which our team identified an initial set of potential projects and criteria, discuss those projects and criteria, and describe the final, narrowed set of possible projects.

Project Brainstorming

Our team began by first compiling all of the suggested project ideas from the given Alaska memo in a document. Then we selected and delegated six relevant themes based on the interest and expertise of team members.

We determined the themes to be food, weatherization, grids/renewable energy/energy storage, energy efficiency (waste heat + line losses), cold climate heat pumps, finance, and community development/social enterprises.

Team members then compiled ideas and resources based on their personal research and expertise. We looked through the application summaries of the Alaska Renewable Energy Fund, the Northwest Arctic Borough's Strategic Energy Plan, and the Environmental Protection Agency's grant awards database to find relevant projects that we added to a compiled spreadsheet.

We specifically looked for projects that were led by the communities and culturally appropriate to the area. We also selected for technical feasibility and financial cost-effectiveness. Similarly, we evaluated our projects by looking at potential community locations, some of which we had found in the Alaskan memo and others which were listed in the Renewable Energy Fund summaries.
At this point, we also began corresponding with Bruce Wright to narrow in on the possibility of working with the Adak community in the Aleutian Islands.

After compiling a spreadsheet with all the ideas, each group member brought forth the top three projects in their assigned theme. From within these projects, we narrowed down the selection to six large ideas. We then evaluated these six ideas based on our selection criteria to come up with two final ideas.

Project Ideas

1Biomass

The fuel obtained from biomass burning can provide renewable, sustainable, and relatively clean energy for Alaskan communities. A variety of sources were considered during the screening exercise including a pellet fuelled biomass heating system, a waste-to-energy facility development, and the combination of fish oil with diesel to power electrical generators and boilers.

Each of these projects was either deemed feasible in a specific Alaskan village or already implemented. In Dutch Harbor for instance, Westward Seafoods uses fish oil in its boilers to produce steam. It has used fish oil in gen-sets since 2002 in a 50/50 ratio with diesel. However, these projects are highly community-dependent, which will be a barrier to nationwide scalability in the future.

2. Wind Energy

The Aleutian Islands and other Alaskan coastal regions are located in an abundant wind energy resource [figure 1]. At 50 meters, the height of a standard community-scale installation, Adak and other Aleutian communities have access to a class 5 or higher wind resource. The growing prevalence of wind power in the state demonstrates the significance of this resource: between 2010 and 2017, installed wind power capacity in Alaska increased by a factor of more than six.

Remote communities are home to 28 installations that integrate wind energy into an existing microgrid. These installations can significantly reduce reliance on costly and harmful diesel-based energy. For example, the Kodiak Electric Association Pillar Mountain Wind installation, built in 2009 and expanded in 2012, provided almost 20 percent of Kodiak's energy in 2016 at half the cost per unit of diesel.

3. Heat Pumps

Heat pumps are a proven space-conditioning technology that move heat using a refrigeration cycle to provide both heating and cooling of indoor areas. The performance of heat pumps in cold climates continues to improve and they have been tested in Alaska. Heat pumps provide low-cost heat at a similar cost to wood heating and emit no CO_2 emissions.

An idea arose in the Tlingit Haida Regional Housing Authority's request to renovate the Saxman Multifamily Low Rent building to include an air-to-water heat pump system that replaces existing oil boilers and offsets 100% of oil use in the mechanical room. This idea of combining public housing developments and heat pump renovations is an interesting design which may be scalable and technically feasible in communities across the state.

4. Waste Heat

Waste heat systems collect the heat generated by power plants that would otherwise dissipate, increasing power plant efficiency and providing a valuable heat resource to communities. The collected heat, stored in water or air, can be used for space heating, to provide domestic hot water, or to prevent municipal water supplies from freezing. Waste heat systems can also be combined with community development projects to provide heating or hot water to common spaces.

Waste heat projects are also cost-effective: implemented heat recovery projects, together with other diesel efficiency measures funded by the Alaska Energy Authority's Denali Commission, are estimated to produce $10.2 million in savings over the lives of the projects. In contrast, the total installation cost was only $5.5 million, or a little more than half the savings produced.

5. Weatherization

The goal of weatherization is to increase the energy efficiency of homes and buildings through the installation of weather stripping, caulking, storm windows, and insulation for instance. It also creates energy security and resiliency while ensuring the resident's health and safety. Both residential and whole-village weatherization initiatives were assessed. According to the Aleutian Regional Energy Plan, if all homes in the Aleutian and Pribilof Islands region were weatherized, it would save 295,198 gallons of diesel fuel annually. This would translate into 3,303 tons of CO_2 emission reductions.

Given the substantial precedence of weatherization in different Alaskan villages as well as the quantifiable carbon emission reductions, these projects would be scalable, technically feasible and easily marketable. However, their high costs require novel and innovative financing solutions.

6. Diesel Efficiency

Diesel generators are dirty-burning fuel sources, but provide a reliable and constant source of electricity. Proper sizing of diesel generators and upgrading to the latest, cleanest technologies can reduce the greenhouse gas emissions and other polluting emissions from diesel generators. These upgrades include installing after treatment devices to target NOx and particulate matter from being released from the combustion. Because many communities already have diesel generators and surrounding diesel infrastructure, this option is cost-effective, feasible, and has large carbon reduction impacts. There are also cogeneration benefits for utilizing waste heat.

7. Hydroponics

Hydroponics uses soilless culture with designed substrates, mixes and sometimes a completely liquid culture with no solids in the root zone. Thus, hydroponic production systems offer no opportunity to sequester soil carbon, as does traditional farming. Carbon sequestration can play a big role in making a cropping system carbon neutral or negative. Other management factors that would affect the carbon neutrality of a hydroponic system include:
1) energy used for lighting or irrigation,
2) energy used for any other management inputs, and
3) nitrous oxide and methane emissions.

The Native Kikiktagruk Inupiat Corp is using hydroponics technology to grow produce inside an insulated, 40-foot shipping container. With effective implementation, the project is scaleable. Hydroponic farms would ideally serve rural communities, as Alaska's minimal road system determines week long transit journies of steeply priced vegetables.
Steep startup costs in Kotzebue were around $200,000, including the customized freight container and the price to fly it in a C-130 transport plane from Anchorage, 550 miles to the southeast.

Screening Criteria

We developed a set of 5 screening criteria to evaluate each of our project options, on a scale of 1 - 3, where 1 is below average, 2 is average, and 3 is above average. In addition to the 5 criteria, the project must "check the boxes" of legality and additionality.

1.Carbon Reduction:

The project must meet at a minimum a reduction of greenhouse gas emissions, through energy efficiency, cogeneration, displacement of carbon-emitting fuels, sequestration, or other reduction technologies and strategies. The project's impact should also be quantifiable in cost per ton.

2.Technical feasibility:

The project must be implementable from a technical standpoint. The materials should be able to be sourced and delivered to the project site, the construction can happen in a reasonable time frame, and the technology is proven, effective, and reliable.

3.Technical sustainability:

The project must be relatively self-sustaining and maintainable, from a technical perspective. After implementation, the technology must be easily operated, relatively self-sustaining, able to be maintained in the event of failure or breakdown, and has an expected life span that matches the need of the community.

4.Cultural sustainability:

The project must be relatively self-sustaining and maintainable, from a community implementability and cultural appropriateness perspective. For example, very foreign technologies that require high levels of knowledge training for locals in order to maintain may be less culturally sustainable than a technology that is home-grown from local communities. For our initial screening, this criteria was left blank, because this can only be determined after a specific community has been identified.

5.Public Health Impact:

The project must improve public health impacts or mitigate negative impacts. This includes reducing impacts from indoor and outdoor air pollution, improving food security and access to nutrition, reducing exposure to dangerous cold temperatures, and other health improvements.

6.Financial Feasibility:

The project must meet certain financial criteria, beyond cost effectiveness. Our screening considered the initial capital expenditure required, maintenance capital, investor attractiveness, and historical track record of sponsorship of similar projects.

Final Project

The results of the criteria-based screening were taken with caution given the lack of granularity of the scale and the lack of knowledge regarding the demographics, geography, and skillset of the community that will ultimately be chosen. Given the recurrent theme of multiple of the proposed projects and the possibility to integrate one with another, we decided to combine potential projects into four overarching umbrellas.

The four schemes are:

1. Power plant retrofitting (waste heat + diesel efficiency)

2. Renewable integration (wind + storage or hydrokinetic + storage)

3. Community engagement (weatherization and/or heat pumps)

4. Hydroponics

We acknowledged that hydroponic growing systems could not achieve carbon emission reductions independently. This was eliminated as a stand-alone project option, but will be integrated in the final project to meet the food security requirement.

The team having agreed that a community engagement proposal was necessary, the next and final step was to choose between retrofit power plant and renewable integration. The increased technical feasibility and ease of maintenance of power plant upgrades over the integration of renewable energy into a grid allowed us to eliminate the latter.