IMPLEMENTATION PLAN FOR A WIND-DIESEL MICROGRID IN SHISHMAREF, AK

MO EARLEY | SIDRA FATIMA | PAAVANI GARG | BRIAN HO | WILLOW LATHAM | DARYA MINOVI

Climate Solutions Living Lab
Harvard Law School

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.

Executive Summary

Shishmaref, an Alaska Native community in the Bering Strait, faces an important juncture. Climate change-driven sea level rise and erosion have made the current location on a barrier island too risky for continued year-round occupation. As the village anticipates relocation to mainland Alaska, the $180 million cost of the move is a major barrier. Financing housing and community infrastructure at the new West Tin Creek Hills site is a pressing challenge.

Like other communities confronting relocation, Shishmaref faces a catch-22: to access many financing sources, it must have established residents, but to establish residents, it needs the funds to move. Through our own independent research and a series of meetings in Anchorage, Alaska, with stakeholders working to support the relocation of Alaska Native villages, we carefully honed our project proposals with this catch-22 in mind in order to maximize the value of our collective work. As a result, we identified three project options that provided the potential to either lower moving costs or unlock new funding sources while ultimately serving the expressed needs of Shishmaref.

Shishmaref's need for relocation is driven in part by the direct and indirect impacts of broader anthropogenic climate change: sea level rise, permafrost thaw, increased storm surges, reduced sea ice, land loss and coastal erosion, all entirely outside the control of the impacted community. The three proposed projects therefore prioritize enabling relocation, but also aim to produce greenhouse gas reductions, where reasonable, that external partners (non-regulated entities) might purchase as greenhouse gas offsets to both contribute to and compensate for the village's relocation.

Following extensive research, we identified three project proposals for further consideration:

Package 1. Hybrid Microgrid Infrastructure for West Tin Creek Hills to Reduce Cost of Energy, Improve Energy Independence and Improve Public Health

Package 2. A "Foothold" Community at West Tin Creek Hills (JBER Barracks),

Package 3. Opportunities for Private Investment to Create Capital for Sustained Community Investment Efforts.

After assessing each Package against our project goals and selection criteria, we determined that Package 3 provided the most significant amount of added value for the community of Shishmaref.

"Shishmaref is going to be relocated. The only question is, is it going to be into the ocean or somewhere else?"

Dr. Jay Butler
Director of the Division of Public Health at Alaska Department of Health and Social Services

Acknowledgements

We would like to thank Professor Wendy Jacobs at the Harvard Law School for the opportunity to study this topic, Seung Kim, our teaching fellow for all his help, and all of the following people who met with us in Alaska.

- Sally Cox, Community Resilience and Climate Adaptation Programs, State of Alaska
- Captain Don Antrobus, U.S. Public Health Service, Village Infrastructure Protection Program Manager, Denali Commission
- Max Neil, Environmentally Threatened Communities Program, Alaska Native Tribal Health Consortium
- Gavin Dixon, Senior Project Manager, Alaska Native Tribal Health Consortium
- Karen Murphy, Coordinator, Western Alaska Landscape Conservation Cooperative
- Annie Weyiouanna, Local Coordinator, Native Village of Shishmaref IRA Council
- David Lockard, Bulk Fuel Program Manager, Alaska Energy Authority
- Karen Pletnikoff, Community Environment & Safety Manager, Aleutian Pribilof Islands Association, Inc.
- Jeffrey A. Herzog, U.S. Army Corps of Engineers, Alaska District
- Ann Y. Gravier, Senior Management Analyst, US Department of Housing and Urban Development
- Tim Leach, Energy Specialist, Alaska Housing Finance Corporation
- Jimmy Ort, Research and Rural Development, Alaska Housing Finance Corporation
- Scott Waterman, Energy Programs Manager, Alaska Housing Finance Corporation
- Soren Johansson, Press & Communications, Alaska Housing Finance Corporation
- Margaret McCall, Rocky Mountain Institute
- Jonathan Kreiss-Tomkins, District 35, Alaska State House of Representatives
- Rebecca Garrett, Alaska Energy Authority
- Katie Conway, Alaska Energy Authority
- Cady Lister, Alaska Energy Authority
- Elizabeth Arnold, Shorenstein Center Fellow, Harvard University
- Tezrah Tippin Poe, Polar Research and Policy Initiative, Harvard University

TABLE OF CONTENTS

Project Goals and Background

Project Background

According to federal and Alaskan officials, 184 out of 213, or 86.4% of Alaskan Native villages, particularly those on the coast or along rivers, experience varying levels of flooding and erosion that threaten the long-term viability of their communities. Due to the absence of quantifiable and up-to-date baseline data for these remote locations, it is difficult to assess the severity of the problem, leaving policy-makers and village leaders alike ill-informed of impending risks and ill-equipped to develop a comprehensive approach to prioritizing, developing, authorizing, and funding activities that can address the needs of these at-risk communities.

Shishmaref, like many other Alaska Native villages, faces a host of significant threats to their community, the effects of climate change being only one. For the past several decades, communities like Shishmaref have discussed what they want to do in response to the challenges caused by climate change and, based on those decisions, worked with government and non-profit actors to develop the necessary plans to make their goals a reality. In the case of Shishmaref, a community significantly threatened by permafrost erosion and changing climate patterns, the community voted to "expand their community" to a new location - West Tin Creek Hills. Yet the decision to move is not enough of a catalyst to make this vote a reality. Unfortunately as the years go on without a move, sea levels are continuing to rise and coastal erosion is only increasing. Figure 1 shows projected erosion impacts in the next three decades.

FIGURE 1: SEA LEVEL RISE AND COASTAL EROSION [USACE PROJECTIONS]

Source: 2017. Data from US Army Corps of Engineers, http://www.poa.usace.army.mil/Portals/34/docs/civilworks/BEA/Shishmaref_Final%20Report.pdf

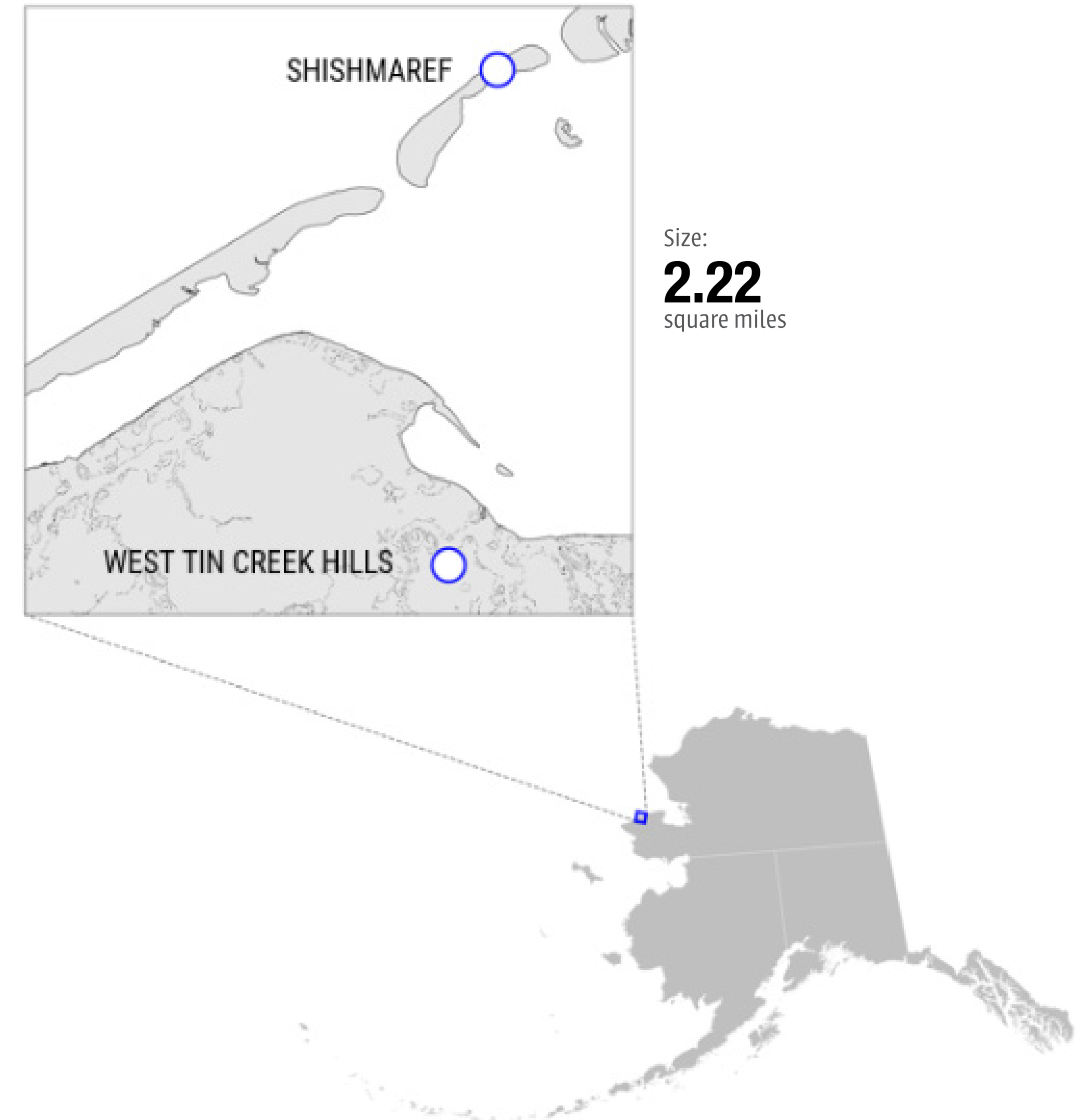
For decades, Shishmaref has had conversations at the regional, state, and national level about what to do to address this problem faced by their community. Many issues surface in these conversations: from lack of political willingness to make decisions that will set precedent for future action or threaten political reputation, to strict legal interpretations of statutes and designations. But the most significant and insurmountable challenge is that of funding. Put simply, the cost of moving a village like Shishmaref is exorbitant, and estimates for similar villages have added to nearly $200 million.

Shishmaref is a village that still lives a mainly subsistence lifestyle, relying on traditional hunting practices that generate very little true income. These are being severely negatively impacted by changing climate: ice no longer freezes which makes it more difficult to hunt. As a result of these cultural practices and their extremely remote location, economic opportunities for generating income are nearly non-existent, both on an individual and community basis.

Unlike other villages, Shishmaref is not located in a place that benefits from trade agreements related to fishing or natural resources like ore mines. So identifying sources of value creation is a challenge, making it nearly impossible to attract any sort of private investment or secure traditional loan products. Thus, the community relies on government or non-profit grants. Consistently securing enough funding to cover the community expansion over the years creates a complicated structure between bureaucratic navigation and government forms, and significant overhead in managing the many moving parts of an expansion plan.

In the case of Shishmaref and other villages like Newtok, extensive planning and research has identified what needs to happen to help these communities move. Still, many questions and gaps in data exist, such as critical geological information about the selected sites for expansion and arctic weather and rates of climate change, that also need to be both funded and conducted. The longer the timeline extends between the decision to expand the community and the actual initiation of that expansion, the more of these studies and analyses become outdated, rendering them useless in the planning efforts.

This ever-extending timeline of expansion negatively impacts the community in other ways. For example, many significant public health challenges exist in these communities due to outdated, quickly-dilapidating, or absent infrastructure, such as their dependence on diesel, physical structures regularly tested by intense weather, and the lack of running water and sanitation systems. The longer these communities stay in place, the worse these scenarios will get. However, once they've decided to pursue expansion, it is nearly impossible to get funding for maintaining existing infrastructure.



Size:
2.22
square miles

FIGURE 2: LOCATION OF SHISHMAREF IN ALASKA

About Shishmaref

573 people

2/3 of the first-year law school student body

$29,375
median household income

25 years old
median age in Shishmaref

42.8%
poverty rate

Implementation Catch-22

These timeline complications create an unfortunate catch-22. Once the community decides to move, they are unable to get funding to support the current needs of their existing community. However, because they cannot get enough funding to move, they are forced to stay, and must do so without the necessary improvements. This catch-22 paralyzes the community, planners, and funders alike, and cannot be ignored when thinking about potential solutions.

Some attempts have been made to try to avoid this catch 22. Specifically, note the use of the word "expansion" rather than "relocation". This important distinction has been creatively selected and carefully utilized to reframe the idea of leaving an old site behind and moving to a new site; rather, investments allow them to expand and grow their community - in area, population, development, and economy - by including the new site nearby that they have selected, West Tin Creek Hills.

In many ways, the Alaska Native village of Shishmaref is fortunate in that significant analysis has been conducted to better understand the community's level of risk and inform the approach to responding to the threat of erosion and permanent change to their lifestyles due to rising sea levels, shifting weather patterns, and rising temperatures. According to a 2003 report developed by the Government Accountability Office (GAO), Shishmaref is one of four villages considered to be in imminent danger from flooding and erosion, and the community agreed to work with federal agencies and other Alaskan state and non-governmental organizations to determine the next steps for relocation. In 2009, GAO released a follow-up report prompted by the growing impacts of climate change that increased the urgency of state and federal responses and found that the absence of a lead federal entity to oversee relocation processes significantly contributed to the lack of action. Despite more than 15 years passing between the original GAO report identifying the need for action and our team's introduction to Shishmaref, the complex legal, political, and financial contexts, along with the difficulties inherent to navigating multiple levels of governance at the local, municipal, state, and federal levels have slowed the relocation process.

Taking all of this complex information into consideration, our team aimed to develop a proposal that complemented the existing plans and proposals supporting Shishmaref, and maximized our comparative advantage in order to make it more likely that our work would assist in catalyzing the expansion of Shishmaref. The complex nature of the problem meant that we couldn't feasibly address all aspects of the challenges faced by Shishmaref; as a result, we focused on the elements we felt would enable us to be most impactful when delivering our solution: the legal and political context, financial sustainability, the timeline, and the implementation catch-22.

Goals

We determined that our final project output would provide a phased proposal for community relocation with two overarching goals:

1. To reduce greenhouse gas emissions, and
2. To provide a sustainable, scalable approach for relocation that could be both used specifically by Shishmaref and provide a template for similar communities threatened by climate change impacts.

Additionally, given the urgent need for relocation, we decided that our project output should prioritize implementability: financial, legal, political, operational, and behavioral, when considering design and technical solutions. Additionally, the relatively limited scale of existing greenhouse gas emissions means that any significant offset would require multiple interventions on a long-term timeframe. Our proposed relocation plan identified the following sections:

- **Community Design:** Best practices for the design, construction, operation, and funding of housing, heating systems, energy infrastructure, water and sewer systems, community layout and services, and a comprehensive process for community empowerment and decision-making.
- **Implementation:** Feasible approaches that link desired physical improvements to a client that will purchase RECs and a detailed, specific financing plan with components that address both immediate relocation and the long-term economic sustainability of the relocated village.
- **Technological Improvements:** Alternative technologies and energy sources that serve public health and social benefits.

Wind Farm in Alaska

Source: https://ensia.com/features/alaska-renewable-energy/

Screening Process

With these goals and assumptions in mind, we moved forward with the process of screening potential options and solutions. Faced with the challenge of identifying innovative and feasible approaches to assist the community of Shishmaref with relocation, our team began first by attempting to better understand the work being done to support the relocation of another similarly-threatened community: the Alaska Native village of Newtok.

By reviewing the existing extensive plans developed by the Newtok Planning Group, we quickly recognized the complicated and interconnected ecosystem of factors dictating the ability of any Alaska Native community to relocate. We conducted further research into the similarities and differences between Newtok and Shishmaref to ensure that lessons-learned by the Newtok Planning Group would be suited to meet the distinct needs of the Shishmaref community. Based on this initial research, we developed a set of screening criteria to guide our efforts:

Screening criteria:

Sustainability and Scalability: Our project should aim to protect and sustain natural resources through: GHG emission reductions, decreases or elimination of fossil fuel use, or generation of renewable energy, and should demonstrate the potential to be adapted and scaled to other communities - Alaska Native or otherwise - experiencing similar challenges related to the threats of climate change.

As our research has progressed, we've recognized that sustainability and scalability are also related to the political landscape and narrative, as well as the existing governance structure within which Shishmaref exists. Thus, our project should be politically palatable based on current or foreseeable trends, and should be implementable within the context of the layers of governance.

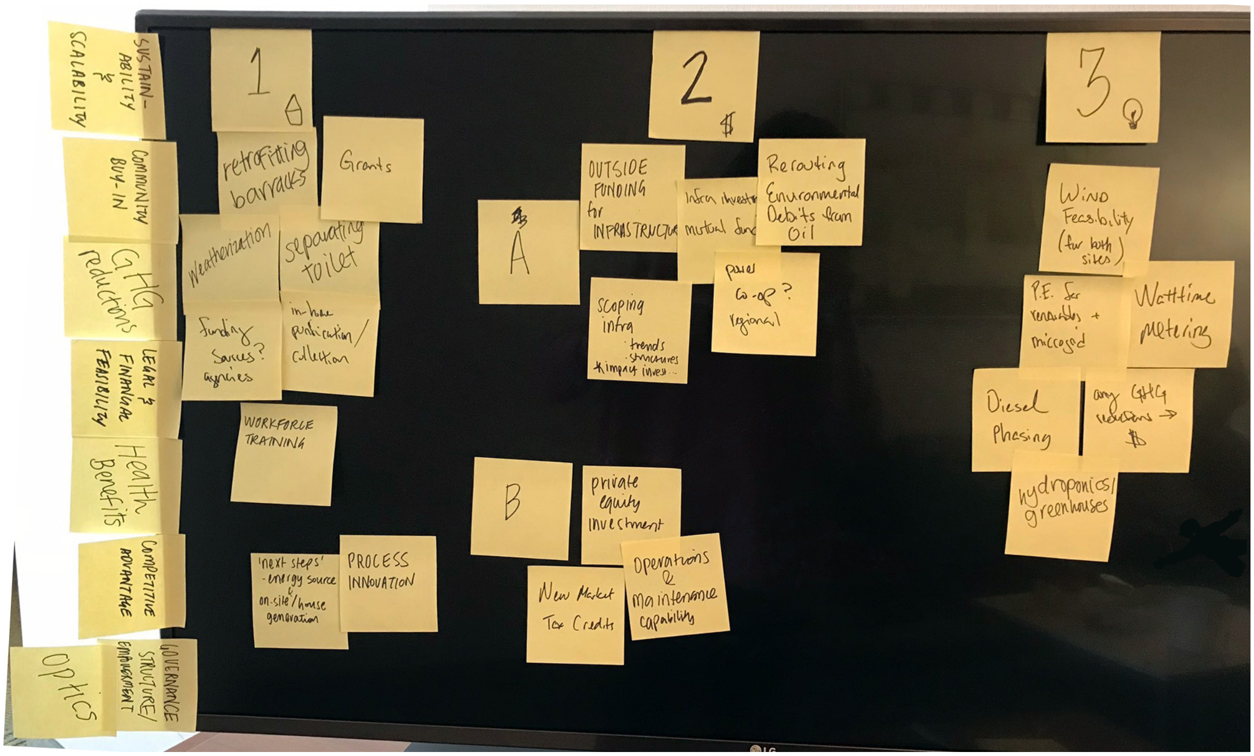
Community Buy-In: Our project should meet the understood needs of the Shishmaref community, either by directly addressing concerns or requirements shared by community members or by providing options and a clear process through which community members are empowered to determine the best course of action based on their preferences.

Our trip to Anchorage and additional research revealed valuable information about how Alaska Native communities currently understand relocation, and due to complex legal, financial, and political barriers, the sequencing of relocation project elements is extremely important. As such, we will take into account the ways in which projects can be limited by these complexities, and more importantly about how they can assist in catalyzing relocation momentum.

Legal and Financial Feasibility: Our project should be legally viable within the federal, state, municipal, and tribal governance infrastructure, and should be financial feasible in that the project should be structured in a way that can reasonably be expected to provide sufficient, timely, and manageable sources of funding to support project implementation.

Demonstrated Competitive Advantage: Our project should appropriately iterate and improve upon existing proposals and subsequent requirements,

FIGURE 3: SCREENING PROCESS



The team's hotel room television acted as a brainstorming board to screen through for potential packages.

designs, and structures in ways that are cost effective, improve public and community health, promote environmental consciousness, and are easier to implement and sustain by actors at all levels working on the complicated challenge of relocation.

ALASKA TRIP

Following our initial screening exercise, several team members traveled to Anchorage, AK where they met with a host of key actors who are working directly on efforts to support Alaska Native community relocation efforts. The team attended a day-long meeting of the Governor's Climate Action Leadership Team focused on climate adaptation efforts and challenges. This opportunity to gain additional context from meetings provided our team with the ability to further refine our approach and outlook to identifying, scoping, and delivering a project that meets both our original criteria as well as newly-identified targets to ensure that this final implementation plan is a valuable tool to the existing actors working on Shishmaref's relocation effort. A detailed account of the trip is in Appendix A.

Team members (left to right: Darya Minovi, Mo Earley, and Brian Ho) with (from right to left) Max Neil, Sally Cox, Dan Atrobus, and Gavin Dixon in Anchorage, AK. Photo by Sidra Fatima.

Feasibility Study

This Feasibility Study sought to evaluate the practicality of 3 project options on a set of cross-cutting measures that capture both practical, environmental, and social considerations.

Package 1: A "Foothold" Community at West Tin Creek Hills (JBER Barracks) evaluated the re-use of temporary barracks to establish a "foothold" community at West Tin Creek Hills. Retrofitted barracks, estimated at 75% of the cost of new construction, could move forward the relocation timeline by lowering the cost barrier of the move, as well as potentially unlock funding sources that require established residents.

We concluded that, while feasible, further analysis of Package 1 presented minimal opportunity for added value by our team. Barracks relocation has already been evaluated and cleared as a reasonable option by several in-depth feasibility studies, including detailed cost analyses and retrofitting plans. Here, we propose several alternative retrofitting options to minimize diesel dependence, and put forward several contingencies for consideration. We recommend that the Shishmaref community continue to consider this option given the detailed information available, as well as take advantage of lessons learned from the Mertarvik relocation.

Package 2: Opportunities for Private Investment to Create Capital for Sustained Community Investment Efforts analyzed alternative financing sources, including private-sector options that the community could access prior to relocation. Constraints and opportunities posed by each were evaluated, focusing in particular on innovative sources and structures that have been under-evaluated by previous studies focusing on government funding. For multiple reasons, this option was not considered feasible: the project would be too small in size to generate a substantial return for investors; there are not many identifiable potential partners willing to invest in a small scale project; aggregating communities in Alaska leads to hurdles in structuring an investment that would deliver consistent returns from all communities. Due to the uncertainties of the proposed project, there is difficulty in pitching a source of return to investors. Similarly, since we were unsure of what projects the relocated village could realistically undertake, we could not guarantee any energy reductions to our investors

Securing private capital did not pass our feasibility study. We will, instead, focus on federal funding, public grants (e.g., Coastal Impact Assessment Program, Rasmussen Foundation Grants), as well as tax deductible donations in order to move the project forward.

Package 3: Hybrid Microgrid Infrastructure for West Tin Creek Hills to Reduce Cost of Energy, Improve Energy Independence and Improve Public Health explored opportunities for energy provision that reduce diesel dependence and food vulnerability. In particular, we evaluated the potential and estimate the costs of a wind or solar-based microgrid, especially relative to current diesel energy prices (both subsidized and unsubsidized). We concluded that a wind-diesel energy microgrid presented a viable option, with both successful precedent projects in Alaska and substantial co-benefits in terms of public health and reduced reliance on diesel deliveries. Capital costs could be high, however, and could require below-market financing options.

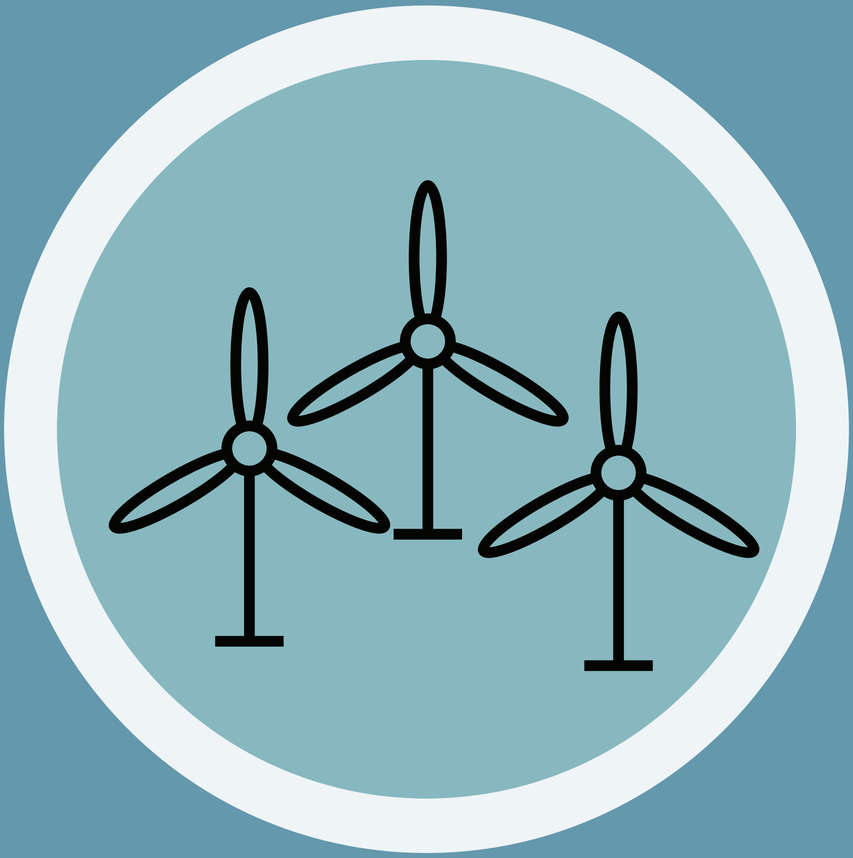
Given that the financing and infrastructure options are tightly linked and mutually interdependent, we recommend the development of an innovative funding structure for a wind-diesel microgrid during the next project phase.

We concluded that both Packages 2 and 3 represent areas where our team could potentially add value, providing deeper analysis over the course of the final feasibility study and implementation plan.

FIGURE 4: SELECTION CRITERIA FROM FEASIBILITY STUDY

CRITERIA	DESCRIPTION
Legal	Regulation, administration and governance considerations
Design	Spatial, site and logistics considerations
Public Health	Project improves community and individual well-being
Cost	Total project budget is feasible
Funding	Appropriate source of funding are available
GHG Reductions	Project produces GHG reductions (and offsets) and is additional

Proposal: A Wind-Diesel Microgrid



Baseline Assumptions

Climate change will have such severe impacts on the island, including the total cost of damages and potential loss of life that it is imperative that Shishmaref expands. But for the community to expand, a concerted and complex coordinated effort brings an equally complicated arena of challenges.

Following our Alaska trip, discussions with people who have been working towards a solution for nearly a decade, brainstorming potential solutions in the screening exercise, and considering the urgency for relocation, we realized that Shishmaref needs both funding, as well as a catalyst for movement. Because of the limitations of our team in expertise, and the course's time constraints, we looked for a project that would create the most value for the community of Shishmaref.

Shishmaref has voted on expansion, formed a Relocation Coalition, and identified an area on Shishmaref Lagoon near Tin Creek. While this would cost around $180 million, our proposal assumes that Shishmaref has created a "toehold" community, which 'expands' the community from the island to the mainland. By securing a small population at West Tin Creek hill, the village can unlock federal and state funding sources that require certain thresholds. For example, the school district requires that at least 20 children are present physically at a location to create a school. This expansion would also reassure public and private investors in the longevity of the community's sustained future. Under the settlement act, the land at West Tin Creek Hill belongs to Shishmaref, so there is no concern for acquiring funds for real estate or legal status to live there. This assumption also determines that the "toehold" community has adequate funding for housing (housing options being: modular housing, new homes with the assistance of the regional housing authority, and weatherized homes designed by the Cold Climate Housing Research Center).

Our proposal hinges on the baseline assumption that Shishmaref has secured funding, and has begun the process of expansion and future relocation to a new site on West Tin Creek Hill. In general, the project also assumes that the priorities outlined in Shishmaref's existing relocation survey have happened or will happen in sequence. This assumes the allocation of significant federal funding, without which relocation is infeasible due to the combined cost of new housing, infrastructure and logistics. The availability of such funding might involve revisions to the Stafford Act and potential increases to the budget of the Denali Commission, as occurred recently for the village of Newtok.

This project also operates on a necessary timescale of two phases: Phase I is the aforementioned solution of establishing a toe-hold community, after which Shishmaref can expand to West Tin Creek Hills, including future relocation. The expansion and relocation are not analyzed in depth, because it is assumed that it will be completed through the efforts currently undertaken by the community, with aid of government agencies and private project partners. Phase II is the proposal that this project analyzes in-depth: a wind-diesel microgrid that will help the community of Shishmaref move away from energy dependence on fossil fuels with a lifetime of over 25 years.

A "Toehold" at West Tin Creek Hill

OVERVIEW

If Shishmaref were to employ the "toehold" strategy to expand to West Tin Creek Hill, the following legal and logistical strategies explore the feasibility of Phase I.

POTENTIAL PARTNERS

For provision of materials and labor, the CCHRC, who helped design the prototype house for the Newtok relocation can provide assistance with designing a small community plan on West Tin Creek Hill. Similarly, the IKEA Foundation, which is the philanthropic arm of IKEA, can potentially provide building materials. Habitat for Humanity, which has a location in Anchorage, can potentially assist with the labor required to construct homes. This is just one set of examples out of many that could be pieced together to make this a reality.

In terms of funding, the creation of the toehold could be achieved through donations from several entities (as discussed further in the microgrid section). Funding could also be secured through offering concessional loans through the Alaska Municipal Bond Bank Authority or Wells Fargo.

The community of Shishmaref could benefit from legal assistance to advocate for scalable legal solutions for the village, as well as other native communities in Alaska that are experiencing similar challenges. Law school clinics throughout the country can assist with legal advocacy in the absence of a law school in Alaska. Clinics may assist through petitioning the current administration to declare the situation Shishmaref a Federal Disaster and unlock FEMA funding as a result. Alternatively, clinics could collaborate to develop a proposal to Congress that requests increasing budget appropriations for the Denali Commission, which recently received a $15 million budgetary increase that will assist the relocation of Newtok.

Given this is such a large project, there is not one single unregulated entity that can be identified in order to undertake it. This project requires a coalition of various institutions: non-profit, educational, private corporations, and financial institutions would need to come together to provide the necessary resources for Shishmaref's expansion and future relocation

LEGAL ANALYSIS

In terms of the land itself, in 1971 Congress passed the Alaska Native Claims Settlement Act (ANCSA), 43 U.S.C. §§ 1601-1628. Among other things, ANCSA was used to extinguish the title of Alaska Natives to millions of acres of land. Under ANCSA, Alaska Native people retained about 44 million acres, but this land is generally held in fee simple by state-chartered private business corporations whose shareholders are Alaska Native peoples.

The Shishmaref community has already considered the question of land ownership, as seen in the feasibility study conducted by the Alaska Department of Commerce:

Land ownership and management significantly influences land availability for community relocation, access and easements that might be required. Formal land ownership in the Shishmaref region has been affected by Alaska Native Allotment Act of 1906, Statehood, the Alaska Native Claims Settlement Act of 1971 (ANCSA), and the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). Prior to Statehood, the federal government owned all the land in the Territory of Alaska. The majority of that land at the time was under management of the Bureau of Land Management (BLM). Statehood provided an entitlement for transfer of federal land to state government. However, selection and transfer of lands to the State were affected by the subsequent passage of ANCSA and ANILCA.

ANCSA established regional and village Alaska Native corporations, and allowed those corporations to select land from the federal government. The Bering Strait Regional Corporation and the Shishmaref Native Corporation were established, allowing them to select subsurface and surface lands from the federal government. Native corporation lands generally include the barrier islands in the vicinity of Shishmaref, and coastal lands around Shishmaref Inlet. In addition, Section 14 (c)(3) of ANCSA allows the transfer of lands from village corporation to municipalities for community related needs.

Around that time, Alaska Native people were given the choice to become shareholders in a Native corporation or complete applications for Native Allotments. Native allotments are considered trust lands under the direction of Bureau of Indian Affairs. Native Allotments within the city limits of Shishmaref and in the vicinity are primarily located on barrier islands, along the shoreline of Arctic Lagoon, and Shishmaref Inlet, and along rivers and creeks that feed into the Inlet.

As seen on Figure 5, the relocation site of West Tin Creek Hills is within the native lands that have been conveyed to the Shishmaref Native Corporation and therefore can be relocated to without agency access permits.

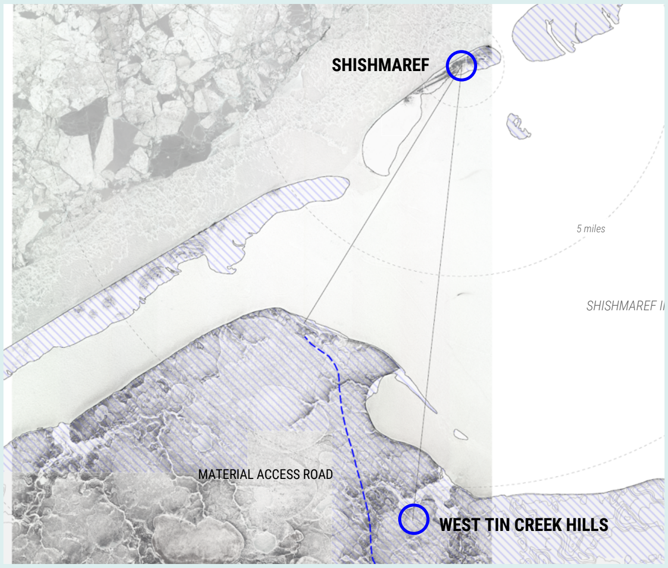


FIGURE 5: SHISHMAREF LAND OWNERSHIP
Remote sensing imagery from DigitalGlobe Foundation

THE STAFFORD ACT

The Stafford Act is the amended version of the Disaster Relief Act, which provides federal funding to natural disasters and emergency situations. The system requires a disaster declaration from the President of the United States, which then authorizes the Federal Emergency Management Agency (FEMA) to provide financial and physical assistance to states and local government. Newtok had previously applied for a disaster declaration, but was denied because slow moving situations had never been declared a federal disaster before. However, there is nothing in the Stafford Act that prevents a President from declaring a slow-moving hazard a federal disaster.

OVERVIEW

Following the feasibility study, adjustments to the original project proposal eliminated the hydroponics section of the development, and instead focuses on workforce development with a prioritization on analyzing funding mechanisms. For the purpose of determining GHG emission reductions, our baseline scenario assumes a diesel energy infrastructure similar to the existing microgrid, with the same load requirements used to design our hybrid renewable microgrid.

The core capital expenditure in our project proposal centers on new, more sustainable energy infrastructure for Shishmaref's expanded site and community through a hybrid wind-diesel microgrid. The system is high-penetration, where greater than 50% on average of the energy demand is met with wind generation. This infrastructure consists of wind turbines (approximately 1 MW of capacity), dispatchable diesel generators, energy storage and a number of necessary associated control and transmission components. Similar systems have been designed and implemented in Alaska.

Shishmaref, like many rural villages in Alaska, is too remote to connect to the main electricity grid and operates on its own microgrid, a localized, self-contained electricity grid with its own generation capacity. In Shishmaref, the current generation is provided almost entirely by generators running on diesel fuel. Diesel fuel can only be delivered to Shishmaref by barge, an expensive and slow logistical process that significantly increases the total cost of electricity. The fuel must be stored in surplus to ensure an adequate reserve exists between shipments, and bulk fuel containers are located throughout the community's existing site. The containers themselves require inspection and maintenance.

Although diesel generation is reliable and relatively simple, there are some drawbacks to this method of energy generation. The reliance on shipped and stored diesel reduces the energy independence and resilience of the community, and also makes them entirely dependent on Alaska's Power Cost Equalization program subsidies to reduce the residential cost of electricity. In addition, combustion-based generators must be used to produce electricity; the age and manufacture of the current gensets in Shishmaref lead to associated health issues related to emissions, as is discussed elsewhere in this document.

Our project proposal envision that following the initial development of a toehold community, which helps to secure additional funding and investment, a more complete expansion of Shishmaref to the mainland can occur. Under this assumed scenario, a community of approximately the same size (or slightly larger) exists on the mainland, with a similar electricity load and infrastructural needs.

Project Design

Project Load

The proposal for the wind-diesel microgrid was based on an estimate of electricity load greater than the existing load for Shishmaref, reflecting the community's intention to grow following an expansion to the mainland. Based on data from AVEC, the community presently generates and uses about 1600 MWh of electricity annually, split equally between residential customers and commercial as well as other customers. For our study, we assume an electricity demand of 2000 MWh annually as determined by AECOM. While the existing community has a population of about 560 persons, this increased load assumes an increased population of 800 persons and associated expanded infrastructure, in accordance with previous studies.

Project Elements and Sizing

The proposed hybrid wind-diesel microgrid contains a few key elements: turbines, diesel generators, energy storage and associated control and transmission components. For the purposes of this document, several microgrid elements were specified following similar projects elsewhere in Alaska or based on best practice. It is important to to note that development of wind or new energy infrastructure would require several technical feasibility studies that are beyond the scope of this document, including actual pilot installations to measure wind potential on site.

An initial analysis of wind power density near the West Tin Creek Hill site indicates wind power classes of 3-4 near the coast (See Figure 6).

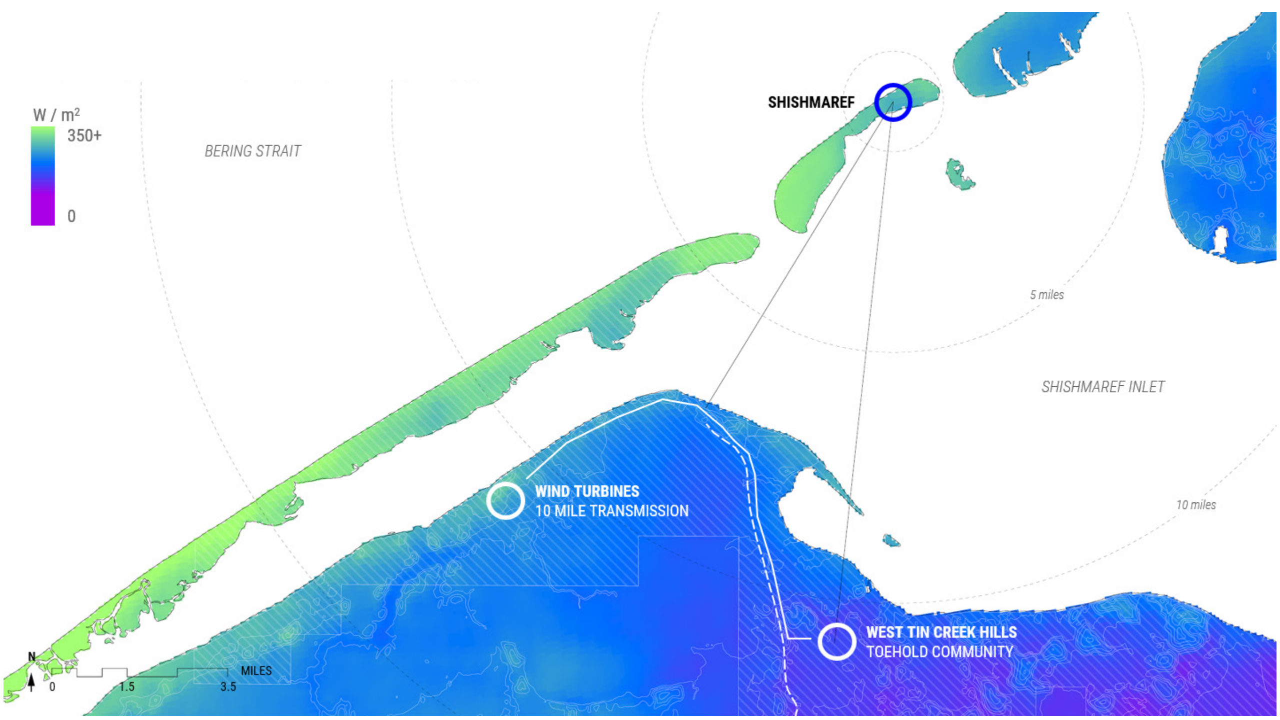


FIGURE 6: WIND POWER DENSITY AT 30 METER HEIGHT

Wind power density data from Alaska Energy Inventory - http://www.akenergyinventory.org/data

Project elements were sized using the National Renewable Energy Lab's (NERL) HOMER software, using historical data from AVEC to understand temporal community electricity demand patterns, wind resource data from the Alaska Energy Data Inventory, and the design load described previously. HOMER software allows for modeling of microgrid design scenarios, and optimizes demands for cost and performance.

Wind turbines - Northern Power Systems NPS-100C, 21- or 24-meter rotor

The NPS-100C has a rated power of 95 kW, and can generate electricity with wind speeds ranging from 3 m/s to 25 m/s; the corresponding power curve provides best performance at 7 to 13 m/s, which matches historical wind data and expected potential on site near Shishmaref. The moderate scale of the turbine is well-suited for smaller microgrid applications, and NPS 100-C systems have been installed in similar rural microgrids in Alaska.

Diesel generators (existing)

While the proposed microgrid features high wind penetration (the proportion of electricity demand met by wind generation), the remote location of Shishmaref means it will be necessary to provide sufficient diesel capacity to power the entire community's need for an extended period of time, or in emergency scenarios where there is a failure of the wind generation system. More generally, dispatchable diesel generators are needed to balance variance and intermittency inherent to wind generation — when wind speeds are slow, demand can be met by the use of diesel fuel.

The diesel generators would likely be run infrequently, and turned on only when demand could not be met by wind alone. Our study assumes a straightforward solution might be the re-use of Shishmaref's existing diesel generators, either moved from the Sarichef Island site or provisioned as part of toehold development. In any case, however, a more complex control infrastructure is needed to operate the diesel systems in coordination with the wind generation systems.

Energy storage (various options)

In addition to diesel generation, additional energy storage can help stabilize generation in the microgrid. Energy storage in the form of chemical batteries or mechanical flywheels can help to shave peak demand, and leverage continuous wind generation potential over an entire day. HOMER modeling suggested a high-capacity installation of storage systems (in the 4 MWh range). At present, this extent of storage capacity would be larger than is typical for community microgrid uses and prohibitively expensive; technological advances in integrated battery-flywheel systems of a modular design suggest storage systems of this scale will be available and more accessible in the near future.

Operation, control and transmission

Beyond the energy generation and storage components of the microgrid, there will need to be a sophisticated control system capable of integrating these elements: detecting periods of low wind generation, turning on the diesel generators when necessary and diverting energy to the appropriate storage system based on anticipated later need (batteries for long-term, flywheels for short-term).

Given the high cost, inherent inefficiency and complexity of energy storage, a hybrid microgrid might leverage optional loads or load flexibility through methods of managing demand to take advantage of excess generation, and thereby reducing peak demand. Such options might include intermittent use of electric boilers to heat greenhouses, homes and community facilities, water pumping into storage and/or purification, and the "charging" of ceramic bricks for thermal storage.

Operational Framework

Our initial analysis indicates that continued operation of the microgrid by AVEC would mitigate the capacity requirement on the village and leverage existing operational patterns and relationships. Further analysis is required on whether the existing operational model is operable and scalable.

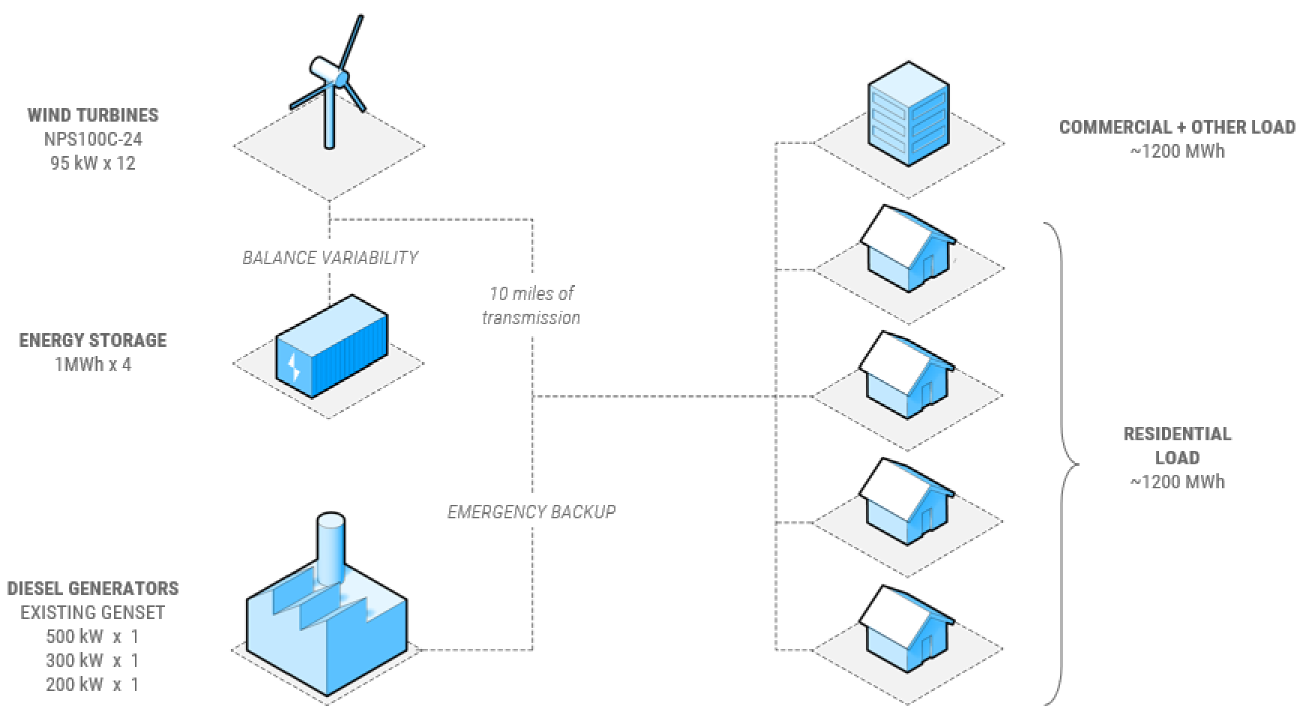


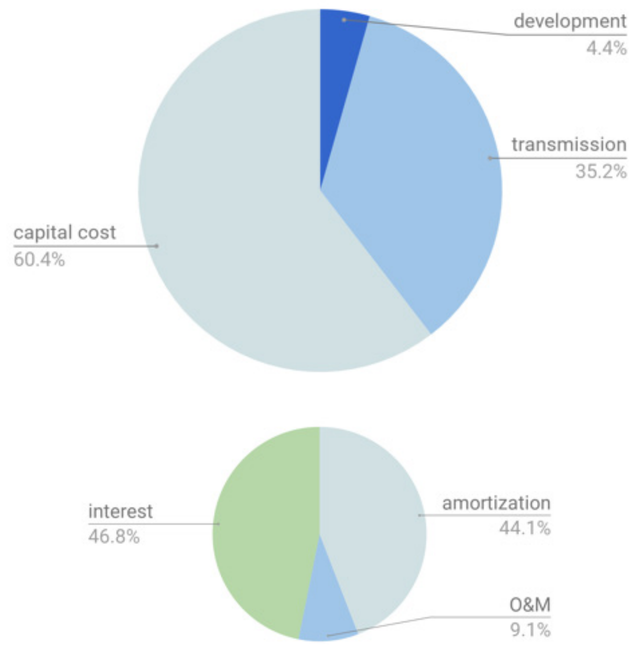
FIGURE 7: MICROGRID DESIGN - 2400 MWh DEMAND GROWTH SCENARIO

Project Cost

Costs fall into two main buckets: up-front costs, which must be paid to get the system up and running, and annual costs, which recur on a running basis. Relative to traditional diesel generation, a wind system has significantly higher up-front costs but low operating and fuel costs each year. Since distribution costs are similar regardless of electricity sources after accounting for transmission, we do not include them here. Additionally, given the level of uncertainty around moving the existing system, we do not consider the cost of bringing existing generators to West Tin Creek Hill.

For a system of this size, we estimate the following costs:

FIGURE 8: MICROGRID COST ESTIMATES (GROWTH CASE)



UP-FRONT COST: $11.4M

- **Capital cost: $8.7M** This includes 12 turbines and additional system components. Estimated using HOMER.
- **Transmission: $4M** This accounts for a distance of approximately 10 miles to the higher wind power density zone along the cost, and estimates cost at $400,000/mile. Transmission costs vary widely depending on voltage, terrain, and existing infrastructure, starting around $200,000/mile. We estimate a lower figure given that lines will be overhead, will follow a delivery road that will have to be constructed anyway, and will require relatively low voltage.
- **Project development costs: $500,000** We use the fixed-cost estimate cited by CITE. However, costs are likely to vary based on site conditions, permitting processes, and opportunities for synergies with other feasibility studies and site analysis that will have to be undertaken for other aspects of the West Tin Creek Hill expansion.

ANNUAL COSTS (YEAR 1):

- **Loan interest: $506,000/year** Assuming that the capital cost will be paid through a loan or bond with non-zero interest, we include a variable annual loan interest cost, starting around approximately $506,000/year and decreasing as the principal is paid off. Actual interest payments would depend on interest/bond coupon rate, amortization period, and financing structure.
- **Operation & Maintenance: $88,000/year** We use HOMER's estimate as a baseline, although actual costs could be higher or lower depending on local conditions and operational structure.

> Additionally, these costs could be lower if a workforce training program were put in place, making it possible for local labor to undertake the majority of at least some operation and maintenance. Workforce training programs is discussed in the phasing and sequencing section.

These are ballpark estimates which are sensitive to assumptions on system design, financing structure, and project development timeline. Higher actual costs could increase the timeline for amortization and/or lower the project's NPV. We have a fair degree of confidence in the microgrid's overall bankability for two reasons: first, a sensitivity analysis shows that the project retains a positive net present value even when using unrealistically negative assumptions. Second, we find that estimates generated through other methods, namely HOMER cost predictions (not specific to the Alaska context) and scaling comparable systems to Shishmaref's demand, are generally in line with ours.

Financing

The high up-front cost of expansion to West Tin Creek Hill and the lack of steady repayment streams make it difficult to finance any part of a move without substantial government participation. However, in the case of a wind system, the long-term cost savings of the switch from diesel, combined with the current subsidy/rate structure, make it plausible to finance an improvement largely by rerouting existing payments.

This creates an unusual opportunity for renewables investment in the energy sector. By combining electricity tariff payments and a power cost subsidy that Shishmaref currently receives into one repayment stream, the community can gradually pay off the cost of a wind system without any additional government support. Given Shishmaref's low overall energy usage, GHG offsets - even if sold at above-market prices - are too small to make a significant impact on project finance. However, potential project partners could contribute by providing low-interest loans or contributing to annual debt service payments.

Power Cost Equalization Program

Given the dramatic gap between urban and rural energy prices in Alaska, the state government has bankrolled the Power Cost Equalization Program (PCE) since 1985, aiming to stabilize rural energy prices at an affordable level. The funds come from the authorized uses of the roughly $1 billion PCE Endowment Fund, and the program is jointly administered and managed by the Regulatory Commission of Alaska and the Alaska Energy Authority. As of 2017, approximately

83,000 Alaskans in more than 190 participating communities receive some form of PCE benefit. The program, which provides economic assistance to rural Alaska communities where the cost of electricity can be 3-5 times the state's average urban rate of around14.82₵/kW, is a lifeline for rural communities.

Of approximately half of energy revenues made up by residential accounts, two-thirds comes from the PCE subsidy. The remainder is split roughly evenly between commercial and "other" users, which include government, non-profit, and community facilities.

Financing Structure

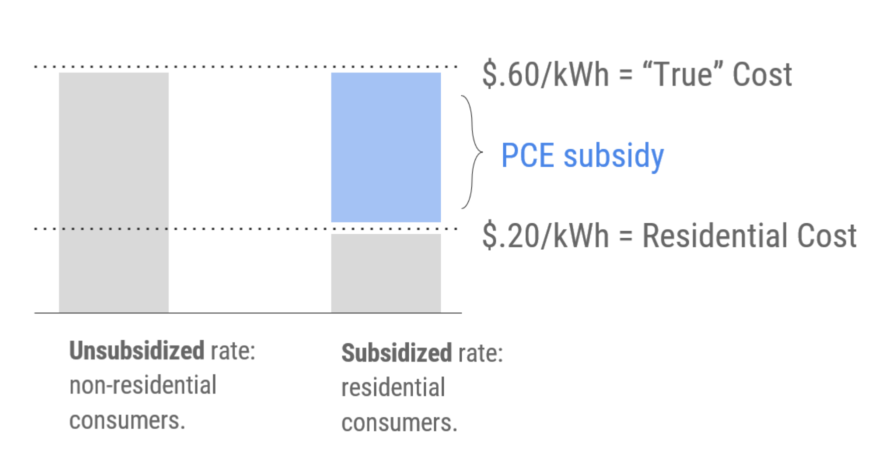
Although individuals currently receive the PCE as an implicit subsidy in their electricity bill, it technically represents a consistent annual cash flow to Shishmaref and similar rural communities. As such, it has potential as a steady, low-risk bond repayment stream that the community could leverage to access up-front financing. We propose a financing structure that uses both the PCE and existing electricity tariffs to pay annual O&M, interest, and amortization costs over a "payoff period," after which both the community the state will realize savings in the form of reduced need for a subsidy and relief from high energy tariffs.

We modelled costs to minimize the amortization (principal payoff) period and total interest paid by assuming the highest possible annual debt service payment. Under this assumption, we estimate that the initial cost of installing sufficient wind capacity could be repaid within approximately 13-15 years, leaving a savings period of between 5 and 12 years, depending on the lifetime of the system.

THE POWER COST EQUALIZATION (PCE) SUBSIDY STRUCTURE

PCE payments are made by the state government to utilities to cover the difference between the true generation and distribution price of electricity (which varies based on fuel and delivery costs) and a fixed per-kilowatt/hour rate (up to a cap of 500 kilowatt-hours/month). Only residential users are eligible for PCE assistance – commercial, government, and non-profit users are charged a non-subsidized rate.

FIGURE 9: ELECTRICITY RATES WITH AND WITHOUT PCE ASSISTANCE



The interest rate on this borrowed amount is critical in determining the project's financial feasibility. We recommend seeking concessional financing from the Alaska Municipal Bond Bank Authority (AMBBA), a public corporation supported by the state Department of Revenue. The AMBBA sells bonds on the national market, levering its strong credit rating (AA-/ Outlook Stable (Fitch) and AA- / Negative Outlook" (S&P)) to access better rates than those available to smaller communities within the state. AMBBA uses these proceeds to buy riskier local bonds at concessional rates, passing on this discount to communities seeking to finance capital projects.

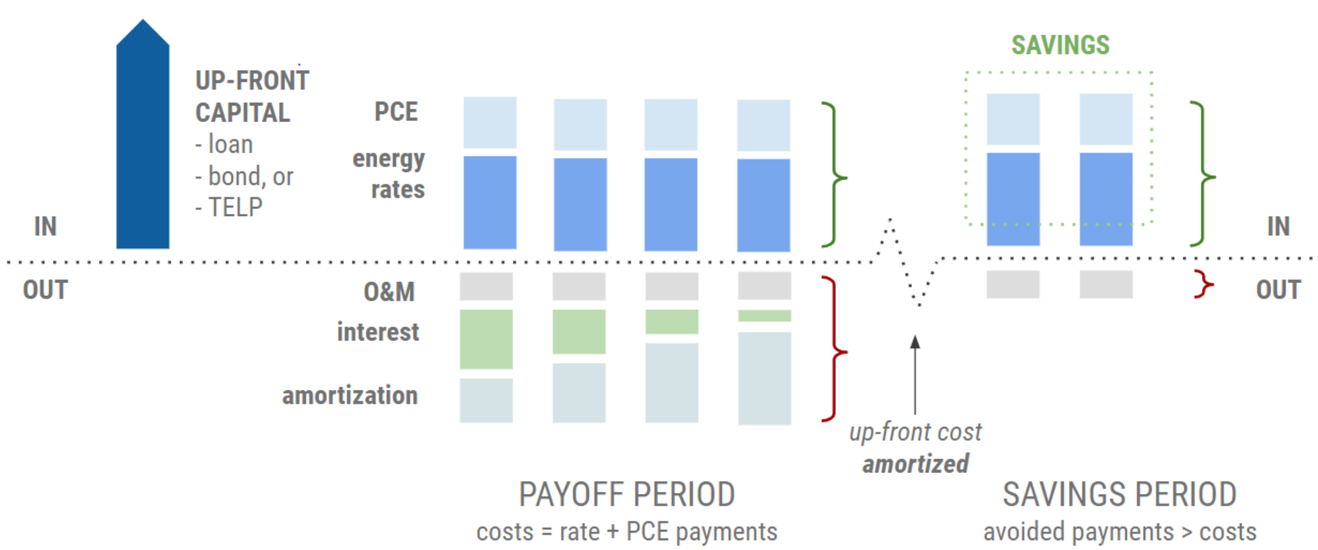
Assumptions and Sensitivities

We ran several versions of this analysis to account for different loan interest rates, annual escalation in PCE levels/electricity rates, O&M cost growth over time, and discount rates for NPV calculation. While the amortization period and total savings vary widely with changes in assumptions, NPV remains positive even in when using pessimistic assumptions across the board. This analysis assumes some community growth, in line with estimates by Shishmaref's leadership. A sensitivity analysis shows that a larger ratepayer base speeds up repayment, even accounting for the increased system load.

Under our baseline scenario, we calculate that up-front costs as high as $17 million can be paid off within a 20 year project lifetime, representing a 30% contingency over baseline estimates (or as high as $14 million in a no-growth scenario - a 23% contingency).

Administration and distribution costs, while not separately analyzed here, could affect the project's financial viability.

FIGURE 10: CASH FLOW OVER MICROGRID LIFETIME



*Not to scale. Trends holds for both growth & no-growth scenarios.

Potential Partners

In order to fund the microgrid, we recommend piecing together funding from a few different sources and project partners, including the PCE subsidy, donations, grants, and private investments.

The PCE subsidy is at risk of being lost as a result of moving towards a more fuel efficient system. The Regulatory Commission of Alaska determines the PCE level for each utility based on a formula that looks at: fuel expenses such as the cost of fuel, transportation; and non-fuel expenses such as salaries, insurance, taxes, parts and supplies, interest and other reasonable costs. Alaska is the global leader in microgrid development, and these wind projects started in Alaska in the early 1990s in anticipation of the subsidy going away.

The subsidy has survived for 40 years, but regulatory overhaul is necessary in order to meet current electricity generation demands in Alaska. More specifically, the AEA and the RCA should modify the formula with which they grant subsidies to allow cost-effective investments in non-diesel alternatives to reflect lower rates for rural customers. One way to do so is to consider a formula for renewable energy projects that places more weight on non-fuel expenses rather than fuel expenses.

We propose that the Emmett Environmental Law & Policy Clinic work as a project partner in order to petition the AEA and RCA to reconsider their allotment of subsidies. Given that this is a regulatory role that the Commission plays, no legislative intervention is necessary.

Donations

Shishmaref is in a difficult situation because it needs a large amount of funding with very few prospects of offset production to exchange for it. Nonetheless, Alaskan Native regimes are unique in that some villages are incorporated as 501(c)(3) corporations, including Shishmaref. The Shishmaref Native Corporation is eligible for tax exempt donations. For example, Wells Fargo announced in November of 2017 that it was committing $50 million over five years for Alaskan Native Communities, specifically for renewable energy and clean water projects.

Similarly, more project partners could be identified by honing in on specific corporate responsibility missions that companies have. Patagonia is a great example because they put money aside to fund organizations and projects that have a focus on preserving and protecting the environment. If Patagonia were to make a donation to our wind microgrid project, as owned by a 501(c)(3) corporation, they would be able to deduct their donation from their taxable income. In this manner, corporations could meet their internal mandates for corporate responsibility while receiving a tax break. Using this incentive, it's possible to attract more donations.

Grants

Several foundations provide grants to initiatives towards clean and renewable energy. For example, the Rockefeller Foundation has provided funding for projects around efficient energy systems in rural areas in the US in the past. The Bill & Melinda Gates Foundation has an Emergency Relief Fund that identifies "slow-onset emergencies" as eligible for funding, and these apply to public health issues, that will be implicated in the case of Shishmaref.

Investments

Corporations can also invest in the microgrid in exchange for wind related tax credit via the Business Energy Investment Tax Credit from the US Tax Code. Large wind projects can provide up to 18% credit in the first year of investment. The following chart shows investments available (as per 26 U.S.C. § 48):

FIGURE 11: TAX CREDITS FOR RENEWABLE ENERGY INVESTMENTS

TECHNOLOGY	2018	2019	2020	2021	2022	FUTURE YEARS
PV, Solar Water Heating, Solar Space Heating/Cooling, Solar Process Heat	30%	30%	26%	22%	10%	10%
Hybrid Solar Lighting, Fuel Cells, Small Wind	N/A	N/A	N/A	N/A	N/A	N/A
Geothermal Heat Pumps, Microtubines, Combine Heat and Power Systems	N/A	N/A	N/A	N/A	N/A	N/A
Geothermal Electric	10%	10%	10%	10%	10%	10%
Large Wind	18%	12%	N/A	N/A	N/A	N/A

As seen above, companies would be able to get an 18% tax credit for their investment in our wind project. As such, a large number of project partners will need to come together to provide the funding in order to make this a reality.

Legal Analysis

Currently, the Alaska Village Electricity Cooperative (AVEC) is the electrical supplier for the community, and it is anticipated that they would continue to provide energy at the new site. AVEC has had great success in Western-remote Alaska using wind generation to offset the fossil fuel power generation that these rural communities rely on.

AVEC could operate the wind farm and micro-grid that is proposed in this section. This system works well as over 50% of utilities in Alaska are co-ops, including the largest utility, Chugach Electric. Another 30% of utilities are municipally owned, making Alaska mostly a Public Power State.

AVEC could provide energy to Shishmaref through a power purchase agreement. A power purchase agreement (PPA) is a contract between two parties, one which generates energy and the other which purchases it. In this case, AVEC would be generating the energy which Shishmaref would purchase.

If Shishmaref required 501(c)(3) donations in order to set up the wind farm, then the microgrid would have to be owned by the Native Village of Shishmaref Corporation and operated by AVEC. This arrangement would require an additional contract along with the PPA: one where in AVEC is contracted to operate the utility facility by Shishmaref, and then sells the electricity back to the organization.

This would need to be carefully constructed into various parts: establishing the ownership of the microgrid by Shishmaref, establishing AVEC as the operator of the microgrid and the outlining the expectations of what AVEC can and can't do with the facility (i.e. parameters of where the supplied energy is going; what authority the appointed co-op has in an operating capacity, grounds for termination, compensation of the board, etc) along with the power purchasing agreement to have the energy created by the wind farm to be sold to the village of Shishmaref.

Finally, the Village of Shishmaref would also need to enter into agreements with contractors for the installation of the wind farm which would require attention to timeline, caps on cost of materials, compensation, and material breach clauses.

Stakeholder Analysis

In a best-case scenario, restructuring Shishmaref's energy supply will require minimal institutional adaptation: it would involve few new partners and little change to stakeholders' roles within the system. The major bottleneck would be changing the legal framework of the PCE at the state level. Given the importance of this funding source to many rural communities, state legislators may be hesitant to allow any changes to its allocation. However, our analysis suggests that potential long-term cost savings from a restructuring could be even higher in other areas of the state (especially those where diesel must be delivered by air), which could create an incentive to open the discussion at the state level.

The City of Shishmaref and its residents, both as ratepayers and potential operating partners, will retain a high degree of financial and operational responsibility for their energy system. Shishmaref will remain responsible for day-to-day operation and maintenance of on-site infrastructure. As such, a robust stakeholder engagement process driven by community input and feedback is a critical first step. Moving forward, the permanent incorporation of community voices into decision-making and strategic direction-setting will also be necessary to ensure a fair and well-functioning energy system.

As mentioned previously, a skills development program to allow for a higher degree of local maintenance could even enhance the sense of community ownership. There could be a role for the Alaska Native Tribal Health Consortium or other actors both at the government and private-level in developing this type of workforce training, some of which are outlined in the phasing and sequencing section.

AVEC, still the proposed energy utility after restructuring, would continue to act as a pass-through for subsidy funds between the state government and the community (albeit in the opposite direction). It would also remain responsible for larger operation and maintenance of generation and distribution systems. Balancing possible lost rate revenue with cost savings in order to make sure that AVEC is not disproportionately impacted by a shift to renewables will be critical, given the important role the cooperative plays in providing energy to the state's farthest-flung rural communities. Additionally, potential economic impacts on diesel providers, although unlikely to be a serious concern, should be considered.

The PCE Endowment Fund would continue to furnish annual PCE allocations, although these would be re-routed to the AMBBA (or another loan holder) as bond repayments, instead of to AVEC as reimbursement for fuel payments. As such, the Regulatory Commission of Alaska and Alaska Energy Authority would retail essential administration, management, and technical assistance roles. The scope of the latter would certainly have to expand to support the community through implementation. Outside partners like the Alaska Microgrid Partnership and the Cold Climate Housing Research Center could also provide sector-specific technical support and assistance. The support of the Alaska Municipal Bond Bank Authority in developing a suitable bond offering could facilitate this process, and is a major part of the value that the Bond Bank provides to many Alaskan communities.

The perceived fairness of this restructuring may pose a challenge, especially for communities that have already invested in renewables and lost PCE subsidies as a result. Although it would provide little help for communities that have already invested, treating Shishmaref as a pilot project that could help pave the way for similar restructurings in other communities could mitigate this concern going forward.

Phasing and Sequencing

Recognizing that the critical path for this project has many moving parts, the following is a suggested project phasing plan.

Phase I: Shishmaref expansion to West Tin Creek Hills and establishment of a toe-hold community.

The timeline for this section is, as previously mentioned, not clear because of funding and logistical blocks. Preliminary phases would include funding and developing a community plan, constructing pioneer roads, preparing future site, developing a housing strategy, and relocating or constructing housing. Facilities proposed for the toehold community include the following basic necessities:

- Residential structures: 25 homes
- Commercial and public buildings: city office, school, community center
- Infrastructure: diesel generator power plant, washeteria, water supply tanks, pioneer road

Phase II: Installation, operation, and maintenance of wind system

A. Project scoping and wind resource selection.

Suitability analysis within West Tin Creek Hills has identified strong wind resources. Future studies would determine exact location contingent on adequate geotechnical foundations, and those with the least harmful environmental impacts.

Specific studies would ensure the project is technically feasible, that environmental risks are reasonable, geotechnical conditions are suitable, and the project will be economically feasible. Wind power feasibility studies can last anywhere from six months to two years to complete

B. Permitting

While permitting and timeline for wind-renewable microgrids vary on the jurisdiction, accessibility to funding and permitting, typically projects take from 4-5 years. This includes land leases, environmental review, addressing socio-economic issues, public safety and cultural impacts. A comprehensive regulatory strategy that will move the project along looks something like the following:

- **Land ownership:** Shishmaref has legal rights to the land under the Settlement Act, so ownership and land acquisition for the wind-farm is not a question.

Regulations: Permitting agencies include the city council, various state agencies including the Alaska Department of Environmental Conservation, Alaska Department of Natural Resources, Alaska State Historic Preservation Office, Regulatory Commission of Alaska, and Alaska Department of Transportation. Federal level authorities may include US Fish and Wildlife Services, the Environmental Protection Agency, U.S. Army Corps of Engineers, the Federal Aviation Administration, and the Bureau of Indian Affairs.

- **Environmental review** must consider flight paths in navigable airspace, disturbance to wetlands, impacts to water quality, and noise. Additionally, wind turbines can impact subsistence hunting and fishing because roads, turbines, and changes to habitat can impact habitat patterns of caribou, moose, and migratory birds. The environmental review process will likely include a few years of studies
- **Design, construction and installation:** Wind farm construction will include building a road, transmission lines, and installation of turbines.
- **Operation and Maintenance** (25 years and ongoing)

FIGURE 12: POTENTIAL PHASING PLAN

PROJECT PROCESS	5 YEARS					10 YEARS					15 YEARS					20 YEARS				
Phase I																				
Funding	■	■	■	■	■															
Relocation Plan		■	■	■	■	■	■													
Establishing Foothold Community				■	■	■	■	■	■	■	■									
Phase II																				
Project Scoping			■	■	■	■														
Wind Resource Selection and Feasibility Study				■	■	■	■													
Regulatory Approval					■	■	■	■												
Environmental Review						■	■	■	■											
Design, Construction and Installation										■	■	■								
Workforce Training												■	■							
Operation and Maintenance												■	■	■	■	■	■	■	■	■

Workforce Development

A major component of maintaining the reliability of this project will include proper and regular maintenance of the wind turbines and systems. Maintenance would be required every six months, before and after the windy season. With any new energy system, workforce development must be a priority in order to ensure proper operation and maintenance.

Gavin Dixon of the Alaska Native Tribal Health Consortium also stated in our meeting that job training opportunities are highly desired by the community. Currently, renewable energy training programs are being facilitated through the following organizations, and funded through the Alaska State Energy Sector Partnership grant:

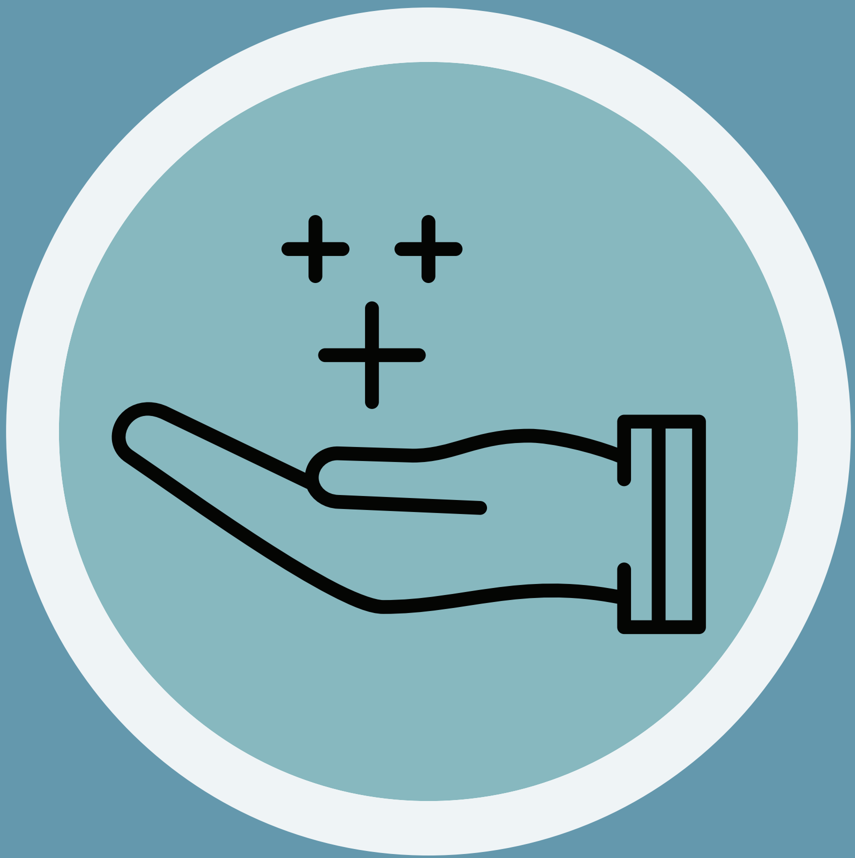
- Alaska Apprenticeship Training Coordinator Association
- Alaska Energy Authority
- AVTEC – Alaska's Institute of Technology
- Alaska Works Partnership, Inc.
- University of Alaska Southeast
- Yukon Inter-Tribal Watershed Council

Furthermore, the US Department of Energy (DOE) Office of Indian Energy supports "tribal efforts to build internal capacity to understand and navigate energy projects […and is] working to build partnerships with universities and other institutions to develop the human capital in the energy sector in Indian Country". The DOE Office of Indian Energy also offers free online training for project development and workforce training to operate and maintain renewable energy systems.

Another resource for workforce development so local staff has the ability to repair, manage, and operate the system is the Alaska Vocational Technical Center (AVTEC) which collaborates with AEA, Denali Commission and others. AVTEC offers courses in Industrial Electricity, which provides a range of in-depth lessons on energy systems and their maintenance and operation, in addition to a 9-week Power Plant Program, with an extra week for those wanting to learn about maintenance.

With this sustainable model of project management and governance in partnership with community stakeholders and government officials, Shishmaref can begin to see the implementation of a renewable energy system.

Project Benefits



Public Health Impacts and Considerations

Greenhouse Gas Emission Reductions

As mentioned previously, the existing load of Shishmaref's diesel microgrid is 1,630 MWh/year, utilizing over 130,000 gallons of diesel annually. Based on community growth projections, AECOM has suggested that the design load of the new site accommodate 800 people. A 2016 AECOM report suggests a 23% increase in design load would be sufficient but we are anticipating a 50% increase in design load, or 2,400 MWh/year. Since the hybrid microgrid will have diesel generation as a backup option, carbon dioxide emissions will not be indefinitely eliminated from the village. Assuming that the system is 100% renewable, this new system will achieve a reduction of 1,980 tonnes of CO2 annually. According to the EPA, this is equivalent to taking 424 passenger vehicles off the road each year. In terms of offset pricing, most carbon offsets sell at $10-25 per tonne. If we assume a conservative estimate of $10 per tonne, this translates to $19,800 in offsets.

Anticipated Public Health Impacts

Housing. If residents are able to salvage existing homes and secure additional homes with improved infrastructure in the toehold community (which is also at lower risk of experiencing flood events), then we can expect fewer accidents and injuries during storms. Improved housing will ideally be properly weatherized, insulated, and ventilated to meet community needs, which will decrease the risk of respiratory conditions previously associated with mold growth and intrusion of diesel emissions. Finally, if community growth projects are accounted for and additional housing is secured, households will be able to split up to their desired configuration, which will likely contribute to stronger familial relations, reduced psychosocial stress, improved school performance in children, and a decrease in the spread of infections within households.

Energy. By transitioning to a wind-diesel microgrid, residents' exposure to diesel emissions such as particulate matter, sulfur dioxide, and nitrogen oxides (and resulting ozone) will decline significantly. A social cost of atmospheric release calculation demonstrated that the decline in particulate matter emissions would only translate to 0.01 lives saved. That being said, there will likely be a decline in respiratory and cardiovascular conditions in the community, which is particularly important to for vulnerable populations like children, asthmatics, and the elderly. The long-term decline in energy costs will also provide families with greater financial security and as a result, less poverty-related stress within families.

Community. While the process of expansion will be stress-inducing for community members, settling in a site that is not under immediate threat from sea level rise and storm surges will ease the stress and anxiety that many residents currently experience on a daily basis. Workforce development for operation and maintenance of the wind-diesel microgrid will provide community members with new skills and revenue streams, which will also alleviate poverty-induced stress that many families experience. Promoting community ownership of the microgrid system will help ensure that it is effectively managed and utilized throughout its lifespan.

Monitoring and Evaluation

In order to achieve the stated greenhouse gas emission reductions and public health benefits, progress should also be monitored on an ongoing basis. Several indicators that may be measured include:

- Accounting energy production by wind turbines (kWh) and how often, for how long, and for what reasons backup diesel generators are used.
- Community health surveys to assess mental health indicators related to stress and anxiety: if appropriate, the survey should be conducted prior to expansion, within 6 months to a year after the toehold community has been established, and on an annual basis following.
- Annual review of clinic health records to monitor trends in respiratory, cardiovascular, and other relevant health indicators in the toehold community.
- Ongoing monitoring of sea level rise and storm surges in the region to evaluate risk of flooding to the West Tin Creek Hills site.

These are just a few of various measures that should be evaluated in order to ensure community needs are met and that quality of life has improved for residents following expansion and the installation of the wind-diesel microgrid. Ideally, monitoring of these indicators should be conducted by the community, as resources allow.

Obstacles and Mitigation Strategies

While the expansion process is an urgent priority for Shishmaref residents, it must be acknowledged that relocation is largely occuring because they do not have other viable options. It is not something that they likely would have pursued in the absence of environmental stressors, and it has and will be a long and stressful process for the community. Therefore, in order to ensure a successful relocation and minimize the existing physical and mental burden that residents are already experiencing, community buy-in must be central to this process.

Community agency, and sense-of-ownership over the expansion process are critical to the long-term success of this project. They must be involved in the planning and implementation from start to finish. This will require surveys to assess needs, meetings with community leaders to socialize each phase of the plan, and "town hall" events to allow community members to provide feedback on progress.

Outside stakeholders involved in this process must also be invested in community ownership, and should pursue any opportunity to share or delegate management of project responsibilities. If it is deemed necessary to create an oversight committee for the expansion process, it must include community leaders, as well as other stakeholders invested in the successful implementation of this project.

In terms of project specifics, the following are potential obstacles that can be mitigated through careful planning:

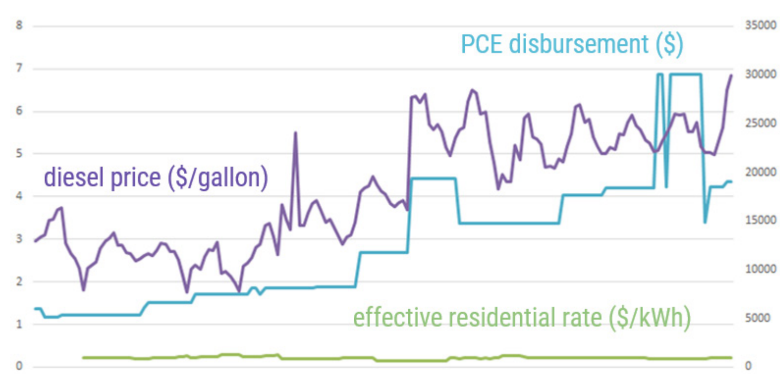
- **Noise pollution from wind turbines:** An existing challenge with wind turbines is the associated noise pollution, which some nearby residents have said contributes to disrupted sleep, headaches, and annoyance. This can contribute to increased stress and lower quality of life for the surrounding community. There have also been reports of nausea, dizziness, and fatigue related to wind turbines, though no evidence thus far has connected the turbines to these symptoms. To mitigate these impacts, previous wind turbine projects should be evaluated to assess ideal proximity between turbines and residents. In addition, community socialization meetings may also be conducted in order to promote understanding of the system and field any potential resident concerns.

- **Workforce training encouraging residents to pursue opportunities elsewhere:** One potential downside of workforce development is community members with newfound skills in renewable microgrid operation and management leave the village to pursue employment opportunities elsewhere. If community members who stay are unable to properly operate and maintain the system, they may be forced to renew their dependence on diesel energy, which would undo the public health benefits associated with the project. In a worst-case situation, the loss of residents may also contribute to weaker social ties or even long-term community dissolution. In order to prevent the loss of skilled labor, the community might explore a few avenues: providing high wages for microgrid operators or other incentives for them to stay, creating a training program where skilled residents can teach other rural Alaska Native communities how to operate renewable microgrids, or investing in other revenue generation streams such as hydroponic greenhouses.

Financial Benefits

Both the State and ratepayers should see some degree of financial benefit from the project. From reduced exposure to volatility: PCE payments (since they are a government top-up of ratepayer chargers, depend on the amount of energy the community consumes and current diesel prices, to long-term savings in electricity prices, or both. In qualitative terms, reduced dependence on both diesel deliveries and state subsidy allocations should benefit the Shishmaref community.

FIGURE 13: PCE VOLATILITY, DRIVEN BY VARIABLE DIESEL PRICES (Shishmaref, 2002-2014).



The Cost of No Action

If the community of Shishmaref was to stay on their current island and protect in place, there are significant costs of no action. A Relocation study completed by AECOM found an increase in healthcare costs, limited sustainability, and the eventual loss of most buildings and critical infrastructure. Costs to stay in place are more financially appealing, with $46 million that would be required in the next five years to replace critical infrastructure as it is impacted by sea level rise, coastal erosion, permafrost thawing, and other extreme weather events.

While it is more affordable at $118 million to stay in Shishmaref, and protect in place, these protections and improvements would only serve the community for the next 15 years; the long term costs over the next 30 years only have a difference of $62 million.

Additional benefits from relocation will include public health benefits, including the soft cost of mental health felt by a community feeling secure in their homes, and future financial benefits from workforce development and greater agency for a community in control of their own land, and reducing energy dependency on diesel.

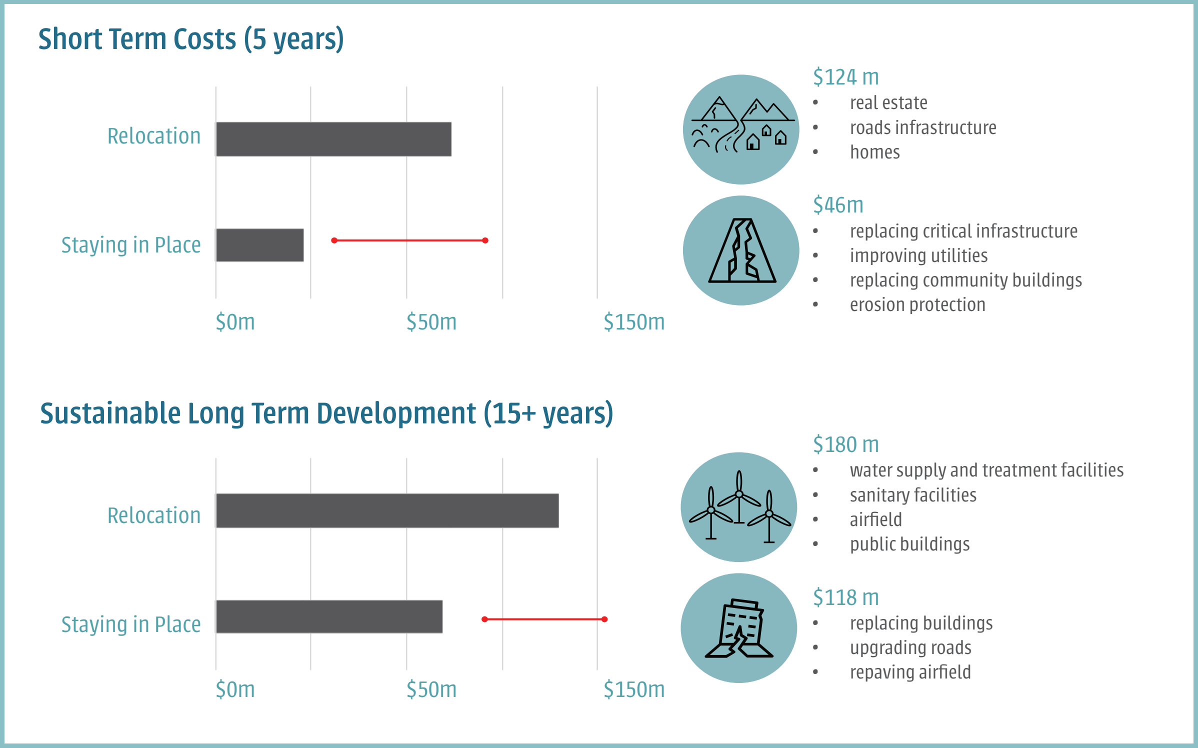


FIGURE 14: THE HIGH COST OF NO ACTION
(Shishmaref Relocation and Collocation Study, USACE, 2004)

Additionality

In traditional climate change-related discussions that are mostly focused on reducing emissions, additionality assesses whether or not a project or activity creates reductions that would not have occurred in absence of the program, project, or incentive. In our work studying Shishmaref's challenges and identifying potential solutions that could assist the community, we were encouraged to consider other dimensions of additionality, especially because our project did not focus specifically on emissions reductions.

So while our project does create emission reductions that would not have occurred otherwise through the transition to a more sustainable energy source, we also chose to apply additionality during our screening process to challenge ourselves to produce a tactical and implementable project that would not have been possible without our work.

As already mentioned, in the case of Shishmaref, many hours of work have already been done by a collection of actors to assist them in their community expansion; we wanted to be sure that our final project was not merely a reiteration of existing solutions, but rather an innovative addition that complemented the work that has already been done.

This reasoning is why, in the end, a project purely focused on the barracks to establish a toe hold community, because it has already been fairly fully developed for Newtok, did not provide us with a sufficient sense of additionality - in the traditional or modified sense - in order to carry it through to implementation. Based on our assessment, we believe that our final microgrid project does meet our traditional and modified additionality requirements to be worthwhile for implementation.

References

26 U.S. Code § 48 - Energy credit.

Abb.com. (2018). ABB microgrid technology to integrate wind power in remote parts of Alaska. [online] Available at: http://www.abb.com/cawp/seitp202/47a0abad6792a0474825824900462cab.aspx [Accessed 6 May 2018].

Abb.com. (n.d.). ABB to enable integration of renewables in Alaskan island microgrid. [online] Available at: http://www.abb.com/cawp/seitp202/BC90B54CC33D1663C1257D50002FAF58.aspx [Accessed 6 May 2018].

Additionality. (2018). Climate Change Authority | Climate Change Authority. [online] Available at: http://climatechangeauthority.gov.au/reviews/carbon-farming-initiative-study/additionality [Accessed 6 May 2018].

AECOM Technical Services, Alaska (2016). City of Shishmaref, Alaska Sarichef Island. Relocation Site

Selection Feasibility Study February 2016. [online] Anchorage, Alaska, pp.3-5. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Site_Selection_Feasibility_Study_FINAL_022316.pdf [Accessed 6 May 2018].

Akenergygateway.alaska.edu. (2018). Community Data Summary: Shishmaref - Alaska Energy Data Gateway. [online] Available at: https://akenergygateway.alaska.edu/community-data-summary/1409434/ [Accessed 7 May 2018].

Alaska Affordable Energy Model: Shishmaref. (n.d.). Retrieved from http://model-results.akenergyinventory.org/current/Shishmaref/potential_projects.html

Alaska Energy Authority (2006). Wind Resource Assessment for Saint Paul, Alaska. [online] Anchorage, AK. Available at: http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/WindResourceAssessment/Saint%20Paul_Wind-data-report.pdf [Accessed 6 May 2018].

Alaska Energy Data Inventory. (n.d.). Retrieved from http://akenergyinventory.org/

Alaska Municipal Bonds (2018). Retrieved from http://alaska.municipalbonds.com/bonds/recent/

Alaska Native Health Status Report(Rep.). (2017, August). Retrieved http://anthctoday.org/epicenter/publications/HealthStatusReport/AN_HealthStatusReport_FINAL2017.pdf

Aliu, S. and Morrow, M. (2011). Shishmaref Potential Relocation Sites. Field Investigation Report. [online] Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Potential_Relocation_Sites_Report_Final.pdf [Accessed 6 May 2018].

Armstrong, R. S. (2012, April 12). Comprehensive, Investment Grade Energy Audit of Shishmaref School, Shishmaref, Alaska(Rep.). Retrieved May 6, 2018, from Energy Audits of Alaska website: http://www.akenergyefficiency.org/wp-content/uploads/2013/05/BSNC-SHH-RSA_Shishmaref_School.pdf

Asia-Pacific Economic Cooperation (2012). Microgrids for Local Energy Supply to Remote Areas and Islands in APEC Region. [online] Moscow, Russia: Institute of Lifelong Education, p.71. Available at: https://www.apec.org/-/media/APEC/Publications/2012/12/Microgrids-for-Local-Energy-Supply-to-Remote-Areas-and-Islands-in-APEC-Region/2012_ewg_microgrids-Formatted.pdf [Accessed 6 May 2018].

Basic Information about Ozone. (n.d.). Retrieved from https://www.epa.gov/ozone-pollution/basic-information-about-ozone#effects

Bering Strait Regional Energy Plan(Rep.). (2015, June). Retrieved http://www.akenergyauthority.org/Portals/0/DNNGalleryPro/uploads/2017/1/27/BeringStraitRegiona EnergyPlan.pdf

Bill & Melinda Gates Foundation. (2018). Emergency Response: Strategy Overvview. [online] Available at: https://www.gatesfoundation.org/What-We-Do/Global-Development/Emergency-Response

[Accessed 6 May 2018].

Bio-Mass Heated Greenhouses: A Manual for Alaskan Schools and Community Organizations(Rep.). (2017, March). Retrieved http://www.akenergyauthority.org/Portals/DNNGalleryProupload/2017/4/5/317Biomass HeatedGreenhouseManual.pdf

Byber, K., Flatz, A., Norbäck, D., Hitzke, C., Imo, D., Schwenkglenks, M., ... & Mutsch, M. (2016). Humidification of indoor air for preventing or reducing dryness symptoms or upper respiratory infections in educational settings and at the workplace. The Cochrane Library.

Case Study: Chena Hot Springs(Rep.). (2010). Retrieved http://www.uaf.edu/files/acep/greenhouseenergy.pdf

Children's HealthWatch (2011). Overwcrowding and Frequent Moves Undermine Children's Health. Retrieved from https://www.issuelab.org/resources/13900/13900.pdf

Cold Climate Housing Research Center (2017, February 10). Mertarvik Housing Master Plan.

Community Reinvestment Act. (2017, September 1). Background & Purpose. Retrieved from https://www.ffiec.gov/cra/history.htm.

Conte, M. and Kotchen, M. (2010). Explaining the Price of Voluntary Carbon Offsets. [online] Available at: http://environment.yale.edu/kotchen/pubs/explain.pdf [Accessed 6 May 2018].

D'Oro, R. (2016, November 4). Arctic Farming Town Turns To Hydroponics For Fresh Greens. U.S. News. Retrieved from https://www.usnews.com/news/business/articles/2016-11-04/arctic-farming-town-turns-to-hydroponics-for-fresh-greens

Data USA. (2018). Shishmaref, AK. [online] Available at: https://datausa.io/profile/geo/shishmaref-ak/ [Accessed 6 May 2018].

Department of Revenue: Alaska Municipal Bond Bank Authority. (2012). Retrieved from http://treasury.dor.alaska.gov/ambba/

Devine, M., Manwell, J., Baring-Gould, E. I., & Pxetrie, B. (n.d.). Wind-Diesel Hybrid Options for Remote Villages in Alaska(Rep.). Retrieved May 6, 2018, from http://www.akenergyauthority.org/Content/Useful documents/Wind-Diesel-Hybrid-Options-for-Remote-Villages-in-Alaska.pdf

Diesel Engines and Public Health. (n.d.). Retrieved from https://www.ucsusa.org/clean-vehicles/vehicles-air-pollution-and-human-health/diesel-engines#.Wu-tfNPwbOS

Drouilhet, S. (n.d.). Wind-Diesel Hybrid System Options for Alaska. [online] Golden, CO. Available at: http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/PDF/Wind-Diesel_Options_Alaska_Steve-Drouilhet_NREL.pdf [Accessed 6 May 2018].

Facts about mold and dampness. (2017, September 5). Retrieved from https://www.cdc.gov/mold/dampness_facts.htm

Full house? How overcrowded housing affects families(Rep.). (2005). Retrieved http://england.shelter.org.uk/__data/assets/pdf_file/0004/39532/Full_house_overcrowding_effects.pdf

FY 2017 Income Limits for Alaska. (2017). Retrieved from https://www.ahfc.us/files/5814/9521/1018/Income_limits_for_Alaska_FY2017.PDF

Grounds, R. (2015, September 1). Igiugig Village Receives Grant for Greenhouse and Wild Foods Project. Retrieved from http://www.igiugig.com/latest-news/administrative-updates/125-greenhouse-and-wild-foods-project-grant

Hennessy, T. W., Ritter, T., Holman, R. C., Bruden, D. L., Yorita, K. L., Bulkow, L., Smith, J. (2008). The Relationship Between In-Home Water Service and the Risk of Respiratory Tract, Skin, and Gastrointestinal Tract Infections Among Rural Alaska Natives. American Journal of Public Health,98(11), 2072-2078. doi:10.2105/ajph.2007.115618

Hobson, M. K. (2015, October 20). A renewable energy success story above the Arctic Circle. Retrieved from https://www.eenews.net/stories/1060026559

Interested in taking the Alaska Growers School? (n.d.). Retrieved from http://www.uaf.edu/ces/ags

Jeffery, R. D. (2013). Adverse health effects of industrial wind turbines. Canadian Family Physician,59(5), 473-475. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3653647/

Laycock, M. (2010, July 20). Arctic Construction: Marines build road for new village over Alaskan tundra. Retrieved from http://www.marforres.marines.mil/Marine-Reserve-News-Photos/Marine-Reserve-News/Article/521433/arctic-construction-marines-build-road-for-new-village-over-alaskan-tundra/

Meyers Farm. (n.d.). Retrieved from http://www.meyersfarm.net/

National Renewable Energy Laboratory (NREL) (2009). Systems Performance Analyses of Alaska Wind-Diesel Projects. Toksook Bay, Alaska. [online] Available at: https://www.nrel.gov/docs/fy09osti/44524.pdf [Accessed 6 May 2018].

Northern Power Systems (n.d.). Remote Alaska Villages Fight Rising Diesel Prices with Wind. Kasigluk, Alaska. [online] Barre, Vermont. Available at: http://www.northernpower.com/wp-content/uploads/2014/04/20141217-Kasigluk-Case-Study-US.pdf [Accessed 6 May 2018].

Ozone Pollution. (n.d.). Retrieved from https://www.epa.gov/ozone-pollution

Palmer, K. (2015, December 17). Shishmaref Gets DOE Support on Energy and Resiliency. Retrieved from https://www.energy.gov/indianenergy/articles/shishmaref-gets-doe-support-energy-and-resiliency

Power Cost Equalization Program Guide(Rep.). (2014, July). http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf

Regoeczi, W. C. (2008). Crowding in Context: An Examination of the Differential Responses of Men and Women to High-Density Living Environments. Journal of Health and Social Behavior,49(3), 254-268. doi:10.1177/002214650804900302

Relocation Report: Newtok to Mertarvik (Rep.). (2011, August). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/Mertarvik_Relocation_Report_final.pdf

Renewable Energy and Energy Efficiency Workforce Development Plan(Rep.). (2012, September 18). Retrieved http://labor.alaska.gov/awib/2012-oct-mtg-binder/ASESP_RE.EE_Workforce_Dev_Plan-Draft.pdf

Renewable Energy Fund Status Report(Rep.). (2018, January). Retrieved http://www.akenergyauthority.org/Portals/0/Programs/RenewableEnergyFund/Documents/2018-REF Status Report.1.27.18.pdf

Robert T. Stafford Disaster Relied and Emergency Assistance Act., Pub. L. No. 93-288 (2016).

Rosen, Y. (2016, May 31). Shift from traditional foods takes toll on Alaska Native populations. Anchorage Daily News. Retrieved from https://www.adn.com/rural-alaska/article/processed-food-comes-diabetes-obesity-alaska-natives/2014/09/29/

Russell Cox, S. (2018). Newtok Planning Group. [online] Commerce.alaska.gov. Available at: https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/NewtokPlanningGroup.aspx [Accessed 6 May 2018].

Schwabe, P. (2016, February). Solar Energy Prospecting in Remote Alaska(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

Schwerdtle, P., Bowen, K., & McMichael, C. (2018). The health impacts of climate-related migration. BMC medicine, 16(1), 1.

Shaw, D. W. (2017, March 26). What Rural Alaska Can Teach the World about Renewable Energy. Scientific American. Retrieved from https://www.scientificamerican.com/article/what-rural-alaska-can-teach-the-world-about-renewable-energy/

Shindell, D. (2015). The social cost of atmospheric release. Climatic Change, 130(2), pp.313-326.

Shishmaref: Estimated electricity generation costs per year. (n.d.). Retrieved from http://model-results.akenergyinventory.org/current/Shishmaref/wind_power.html

Shishmaref Local Economic Development Plan 2013-2018(Rep.). (2012). Nome, AK: Kawerak.

Shishmaref Strategic Management Plan(Rep.). (2016, September). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/1_Shishmaref_SMP_September_2016.pdf

Shishmaref Wind Feasibility and Conceptual Design. (2017, December 15). Retrieved from https://www.omb.alaska.gov/ombfiles/19_budget/DCCED/Proposed/2019proj61641.pdf

Solari, C. D., & Mare, R. D. (2012). Housing crowding effects on children's wellbeing. Social Science Research,41(2), 464-476. doi:10.1016/j.ssresearch.2011.09.012

Stories from Shishmaref, Alaska's Climate Frontline. (n.d.). Retrieved from https://soundcloud.com/warmregardspodcast/stories-from-shishmaref-alaskas-climate-frontline

Struzik, E. (2016, March 17). Food Insecurity: Arctic Heat Is Threatening Indigenous Life. Yale Environment 360. Retrieved from https://e360.yale.edu/features/arctic_heat_threatens_indigenous_life_climate_change

Tong, S. (2017). Flooding-related displacement and mental health. The Lancet Planetary Health, 1(4), e124-e125.

Toomey, D. (2016, June 23). Unable to Endure Rising Seas, Alaskan Villages Stuck in Limbo. Yale Environment 360. Retrieved from https://e360.yale.edu/features/sea_level_rise_alaska_native_newtok_shishmaref_kivalina

United States Army Corps of Engineers, Alaska District (2004). Shishmaref Partnership: Shishmaref Relocation and Collocation Study. Preliminary Costs of Alternatives. [online] Seattle, WA: Tetra Tech, Inc. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/USACE_relocation%20plan_shishmaref.pdf [Accessed 6 May 2018].

United States Department of Agriculture (2017, January). Alaska Rural Homeownership Guide. [online] Available at: https://www.rd.usda.gov/files/Alaska%20Rural%20Homeownership%20Guide%2001_11_17_v2.pdf

United States Department of Energy, Office of Indian Energy (2013). Developing Tribal Energy Projects: Community Energy Planning. Planning Brings Vision Into Focus. [online] Available at: https://www.nrel.gov/docs/fy13osti/56272.pdf [Accessed 6 May 2018].

United States Department of Energy, Office of Indian Energy (2013). Alaska Strategic Energy Plan and Planning Handbook. [online] Washington, D.C.: United States Department of Energy, Office of Indian Energy, National Renewable Energy Laboratory. Available at: https://www.energy.gov/sites/prod/files/2014/05/f16/AKStrategicPlanningHandbook_v17.pdf [Accessed 6 May 2018].

United States Environmental Protection Agency (2012). Sustainable Energy Opportunities: Best Practices for Alaska Tribes. [online] Available at: https://19january2017snapshot.epa.gov/sites/production/files/2015-08/documents/sustainable_energy_opportunities_resource_guide.pdf [Accessed 6 May 2018].

United States Environmental Protection Agency. (2017). Greenhouse Gas Equivalencies Calculator | US EPA. [online] Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator [Accessed 6 May 2018].

United States General Accounting Office (2003). Alaska Native Villages. Most Are Affected by Flooding and Erosion, but Few Qualify for Federal Assistance. [online] Available at: https://www.gao.gov/new.items/d04142.pdf [Accessed 6 May 2018].

United States Government Accountability Office (2009). Alaska Native Villages. Limited Progress Has Been Made on Relocating Villages Threatened by Flooding and Erosion. [online] Available at: https://www.gao.gov/new.items/d09551.pdf [Accessed 6 May 2018].

U.S. State Solar Resource Maps. (n.d.). Retrieved from https://www.nrel.gov/gis/solar.html

Vaught, D. (2011, August 26). Buckland Wind-Diesel Hybrid Feasibility Study Report(Rep.). Retrieved https://www.v3energy.com/wp-content/uploads/2010/09/Buckland-Wind-Diesel-Hybrid-Feasibility-Study-Final-V3-Energy-LLC.pdf

Vaught, D. (2011, August 26). Deering Wind-Diesel Hybrid Feasibility Study Report(Rep.). Retrieved https://www.v3energy.com/wp-content/uploads/2010/09/Deering-Wind-Diesel-Hybrid-Feasibility-Study-Final-V3-Energy-LLC.pdf

Village Energy Efficiency Program(Rep.). (2012). Retrieved http://www.akenergyauthority.org/Content/Efficiency/EEC/Documents/Shishmaref_FinalReport_VEEP.pdf

Waldholz, R. (2017, January 18). Obama denies Newtok's request for disaster declaration. Alaska Public Media. Retrieved from https://www.alaskapublic.org/2017/01/18/obama-denies-newtoks-request-for-disaster-declaration/

Waldholz, R. (2017, December 8). To house a village, Newtok looks to unlikely source: Army surplus. Alaska Public Media. Retrieved from https://www.alaskapublic.org/2017/12/08/to-house-a-village-newtok-looks-to-unlikely-source-army-surplus/

What You Need to Know About Impact Investing (2018); Retrieved from https://thegiin.org/impact-investing/need-to-know/#what-is-impact-investing.

Whitmore, J. (2015, February 11). No evidence wind farms directly impact health: NHMRC. Retrieved from https://theconversation.com/no-evidence-wind-farms-directly-impact-health-nhmrc-37470

Why is it important to eat vegetables? (n.d.). Retrieved from https://www.choosemyplate.gov/vegetables-nutrients-health

The Wind-diesel Grant AEA # 2195377. (2016, February). Retrieved from https://www.nwabor.org/wp-content/uploads/The-Wind-diesel-Grant-AEA-2195377-Buckland-Deering-and-Noorvik.pdf

Yoder, S. (2018, January 8). Assessment of the Potential Health Impacts of Climate Change in Alaska(Rep.). Retrieved http://www.epi.alaska.gov/bulletins/docs/rr2018_01.pdf

Appendix A
Memorandum on Alaska Visit

MEMORANDUM

To Professor Wendy Jacobs and Debra Stump,
Climate Solutions Living Lab and Emmett Environmental Law and Policy Clinic
From Alaska Team One: Brian Ho, Darya Minovi, Mo Earley, Paavani Garg, Sidra Fatima, Willow Latham
Topic Trip to Anchorage, Alaska from February 22 - 26

May 6, 2018

Overview

As part of the Climate Solutions Living Lab course, our project team traveled to Anchorage, Alaska to speak with several different stakeholders involved in Shishmaref's ongoing community expansion efforts, as well as similar efforts involving other rural Alaska Native villages. The team benefited greatly from the early exposure to those with significant on-the-ground experience, which was often times specifically relevant to our project scope. Despite its brief nature, the trip overall was extremely productive.

Key Findings

- There are many motivated individuals working to assist rural communities like Shishmaref at both the local and state level, as well as from the public, private and non-profit sectors. Alaska is host to a relatively fragmented and decentralized structure of governance, with many services and subsidies provided by public corporations and consortiums.

- The Denali Commission is well-positioned to support relocation efforts, but is limited by a small budget and a lack of federal support; this extends more generally to the inability to secure federal relief funding.

- It is clear that economic limitations, political challenges and overall uncertainty around the timing of relocation, and Shishmaref's commitment to it, impede investment of the limited resources that are available.

- While weatherization and energy efficiency programs are valued in a cold-weather state with high energy costs, greenhouse gas reduction efforts are of a lower priority in regards to Shishmaref and similar communities. The priority remains on reliability, simplicity and low cost.

Trip Details

The team participated in meetings on Friday and Monday. Below are summaries of individual meetings attended:

FRIDAY 2/23

Meeting with Sally Cox

- Sally Cox, Community Resilience and Climate Adaptation Programs, State of Alaska
- Captain Don Antrobus, U.S. Public Health Service, Village Infrastructure Protection Program Manager, Denali Commission
- Max Neil, Environmentally Threatened Communities Program, Alaska Native Tribal Health Consortium
- Gavin Dixon, Senior Project Manager, Alaska Native Tribal Health Consortium
- Karen Murphy, Coordinator, Western Alaska Landscape Conservation Cooperative
- Annie Weyiouanna, Local Coordinator, Native Village of Shishmaref IRA Council
- David Lockard, Bulk Fuel Program Manager, Alaska Energy Authority
- Karen Pletnikoff, Community Environment & Safety Manager, Aleutian Pribilof Islands Association, Inc.
- Jeffrey A. Herzog, U.S. Army Corps of Engineers, Alaska District
- Ann Y. Gravier, Senior Management Analyst, US Department of Housing and Urban Development

The meeting provided a broad overview of various issues related to the relocation of Shishmaref, with a broad set of official stakeholders, with specific discussions on energy, housing, water and health. An immediate conclusion from the meeting is that greenhouse gas emission reductions are not considered a primary objective. Additionally, another lesson learned was that given the extent of prior and ongoing efforts related to Shishmaref, our best opportunities to do meaningful work might require a tighter and more specific scope.

Overall, it was very useful to hear from a breadth of experts sitting in one room. The meeting deepened our understanding of the current situation and planning efforts.

Post-meeting conversation with Gavin Dixon

Gavin was a great resource. He works closely with Native communities via the ANTHC, can could provide checks on what is feasible or is not. His major insights are into issues related to the community in Shishmaref, and he also has relevant experience in energy and electricity programs.

MONDAY 2/23

Meeting with the Alaska Housing Finance Corporation

- Tim Leach, Energy Specialist, Alaska Housing Finance Corporation
- Jimmy Ort, Research and Rural Development, Alaska Housing Finance Corporation
- Scott Waterman, Energy Programs Manager, Alaska Housing Finance Corporation
- Soren Johansson, Press & Communications, Alaska Housing Finance Corporation

AHFC sits on the the funding side of the agency fence. As a public non-profit corporation, they provide and administer a variety of financing options and programs: grants (funded by HUD), packaged mortgages (akin to the role of Fannie Mae and Freddie Mac), rebates, energy audits and technical assistance. Despite their name, AHFC does work in both the commercial and residential sectors.

Although the AHFC is interested in helping Shishmaref, uncertainty around the timing of and commitment to a move makes it hard to direct investment into existing infrastructure that might be abandoned, or long-term infrastructure at a new site without other supporting elements. AHFC also expressed interested in GHG offsets at the scale of the entire state, but not at a village level. In a prior project in Shishmaref, AHFC has encountered some capacity issues around the availability of those in the community who can manage multiple grant programs or complex technical assessments.

Governor's Climate Action for Alaska Leadership Team Conference

Our team was fortunate to be invited to this meeting by Sally Cox, where we had the opportunity to listen to climate leaders in Alaska around impacts to infrastructure, mitigating climate impacts on community health, science around sea-level change and climate change impacts to Alaska's coastline, evaluating risk of permafrost thaw, the impact of climate change on environmentally threatened communities, coastal flooding and erosion, and increasing resiliency in a changing climate.

Each presentation deepened our insight into the multifaceted changes facing Alaskan Native tribal communities and those who are working to solve them.
With regards to uncertainty, there is a lack of data: on permafrost thawing, projections of future changes, high-spatial resolution to track climate change, lack of capacity for communities to document changes. There is also the issue of availability of technical data around environmental assessments, which limits government movement on projects, because studies are lengthy and expensive. Furthermore, there is a lack of knowledge at many levels on technical challenges: because of the variability of the challenge, there isn't much certainty in future projections of extreme weather events, and what the level of impact will be. Finally, many of the challenges were related to funding sources and legal challenges in terms of lack of clarity around what federal laws govern in response to climate change disaster events in Alaska.

Climate Change Impacts to Infrastructure Workshop

Federal Agency action, policy and funding discussion

- Don Antrobus, Denali Commission
- Steve Gray, USGS
- Brent Nichols, DHSEM
- Ann Gravier, HUD
- Ramona Van Cleve, FEMA
- Shirley Kelly, EDA
- Sarena Selbo, USFWS
- Tom Hennessy, CDC
- Malina Chase, BIA
- Tami Fordham, EPA

Part of the Governor’s Climate Action for Alaska Leadership Team conference, this discussion was a convening of a lunch panel with the “federal family” of officials based in Alaska. It was clear that those present and working at the federal level care are cognizant of the challenges present in Shishmaref. There appears to be close collaboration with the Denali Commission and Sally Cox on multiple projects related to Shishmaref and other rural villages.

Immediate and long-term action discussion

- Nils Andreassen, Secretariat of the Climate Action Leadership Team
- Don Antrobus

This panel focused on next steps and drawing conclusions at the end of the day. The outcomes of that discussion are listed below:

Challenges and Barriers

- Stafford Act
- Funding for planning versus implementation versus science
- Lack of coordinating agencies
- Lack of policy on protect-in-place vs relocation
- Lack of policy on family versus village relocations
- Conflicting authorities and regulations, local capacity, NEPA

Recommendations:

- Strengthen state-federal relationship
- Consistent state-federal policies with respect to relocation
- Advocate for an update to GAO Report 09-551
- Amend the Stafford Act
- Perform a no-action economic analysis
- Establish a $200M state village protection, relocation and match fund
- Use $50M of unobligated surface transportation funds for VPRM as seed
- Adopt UAF/USACE statewide threat assessment as criterion for allocation

- Advocate for increased federal implementation funding
- Advocate for decreased local match on federal grants and loans
- Provide $50M for construction of a school and critical infrastructure in Mertarvik
- Provide $45M for construction of evacuation centers in other villages
- Streamline ROW and land transfer procedure
- Request OMB establish Cross Agency Priority (CAP) for infrastructure protection
- Increase funding for DCRA local government assistance programs
- Advocate for changes to NEPA

Appendix B
Implementation Study

Final Feasibility Study
Shishmaref Relocation

March 12, 2018
Climate Solutions Living Lab
Prof. Wendy Jacobs

Alaska Team 1
Brian Ho, Darya Minovi, Mo Earley, Paavani Garg, Sidra Fatima, and Willow Latham

Table of Contents

I. Executive Summary

As you have read in the implementation plan - Shishmaref is a community that is in dire need of relocation as well as opportunities to reduce its dependency on diesel. The Community needs to focus on creating a sustainable community that would fulfil not only its energy requirements - but also address food security, water, sanitation, job opportunities, etc. In this feasibility study, we considered various options on how to facilitate a small portion of this daunting project.

As you will note, we considered three options but only two of them made it into our implementation plan. They are described as below:

Package 1: Hybrid Microgrid Infrastructure for West Tin Creek Hills to Reduce Cost of Energy, Improve Energy Independence and Improve Public Health explores opportunities for energy provision that reduce diesel dependence and food vulnerability. In particular, we evaluate the potential and estimate the costs of a wind or solar-based microgrid, especially relative to current diesel energy prices (both subsidized and unsubsidized). We conclude that a wind-diesel energy microgrid presents a viable option, with both successful precedent projects in Alaska and substantial co-benefits in terms of public health and reduced reliance on diesel deliveries. Capital costs could be high, however, and could require below-market financing options.

Package 2: A “Foothold” Community at West Tin Creek Hills (JBER Barracks) evaluates the re-use of temporary barracks to establish a “foothold” community at West Tin Creek Hills. Retrofitted barracks, estimated at 75% of the cost of new construction, could move forward the relocation timeline by lowering the cost barrier of the move, as well as potentially unlock funding sources that require established residents.

We conclude that, while feasible, further analysis of Package 1 presents minimal opportunity for added value by our team. Barracks relocation has already been evaluated and cleared as a reasonable option by several in-depth feasibility studies, including detailed cost analyses and retrofitting plans. Here, we propose several alternative retrofitting options to minimize diesel dependence, and put forward several contingencies for consideration.

Moreover, over the course of preparing the feasibility study - we discovered that all the barracks had been utilized for the Newtok relocation. As such, in our implementation plan we propose the creation of the “Foothold” Community - but consider donations of materials and labor to create the initial housing unit.

Package 3: Opportunities for Private Investment to Create Capital for Sustained Community Investment Efforts analyzes alternative financing sources, including private-sector options, that the community could access prior to relocation. Constraints and opportunities posed by each are evaluated, focusing in particular on innovative sources and structures that have been under-evaluated by previous studies focusing on government funding. For multiple reasons, this option is not considered feasible: the project would be too small in size to generate a substantial return for investors; at this time, there are not many identifiable potential partners willing to invest in a small scale project; aggregating communities in Alaska leads to hurdles of structuring an investment that would deliver consistent returns from all communities. Due to the uncertainties of the proposed project, there is difficulty in pitching a source of return to investors. Similarly, since we are unsure of what projects the relocated village could realistically undertake, we cannot make guarantees of any energy reductions to our investors

As such, we find that securing private capital does not pass our feasibility study. In our implementation plan, we instead focused on federal funding, public grants (e.g., Coastal Impact Assessment Program, Rasmussen Foundation Grants), as well as tax deductible donations in order to move the project forward.

II. Description of Screening Exercise and Results

According to federal and Alaskan officials, 184 out of 213, or 86.4 percent of Alaska Native villages, particularly those on the coast or along rivers, experience varying levels of flooding and erosion that threaten the long-term viability of their communities.[1] Due to the absence of quantifiable and up-to-date baseline data for these remote locations, it is difficult to assess the severity of the problem, leaving policy-makers and village leaders alike ill-informed of impending risks and ill-equipped to develop a comprehensive approach to prioritizing, developing, authorizing, and funding activities that can address the needs of these at-risk communities.

In many ways, the Alaska Native village of Shishmaref is fortunate in that significant effort has been invested and analysis has been conducted to better understand the community's level of risk and inform the approach to responding to the threat of erosion and permanent change to their lifestyles due to rising sea levels, shifting weather patterns, and rising temperatures. According to a 2003 report developed by the Government Accountability Office (GAO), Shishmaref is one of four villages considered to be in imminent danger from flooding and erosion, and the community agreed to work with federal agencies and other Alaskan state and non-governmental organizations to determine the next steps for relocation. In 2009, GAO released a follow-up report prompted by the growing impacts of climate change that increased the urgency of state and federal responses and found that the absence of a lead federal entity to oversee relocation processes significantly contributed to the lack of action.[2] Despite more than 15 years passing between the original GAO report identifying the need for action and our team's introduction to Shishmaref, the complex legal, political, and financial contexts, along with the difficulties inherent to navigating multiple levels of governance at the native, municipal, state, and federal levels have slowed the relocation process.

Faced with the challenge of identifying innovative and feasible approaches to assist the community of Shishmaref with relocation, our team began first by attempting to better understand the work being done to support the relocation of another similarly-threatened community, the Alaska Native village of Newtok. By reviewing the existing extensive plans developed by the Newtok Planning Group, we quickly recognized the complicated and interconnected ecosystem of factors dictating the ability of any Alaska Native community to relocate.[3] We conducted further research into the similarities and differences between Newtok and Shishmaref to ensure that lessons-learned by the Newtok Planning Group would be suited

[1] United States General Accounting Office (2003). Alaska Native Villages. Most Are Affected by Flooding and Erosion, but Few Qualify for Federal Assistance. [online] Available at: https://www.gao.gov/new.items/d04142.pdf.
[2] United States General Accounting Office (2003). Alaska Native Villages. Most Are Affected by Flooding and Erosion, but Few Qualify for Federal Assistance. [online] Available at: https://www.gao.gov/new.items/d04142.pdf.
[3] Russell Cox, S. (2018). Newtok Planning Group. [online] Commerce.alaska.gov. Available at: https://www.commerce.alaska.gov/web/dcra/PlanningLandManagement/NewtokPlanningGroup.aspx

to meet the distinct needs of the Shishmaref community. Based on this initial research, we developed a set of screening criteria to guide our efforts:

- **Sustainability and Scalability:** our project should aim to protect and sustain natural resources - such as through GHG emission reductions, decreases or elimination in fossil fuel use, or generation of renewable energy - and should demonstrate the potential to be adapted and scaled to other communities - Alaska Native or otherwise - experiencing similar challenges related to the threats of climate change.
  - As our research has progressed, we've recognized that sustainability and scalability are also related to the political landscape and narrative, as well as the existing governance structure within which Shishmaref exists. Thus, our project should be politically palatable.
- **Community Buy-In:** our project should meet the understood needs of the Shishmaref community, either by directly addressing concerns or requirements shared by community members or by providing options and a clear process through which community members are empowered to determine the best course of action based on their preferences.
  - Our trip to Anchorage and additional research revealed valuable information about how Alaska Native communities currently understand relocation, and due to complex legal, financial, and political barriers, the sequencing of relocation project elements is extremely important. As such, we will take into account the ways in which projects can be limited by these complexities, and more importantly about how they can assist in catalyzing relocation momentum.
- **Legal and Financial Feasibility:** our project should be legally viable within the federal, state, municipal, and tribal governance infrastructure, and should be financial feasible in that the project should be structured in a way that can reasonably be expected to provide sufficient, timely, and manageable sources of funding to support project implementation.
- **Demonstrated Competitive Advantage:** our project should appropriately iterate and improve upon existing proposals and subsequent requirements, designs, and structures in ways that are cost effective, improve public and community health, promote environmental consciousness, and are easier to implement and sustain by actors at all levels working on the complicated challenge of relocation.

Our initial brainstorming efforts focused on developing project ideas that fell into six distinct categories:

- **Housing**
- **Community Power / Alternative Energy**
- **Community Layout**
- **Water / Sewer Infrastructure**
- **Funding Sources**
- **Food Security**

We also determined that our final project output would provide a phased proposal for community relocation with two overarching goals:

1) To reduce greenhouse gas emissions, and
2) To provide a sustainable, scalable approach for relocation that could be both used specifically by Shishmaref and provide a template for similar communities threatened by climate change impacts.

And finally, given the urgent need for relocation, we decided that our project output should prioritize implementability - financial, legal, political, operational, and behavioral - when considering design and technical solutions. Additionally, the relatively limited scale of existing greenhouse gas emissions means that any significant offset would require multiple interventions on a long-term timeframe. As such, our proposed relocation plan identified the following sections:

- **Community Design:** including best practices for the design, construction, operation, and funding of housing, heating systems, energy infrastructure, water and sewer systems, community layout and services, and a comprehensive process for community empowerment and decision-making.
- **Implementation Strategies:** including feasible approaches that link desired physical improvements to a client that will purchase RECs and a detailed, specific financing plan with components that address both immediate relocation and the long-term economic sustainability of the relocated village.
- **Technological Improvements:** including alternative technologies and energy sources that serve public health and social benefits.

Following our initial screening exercise, several team members traveled to Anchorage, AK where they were able to meet with a host of key actors working directly on efforts to support Alaska Native community relocation efforts, including attending a day-long meeting of the Governor's Climate Action Leadership Team focused on climate adaptation efforts and challenges. The opportunity to gain additional context on this trip provided our team with the ability to further refine our approach and outlook to identifying, scoping, and delivering a project that meets both our original criteria as well as newly-identified targets to ensure our final implementation plan would be valuable tool to the existing actors working on Shishmaref's relocation effort.

III. Package Narratives

We used results from the screening exercise, ongoing research and findings from travel to develop the three broad sections of our relocation plan into three project packages, to be analyzed in our feasibility study. Each package consists of a specific project as well as its supporting programs and other aspects. The packages serve the broader goals of community design, implementation strategies and technological improvements, but focus on a specific intervention known to be relevant to stakeholders and applicable to Shishmaref. The packages evaluated in our feasibility study are:

1. A “Foothold” Community at West Tin Creek Hills (JBER Barracks)
2. Opportunities for Private Investment to Create Capital for Sustained Community Investment Efforts
3. Hybrid Microgrid Infrastructure for West Tin Creek Hills to Reduce Cost of Energy, Improve Energy Independence and Improve Public Health

Conceptually, the packages explore the areas of housing, finance and infrastructure to support the relocation of Shishmaref. Each package was developed at a schematic level to provide operating assumptions and a basis for comparison, and then analyzed against a set of feasibility criteria. Each criteria was applied to all projects, but with differing emphasis depending on the specifics of the package proposal. The criteria included in our feasibility study are:

Criteria	**Description**
Legal	*Regulation, administration and governance considerations*
Design	*Spatial, site and logistics considerations*
Public Health	*Project improves community and individual well-being*
Cost	*Total project budget is feasible*
Funding	*Appropriate source of funding are available*
GHG	*Project produces GHG reductions (and offsets) and is additional*

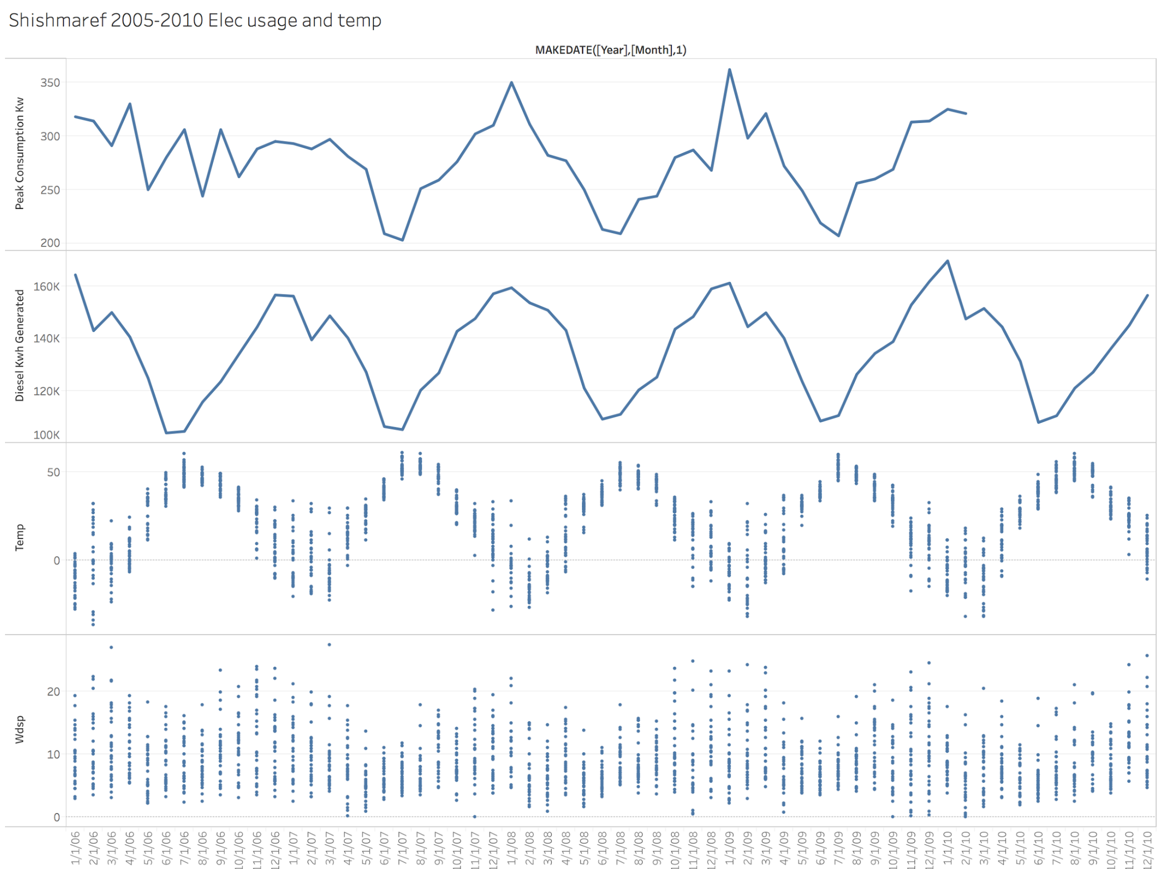
Package 1: Hybrid Microgrid Infrastructure for West Tin Creek Hills to Reduce Cost of Energy, Improve Energy Independence and Improve Public Health

This package explores opportunities for energy provision that reduce diesel dependence and food insecurity. In particular, we evaluate the potential and estimate the costs of a wind or solar-based microgrid, especially relative to current diesel energy prices (both subsidized and unsubsidized). We conclude that a wind-diesel energy microgrid presents a viable option, with both successful precedent projects in Alaska and substantial co-benefits in terms of public health and reduced reliance on diesel deliveries. Capital costs could be high, however, and could require below-market financing options.

Criteria	**Description**
Legal	*Major concern would be loss (or reduction) of PCE subsidy; subsidy can be repurposed*
Design	*Generation projections dependent on available data; access road needed*
Public Health	*Reduced diesel-burning emissions and produce from greenhouses create benefits*
Cost	*Generation costs of electricity would vary with generation mixture; high capex*
Funding	*Loans and grants are available to support use of renewables*
GHG	*Renewable penetration would directly contribute to GHG emission reductions*

3.1 | PACKAGE DESCRIPTION

As Shishmaref plans for its relocation to the selected West Tin Creek Hills location, there will be a need to design and develop new energy infrastructure, as extending the existing grid on the barrier island to the mainland is not feasible for both technical and operational reasons. The construction of new energy infrastructure presents an opportunity for Shishmaref's new village to adopt a hybrid microgrid with both renewable and diesel energy generation — which would reduce GHG emissions over the existing diesel generation facilities in the old location, promote local energy independence, reduce dependence on expensive diesel shipped-to-site and create public health benefits.



The trends of Peak Consumption Kw, Diesel Kwh Generated, Temp and Wdsp for MAKEDATE([Year],[Month],1). The data is filtered on Year, which ranges from 2005 to 2010.

A cost-effective microgrid project will need to serve the entire energy needs of a complete relocated community, with reserve capacity for emergencies and consistent service. Project design and financing depends on accurate sizing and load estimation.

In theory, load estimation is feasible given data available from AVEC, which operates Shishmaref's existing generation facilities. Shishmaref's current village is served by a system of three diesel generators, providing about 1,670 MWh in gross generated electricity per year. These generators serve roughly 150 residences (790 MWh per year) and 18 commercial facilities (360 MWh per year). Peak (kW) and cumulative (kWh) loads are highest during the winter season, even though most heating is from fuel oil.[4] A microgrid for a relocated village would at minimum have to provide equivalent generation capacity, but ideally would meet the village's desire to grow from 600 to 800 persons.[5] In addition, detailed energy audits performed by the AHFC can help inform projections for energy usage for similar buildings on the relocated site.[6]

An alternative microgrid design scenario would be to build a "minimum viable" generation capacity on the new site, aimed at serving a "foothold" community. This would reduce initial capital expenditure, but would likely have a higher per-Watt capital cost and an even higher per-kWh operation cost in the long run due to loss of economy of scale. Given the relatively small size of Shishmaref, this option may not make a lot of sense; but under this scenario the initial microgrid would provide energy only for a small set of initial pioneer homes (e.g. 13 modified barracks) and critical facilities, with capabilities for future expansion.

The microgrid could be structured in a few different ways:[7]

1. Low-penetration renewable generation which acts as a small "negative load" for diesel generators
2. High-penetration renewables without storage with dispatchable diesel generators to control for variance; excess generation could be used for heating
3. High- or mid-penetration renewables with storage as well as dispatchable diesel generators to control for variance

All options have been tried before in Alaska in various contexts (including an all-renewable microgrid on Kodiak Island[8]); the state is considered a leader in the develpment of rural microgrids with renewables.[9] The penetration of renewables corresponds with GHG emission reductions, assuming additionality over a base case of diesel-only energy generation. Most likely, wind turbines would be the primary source of renewable energy generation, supplemented by photovoltaics. A discussion of these two renewables is included below.

---

[4] Akenergygateway.alaska.edu. (2018). Community Data Summary: Shishmaref - Alaska Energy Data Gateway. [online] Available at: https://akenergygateway.alaska.edu/community-data-summary/1409434/

[5] AECOM Technical Services, Alaska (2016). City of Shishmaref, Alaska Sarichef Island. Relocation Site Selection Feasibility Study February 2016. [online] Anchorage, Alaska, pp.3-5. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Site_Selection_Feasibility_Study_FINAL_022316.pdf

[6] Armstrong, R. S. (2012, April 12). *Comprehensive, Investment Grade Energy Audit of Shishmaref School, Shishmaref, Alaska*(Rep.). Retrieved May 6, 2018, from Energy Audits of Alaska website: http://www.akenergyefficiency.org/wp-content/uploads/2013/05/BSNC-SHH-RSA_Shishmaref_School.pdf

[7] Devine, M., Manwell, J., Baring-Gould, E. I., & Petrie, B. (n.d.). *Wind-Diesel Hybrid Options for Remote Villages in Alaska*(Rep.). Retrieved from http://www.akenergyauthority.org/Content/Useful documents/Wind-Diesel-Hybrid-Options-for-Remote-Villages-in-Alaska.pdf

[8] Abb.com. (n.d.). ABB to enable integration of renewables in Alaskan island microgrid. [online] Available at: http://www.abb.com/cawp/seitp202/BC90B54CC33D1663C1257D50002FAF58.aspx

[9] Shaw, D. W. (2017, March 26). What Rural Alaska Can Teach the World about Renewable Energy. *Scientific American*. Retrieved from https://www.scientificamerican.com/article/what-rural-alaska-can-teach-the-world-about-renewable-energy/

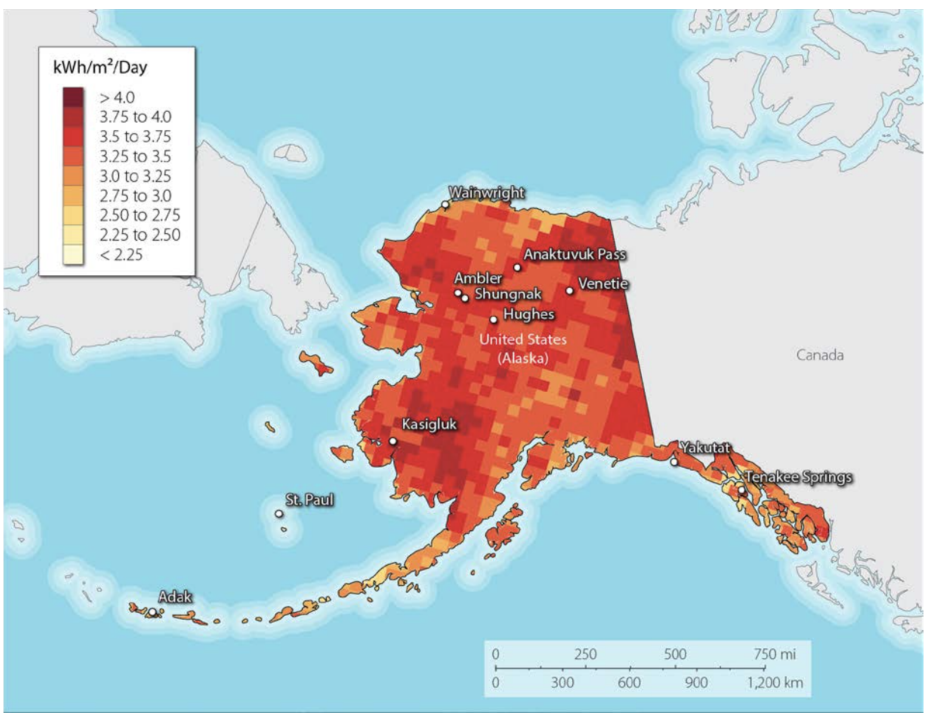
Renewable Energy Sources / Microgrid Components

Wind and solar energy have been identified as two potential options for supplementing energy production in Shishmaref so as to decrease their dependency on diesel. The feasibility of each renewable source of energy is explored below.

Solar

In 2016, the US Department of Energy's Office of Indian Energy conducted a Solar Energy Prospecting analysis for rural Alaska. The analysis aimed to explore diversification of energy sources for Alaska Native communities for the following reasons: 1) many Alaskan communities are vulnerable to fluctuations in oil prices, 2) renewable energy technologies have advanced tremendously and the cost of equipment has decreased, and 3) renewable energy would provide communities with greater energy independence.[10]

Solar energy has been identified as a potential option for Alaska due its expansive geography and meteorological conditions that are suitable for solar energy production, such as low ambient temperatures, which increase the efficiency of solar panels, and the reflectivity of sunlight off snow. Using data from a 40-km satellite and surface cloud cover database, they constructed a map on solar resources in Alaska, shown below.[11]



---

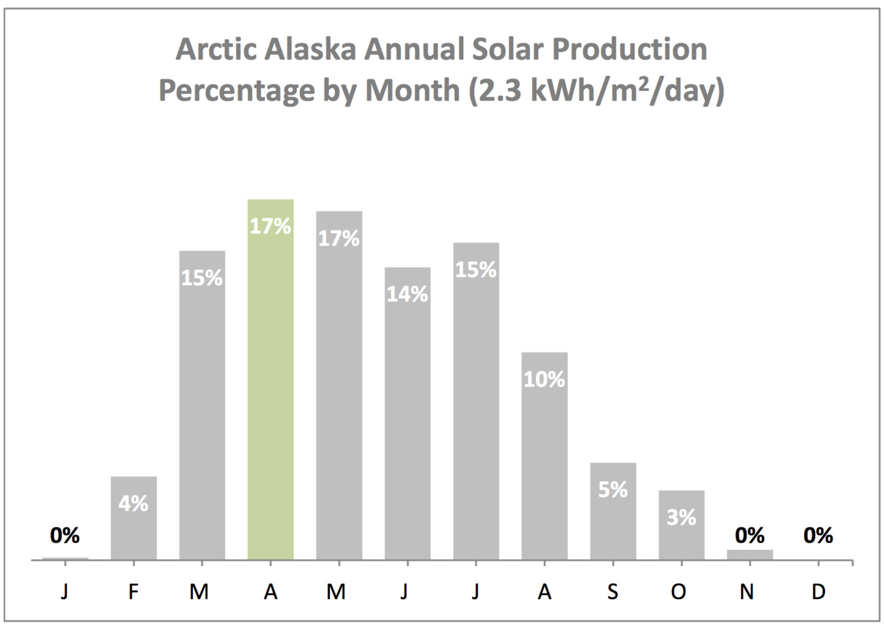
[10] Schwabe, P. (2016, February). *Solar Energy Prospecting in Remote Alaska*(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

[11]Schwabe, P. (2016, February). *Solar Energy Prospecting in Remote Alaska*(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

Based on this map, the West Tin Creek location falls within the 3.0-3.25 kWh/m^2/day solar insolation range.[12] It should be noted that compared to the lower 48, which has solar insolation ranges up to 8.5 kWh/m^2/day, Alaska's solar insolation range is relatively low.[13]

Since Shishmaref was not specifically included in this analysis, for the purpose of this feasibility assessment we have used the village of Wainwright as a proxy, as it falls within the same solar insolation range as Shishmaref. Based on the assessment, it is projected that Wainwright could produce 73,881 kWh of power with a 100-kW system.[14] For comparison, Shishmaref's existing system consists of one 500-kW, one 300-kW, and one 200-kW diesel generator.[15] In addition, in 2012 the village generated approximately 1,627,321 kWh of electricity, therefore based on these estimates, at least 22 100-kW systems would be required to meet their energy requirements.[16]

It should be noted that given Alaska's geographic location, solar production varies greatly throughout the year, with highest production between March and August. During the months of September through February, solar production drops off, and is at around 0% during the winter.[17]



---

[12] Schwabe, P. (2016, February). *Solar Energy Prospecting in Remote Alaska*(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

[13] U.S. State Solar Resource Maps. (n.d.). Retrieved from https://www.nrel.gov/gis/solar.html

[14] Schwabe, P. (2016, February). *Solar Energy Prospecting in Remote Alaska*(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

[15] United States Army Corps of Engineers, Alaska District (2004). Shishmaref Partnership: Shishmaref Relocation and Collocation Study. Preliminary Costs of Alternatives. [online] Seattle, WA: Tetra Tech, Inc. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/USACE_relocation%20plan_shishmaref.pdf

[16] http://www.kawerak.org/ledps/shishmaref.pdf

[17] Schwabe, P. (2016, February). *Solar Energy Prospecting in Remote Alaska*(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

Given the low solar capacity factor in Wainwright (8%) and varied solar production in Alaska overall, solar energy alone would not be sufficient to meet the energy demands of Shishmaref.

Greenhouses

As increasing ocean temperatures have caused sea ice to melt sooner each year, food insecurity has become a growing problem for the subsistence hunters of Shishmaref, and many other Alaska Native villages.[18] As a result, several villages have turned to greenhouses as a reliable source of food and income generating mechanism for the community. Some successful examples include:

- **Bethel, Alaska** - Established Meyers Farm in 2002, a greenhouse which now produces fresh food to the community. They also sell produce boxes to nearby villages and sell goods at their farm stand twice a week.[19]
- **Kotzebue, Alaska** - Established Arctic Greens greenhouse within an insulated 40 foot shipping container. Uses hydroponics and magenta LED lights to grow produce, which is sold to nearby supermarkets.[20]
- **Igiugig, Alaska** - Established greenhouse in 2015 with funding from the First Nations Development Institute’s Seeds of Native Health program. Efforts heavily focused on community participation in harvesting food, assisting in the greenhouse, and learning food preservation methods.[21]

It appears that there are a slew of companies that have built hydroponic greenhouses (since the soil is not suitable for growing produce) suitable for Arctic climates. However, several challenges must be overcome for this to be a feasible option for Shishmaref.

First, they must secure capital costs for the greenhouse. Depending on the size and type of greenhouse and ease of transporting the materials, start-up costs for greenhouses in rural Alaska have ranged from $4,000 for small household greenhouses in Anaktuvuk Pass to $200,000 for the sophisticated system in Kotzebue. Some organizations that have funded other village greenhouse project include the First Nations Development Institute and Alaska Native

[18] Struzik, E. (2016, March 17). Food Insecurity: Arctic Heat Is Threatening Indigenous Life. *Yale Environment 360*. Retrieved from https://e360.yale.edu/features/arctic_heat_threatens_indigenous_life_climate_change
[19] Meyers Farm. (n.d.). Retrieved from http://www.meyersfarm.net/
[20] D'Oro, R. (2016, November 4). Arctic Farming Town Turns To Hydroponics For Fresh Greens. *U.S. News*. Retrieved from https://www.usnews.com/news/business/articles/2016-11-04/arctic-farming-town-turns-to-hydroponics-for-fresh-greens
[21] Grounds, R. (2015, September 1). Igiugig Village Receives Grant for Greenhouse and Wild Foods Project. Retrieved from http://www.igiugig.com/latest-news/administrative-updates/125-greenhouse-and-wild-foods-project-grant

Federation's Alaska Marketplace. Many additional funding sources are listed in the Alaska Energy Authority's Biomass Heated Greenhouse Handbook.[22]

Once start-up funds are secured, they must overcome several challenges to keep operating costs low. In order for them to grow produce year-round, the question of powering the greenhouse must be answered. Solar heating would likely be sufficient to heat the greenhouse during summer months, but in the winter they would have to rely on alternative means. A successful example of this is Chena Fresh, a hydroponic greenhouse near Fairbanks, which utilizes geothermal power from the nearby hot springs to operate the lights and other electrical equipment in their greenhouse. Since geothermal is not available in Shishmaref, they might consider using wind energy, wood heating, or recovered heat from the diesel generators.[23] This would reduce the community's dependence on diesel, which typically accounts for a significant portion of greenhouse operating costs.

Another method for reducing operating costs is selling excess produce to nearby communities. Given that Shishmaref is not accessible by road, transporting the produce would be difficult. In addition, further community assessments would need to be conducted with Shishmaref to evaluate whether they are interested in having greenhouses in their village.

If these initial questions are answered, however, greenhouses could provide a reliable, healthy food option for the community. It would also be an opportunity to empower community members by training them in new skills and creating new livelihood options. They may also consider partnering with the University of Alaska, Fairbanks' Alaska Growers School on training opportunities.[24]

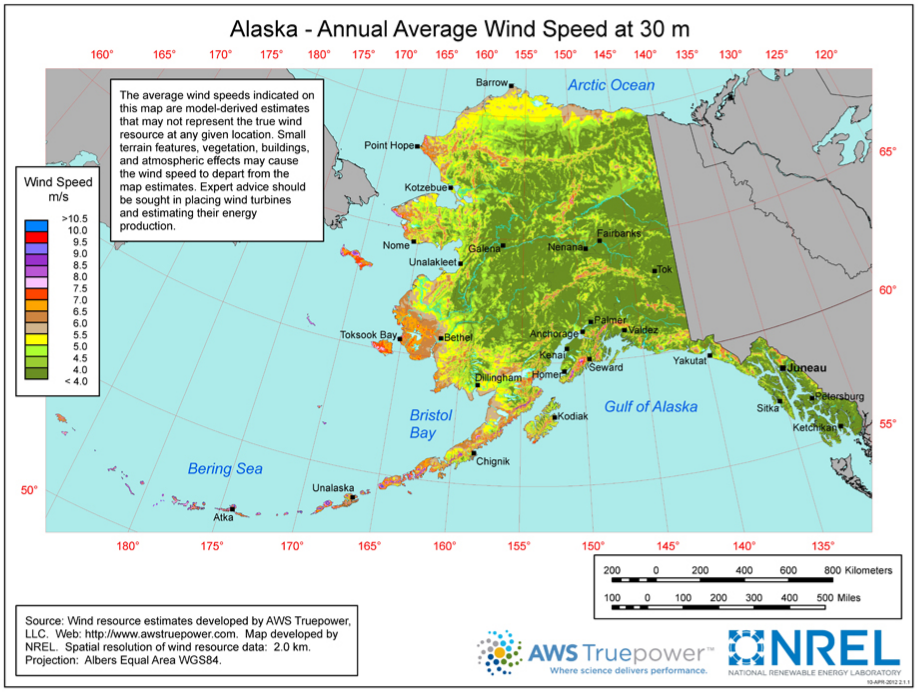
Wind

[22] *Bio-Mass Heated Greenhouses: A Manual for Alaskan Schools and Community Organizations*(Rep.). (2017, March). Retrieved http://www.akenergyauthority.org/Portals/0/DNNGalleryPro/uploads/2017/4/5/317BiomassHeatedGreenhouseManual.pdf

[23] *Case Study: Chena Hot Springs*(Rep.). (2010). Retrieved http://www.uaf.edu/files/acep/greenhouseenergy.pdf

[24] Interested in taking the Alaska Growers School? (n.d.). Retrieved from http://www.uaf.edu/ces/ags

Fortunately, Shishmaref and its new site have significant wind resources. Wind potential is higher to the west of the West Tin Creek site, but the differences may not justify the extended



transmission distance.[25]

There are several wind energy efforts ongoing at Shishmaref. A trial 2.4 kW turbine was installed on the barrier island as part of a Department of Energy Tribal Energy Program grant in 2015, with the potential to generate 5 MWh per year.[26] AVEC has also proposed a larger feasibility and conceptual design for wind energy generation.[27]

Despite the potential for wind resources, capital costs could be prohibitive. A modeled wind power project included in the AEA's Alaska Affordable Energy Model estimates capital costs of $3.5 million for a 275 kW install, with annual generation of 675 MWh and a capacity factor of 0.28.[28] This would represent 40% penetration; the modeled lifetime energy cost savings would only account for about ⅓ of initial capital expenditure. It is unclear where this model positioned the wind turbines, or their relative scale.

[25] Alaska Energy Data Inventory. (n.d.). Retrieved from http://akenergyinventory.org/

[26] Palmer, K. (2015, December 17). Shishmaref Gets DOE Support on Energy and Resiliency. Retrieved from https://www.energy.gov/indianenergy/articles/shishmaref-gets-doe-support-energy-and-resiliency

[27] Shishmaref Wind Feasibility and Conceptual Design. (2017, December 15). Retrieved from https://www.omb.alaska.gov/ombfiles/19_budget/DCCED/Proposed/2019proj61641.pdf

[28] Shishmaref: Estimated electricity generation costs per year. (n.d.). Retrieved from http://model-results.akenergyinventory.org/current/Shishmaref/wind_power.html

For reference, Alaskan wind turbines are usually in the 65-100 kW range, so the project modeled above would constitute anywhere from three to five turbines [29] For wind energy to completely serve an estimated load of 2000 MWh per year, assuming a capacity factor of 0.30, would require about 800 kW of installed generation. .

Wind power has been used successfully elsewhere in Alaska. Kodiak Island's all-renewable microgrid features a 9 MW wind farm (in addition to about 19 MW produced from hydropower facilities) which serves 15,000 people.[30] The rural northwestern Native villages of Buckland and Deering have undergone feasibility studies,[31] conceptual design and construction of wind turbines: two 100 kW turbines in Buckland at a cost of $6 million, and one 100 kW turbine in Deering at a cost of $3 million.[32] [33] Both projects were funded by a grant from the State of Alaska's Renewable Energy Fund.

The projects in Buckland and Deering would represent about one-quarter to one-eight the necessary capacity to completely serve Shishmaref's needs with wind alone. It is worth noting the Renewable Energy Fund has proposed a $2.5 million wind feasibility for the village of Shishmaref, for the Governor's FY19 budget, aligned with AVEC's request.[34]

Storage and Other Considerations

Microgrids designed with energy storage solutions would enable peak load shaving and possible redundancy and resiliency, although energy storage would lead to lower overall efficiencies due to conversion. Common storage solutions include mechanical flywheels, primarily designed to stabilize against intermittencies from renewable generation.[35]

Alternatively, excess and off-peak generated energy could be provided to optional or less time-dependent loads: providing supplementary heating through electric heat pumps, or operating the pump systems for community water supplies.

---

[29]Devine, M., Manwell, J., Baring-Gould, E. I., & Petrie, B. (n.d.). Wind-Diesel Hybrid Options for Remote Villages in Alaska(Rep.). Retrieved May 6, 2018, from http://www.akenergyauthority.org/Content/Useful documents/Wind-Diesel-Hybrid-Options-for-Remote-Villages-in-Alaska.pdf

[30] Abb.com. (n.d.). ABB to enable integration of renewables in Alaskan island microgrid. [online] Available at: http://www.abb.com/cawp/seitp202/BC90B54CC33D1663C1257D50002FAF58.aspx

[31] Vaught, D. (2011, August 26). *Buckland Wind-Diesel Hybrid Feasibility Study Report*(Rep.). Retrieved https://www.v3energy.com/wp-content/uploads/2010/09/Buckland-Wind-Diesel-Hybrid-Feasibility-Study-Final-V3-Energy-LLC.pdf and Vaught, D. (2011, August 26). *Deering Wind-Diesel Hybrid Feasibility Study Report*(Rep.). Retrieved https://www.v3energy.com/wp-content/uploads/2010/09/Deering-Wind-Diesel-Hybrid-Feasibility-Study-Final-V3-Energy-LLC.pdf

[32]Hobson, M. K. (2015, October 20). A renewable energy success story above the Arctic Circle. Retrieved from https://www.eenews.net/stories/1060026559

[33]The Wind-diesel Grant AEA # 2195377. (2016, February). Retrieved from https://www.nwabor.org/wp-content/uploads/The-Wind-diesel-Grant-AEA-2195377-Buckland-Deering-and-Noorvik.pdf

[34]*Renewable Energy Fund Status Report*(Rep.). (2018, January). Retrieved http://www.akenergyauthority.org/Portals/0/Programs/RenewableEnergyFund/Documents/2018-REF Status Report.1.27.18.pdf

[35] The Wind-diesel Grant AEA # 2195377. (2016, February). Retrieved from https://www.nwabor.org/wp-content/uploads/The-Wind-diesel-Grant-AEA-2195377-Buckland-Deering-and-Noorvik.pdf

The location of the renewable generation facilities would need to be optimized for both available natural resources and transmission costs — long distance from the relocated village to a suitable site for wind or solar might become prohibitively expensive.

Diesel
In all cases, diesel generators would still be used to provide a dispatchable energy source and backup generation. Since diesel would likely remain a primary source of heating fuel, infrastructure to store and receive deliveries of diesel would be included in any relocated village design.

Workforce Development
With any new energy system, workforce development must be a priority in order to ensure proper operation and maintenance. Gavin Dixon of the Alaska Native Tribal Health Consortium also stated in our meeting that job training opportunities are highly desired by the community.

Currently, renewable energy training programs are being facilitated through the following organizations, funded through the Alaska State Energy Sector Partnership grant[36]:

- Alaska Apprenticeship Training Coordinator Association
- Alaska Energy Authority
- AVTEC – Alaska's Institute of Technology
- Alaska Works Partnership, Inc.
- University of Alaska Southeast
- Yukon Inter-Tribal Watershed Council

3.2 | LEGAL CONSTRAINTS

The biggest legal constraint to consider in this analysis is that of the PCE subsidy loss and whether it would be worthwhile to lose the massive diesel dependent subsidy in place of creating an energy efficient microgrid. However, there may be legal ways to reappropriate the PCE subsidy to the microgrids.

The PCE program was established in 1985 as one of the components of a statewide energy plan, providing economic assistance to customers in rural areas of Alaska. Prior to the PCE program, there was the Power Production Assistance Program and the Power Cost Assistance Program. The PCE program provides economic assistance to communities and residents in rural areas of Alaska where, in many instances, the kilowatt- hour charge for electricity can be three to five times higher than the average kWh rate of 14.82¢ (7/14) in Anchorage, Fairbanks or Juneau. The PCE program was established to assist rural residents at the same time state

[36] *Renewable Energy and Energy Efficiency Workforce Development Plan*(Rep.). (2012, September 18). Retrieved http://labor.alaska.gov/awib/2012-oct-mtg-binder/ASESP_RE.EE_Workforce_Dev_Plan-Draft.pdf

funds were used to construct major energy projects to assist more urban areas. Most urban and road connected communities benefit from major state-subsidized energy projects such as the Four Dam Pool, Bradley Lake, and the Alaska Intertie. Rural communities not on the road system that are dependent on diesel fuel do not benefit from the large subsidized energy projects, and PCE is a cost-effective alternative to provide comparable rate relief to rural residents[37].

The program is established via *legislative* means through Alaska state statute 42.45.110. Given that this is a legislative subsidy, it would be harder to advocate for a change in the statute itself in order to provide a similar subsidy for the microgrid dependent facility.

Nonetheless, there is a way around this. The fund is administered by the Alaska Energy Authority and is composed of:

1. Appropriations by the State Legislature.
2. Appropriations from the NPRA.
3. Gifts, bequests, and contributions from other sources.
4. Interest earned on the fund balance[38]

Moreover, The Regulatory Commission of Alaska determines the PCE level for each utility based on: fuel expenses such as the cost of fuel, transportation; and, non-fuel expenses such as salaries, insurance, taxes, parts and supplies, interest and other reasonable costs[39].

As such, it would be feasible to approach the NPRA to renegotiate the appropriations that the community receives from them and for what purpose they are earmarked. Moreover, the microgrid utility facility can send a request to the Regulatory Commission of Alaska in order to be added into the PCE program, as they determine which utilities are available for the subsidy. In order to be up for review the utility must provide the RCA its costs for a specific time period, usually a year. The utility must also report how many kilowatt hours have been generated and sold during the same time period, as well as how many gallons of fuel it took to produce the kilowatt hours generated, and the cost of that fuel[40]. Moreover, the RCA specifies an electric utility is required to install and maintain necessary metering equipment. The statute also

[37] *Power Cost Equalization Program Guide(Rep.). (2014, July). Retrieved http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf*

[38] *Power Cost Equalization Program Guide(Rep.). (2014, July). Retrieved http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf*

[39] *Power Cost Equalization Program Guide(Rep.). (2014, July). Retrieved http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf*

[40] *Power Cost Equalization Program Guide(Rep.). (2014, July). Retrieved http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf*

requires a utility to use energy conservation measures when and where possible, and to determine if it can generate electricity with *fuel other than diesel*. 3 AAC 107.240 (E) states that "An eligible electric utility shall organize and maintain, in accordance with standard accounting practices, the accounts of its electric fund as a separate accounting entity in a self-balancing set of account that includes the assets, liabilities, balance, revenue, and expenses of the electric fund.[41]"

As such, it is clear from the language above that although a large part of the PCE subsidy goes towards diesel dependent communities, the program rewards communities that works towards energy conservation and generate electricity with fuel other than diesel. Moreover, the RCA has *efficiency* standards that must be met in order to receive the subsidy - something that can easily be achieved by the microgrids.

Therefore, it would be possible to replace the subsidy received for diesel dependent systems with a subsidy for the microgrid. *However*, it would be impossible to receive this subsidy for microgrids for State and Federal offices and facilities, as well as commercial customers, including schools[42]. However, the regulations do not clarify whether the utility facility cannot be installed in those commercial spaces - just that the PCE credit is not given to commercial customers. As such, it may be possible to install the microgrids in schools and have residential customers still receive a subsidy from electricity generated through the microgrids.

3.3 | DESIGN CONSTRAINTS

Implementation of this package might be constrained by unreliable data on land-cover and energy patterns, and available existing materials. Aggregated data from AEA and other relevant agencies will inform optimal locations for wind and solar energy generators, while greenhouse models would have to be designed in accordance with the climate.

In terms of locating wind and solar energy generators, the implementation plan will assess adequate siting needs in order for optimal penetration from both systems. According to the Shishmaref Village report in the Bering Strait Regional Energy Plan[43], the potential for a hybrid wind-diesel energy system is high. Thus, there are no limiting design constraints, as yet identified, to the implementation of this aspect of the package.

Design and installation of greenhouses is not a constraint as there are many cases of cold-climate areas with hydroponic greenhouses. According to the AECOM Shishmaref Relocation

---

[41] *Power Cost Equalization Program Guide(Rep.). (2014, July). Retrieved http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf*

[42] *Power Cost Equalization Program Guide(Rep.). (2014, July). Retrieved http://www.akenergyauthority.org/Content/Programs/PCE/Documents/PCEProgramGuideJuly292014EDITS.pdf*

[43] *Bering Strait Regional Energy Plan*(Rep.). (2015, June). Retrieved http://www.akenergyauthority.org/Portals/0/DNNGalleryPro/uploads/2017/1/27/BeringStraitRegionaEnergyPlan.pdf

Feasibility Study, the soil and silt in West Tin Creek Hill will be suitable for development. Considerations in the implementation of the greenhouses will necessitate an adequate site study to locate structures in close proximity to generators or heat pumps that may be necessary to heat greenhouses in colder months.

The only design constraint is the delivery of produce for sale: the assumptions in this package do not account for available and feasible infrastructure to connect this project in economies of scale. Transportation of materials would be contingent on the construction of an access road from the Shishmaref Inlet to the new site, so barges could access and deliver both building materials, and distribute produce from the hydroponic greenhouses.

3.4 | PUBLIC HEALTH IMPACTS

Baseline Health

The process of diesel generation emits harmful contaminants such as nitrogen oxides (NOx), sulfur dioxide, and particulate matter. The reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight creates ozone.[44] Breathing ozone can irritate the respiratory system, causing chest pain, coughing, and airway inflammation. In severe cases, it can reduce lung function and harm lung tissue. People most at risk from exposure to ozone are asthmatics, children, older adults, and people who work outdoors.[45]

Particulate matter (PM) can also have adverse effects on respiratory health. PM can include, among other things, organic chemicals, metals, dust particles, and acids like nitrate and sulfate.[46] Exposure to PM is associated with the onset of respiratory and cardiovascular illness, and smaller particles like PM2.5 (which is present in diesel exhaust) can be inhaled more deeply and are therefore not as easy to expel through sneezing or coughing, making them more likely to deposit in the lungs.[47] Exposure to PM has been linked to premature death and children and the elderly are most vulnerable to negative health effects.[48] It can also exacerbate the effects of Chronic Obstructive Pulmonary Disease (COPD), which was the fifth leading cause of death among Alaska Native from 2012-2015.[49]

The dual challenges of poor nutrition and food insecurity are also a concern in Shishmaref. As of 2017, more than 35% of Alaska Native adults are obese and across the tribal health regions,

---

[44] Ozone Pollution. (n.d.). Retrieved from https://www.epa.gov/ozone-pollution

[45] *Basic Information about Ozone. (n.d.). Retrieved from https://www.epa.gov/ozone-pollution/basic-information-about-ozone#effects*

[46] Yoder, S. (2018, January 8). *Assessment of the Potential Health Impacts of Climate Change in Alaska*(Rep.). Retrieved http://www.epi.alaska.gov/bulletins/docs/rr2018_01.pdf

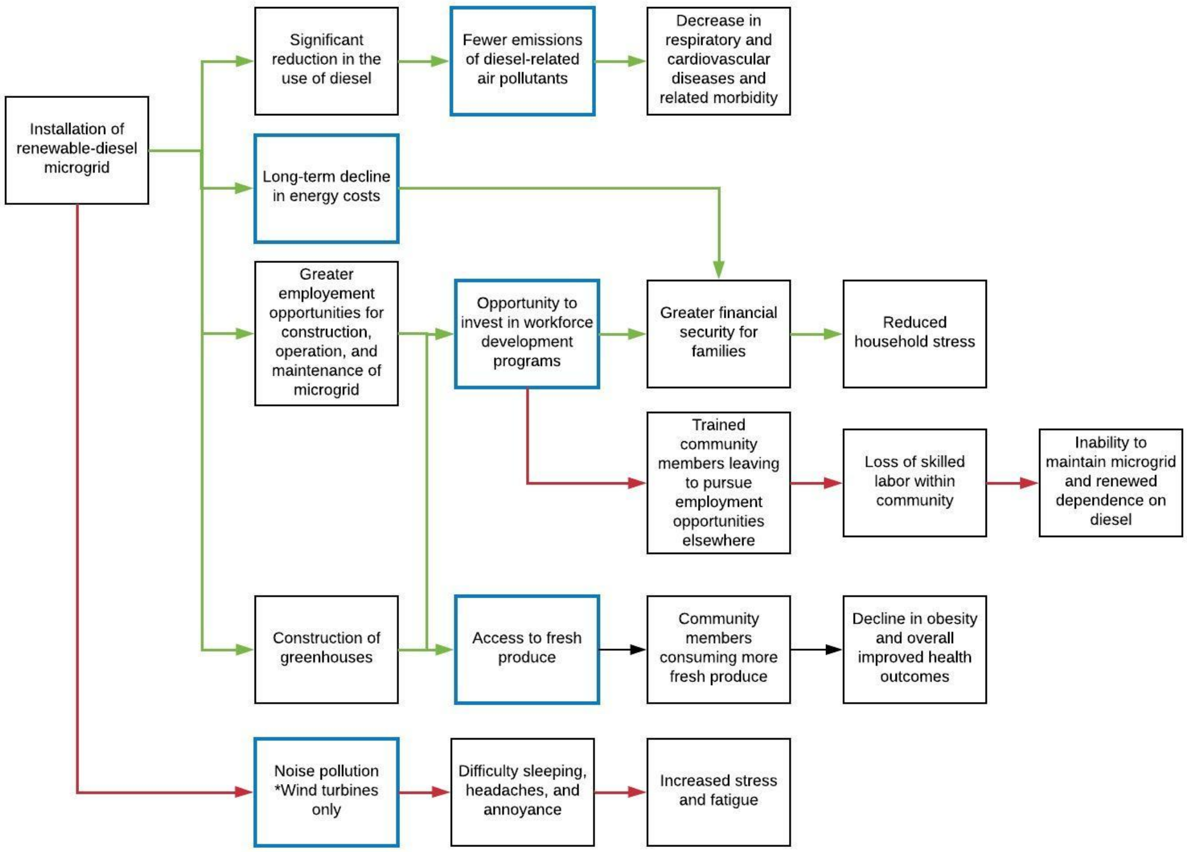
[47] Yoder, S. (2018, January 8). *Assessment of the Potential Health Impacts of Climate Change in Alaska*(Rep.). Retrieved http://www.epi.alaska.gov/bulletins/docs/rr2018_01.pdf

[48] Diesel Engines and Public Health. (n.d.). Retrieved from https://www.ucsusa.org/clean-vehicles/vehicles-air-pollution-and-human-health/diesel-engines#.Wu-tfNPwbOS

[49] *Alaska Native Health Status Report*(Rep.). (2017, August). Retrieved http://anthctoday.org/epicenter/publications/HealthStatusReport/AN_HealthStatusReport_FINAL2017.pdf

only 2.5-22.3% of adults are meeting recommendations for fruit and vegetable consumption.[50] In addition, in recent years most villages have transitioned to processed foods and candy in order to supplement current traditional diets.[51] Another concern is that access to traditional maritime food sources has become more precarious with sea ice thawing sooner each year.

Conceptual Model and Public Health Impacts



Key: Green = Intended Benefit; Red = Unintended Consequence; Blue = Project Impact

Project Impact	Anticipated Health Effect	Opportunities to Maximize Public Health Benefits
Fewer emissions of diesel-related pollutants	By transitioning to renewable energy and effectively displacing diesel, there will be a significant reduction in diesel use and the accompanying emissions. As a result, there will	Exploring other ways in which to reduce energy use and/or other sources of pollution throughout the community.

[50] *Alaska Native Health Status Report*(Rep.). (2017, August). Retrieved http://anthctoday.org/epicenter/publications/HealthStatusReport/AN_HealthStatusReport_FINAL2017.pdf
[51]Rosen, Y. (2016, May 31). Shift from traditional foods takes toll on Alaska Native populations. *Anchorage Daily News*. Retrieved from https://www.adn.com/rural-alaska/article/processed-food-comes-diabetes-obesity-alaska-natives/2014/09/29/

	likely be a decline in respiratory and cardiovascular diseases in the area.	
Long-term decline in energy costs	By no longer relying on expensive diesel deliveries and it's volatile prices and transitioning to a renewable source, the cost of energy will eventually decline. This will provide families with additional income to invest elsewhere and likely reduce poverty-associated stress.	Investing in home weatherization and exploring other measures to reduce energy use can also maximize these cost savings over time.
Opportunity to invest in workforce development programs	- In our conversations with government officials in Alaska we learned that workforce development opportunities are highly desired by the community. Therefore, the installation of a renewable-diesel microgrid serves as an opportunity to invest in workforce development programs that can teach residents how to operate and maintain the system. By including the community over this process, there will likely be a greater sense of ownership for this system and willingness to effectively manage it. In addition, with new employment opportunities, families will likely have greater financial security, and as a result, experience less poverty-related stress. - The construction and management greenhouses may also provide an opportunity for workforce development in the community. This could similarly contribute to greater financial security and reduced household stress.	Given that there are other rural Alaska Native villages that have installed wind-diesel microgrids and greenhouses, opportunities to engage and/or partner with these communities should be explored. This may provide an opportunity to share lessons between communities that are also rurally located and may share similar traditions. Another opportunity to maximize benefits from these programs is also investing in youth education. A lack of hope for the future has been cited as a challenge in Shishmaref,[52] therefore using the greenhouses for environmental education and/or volunteering may empower them to feel invested in the community.
Access to fresh produce	With a greenhouse operating year-round, community members can supplement their diet with fresh produce, which can significantly reduce the the risk of chronic disease in the community.[53]	Since fresh produce is not part of the traditional diet in Shishmaref, community investment in this initiative should be achieved before moving forward. Opportunities to engage with other Alaska Native communities who recently installed greenhouses and incorporated fresh produce in their diet should be explored.

[52] Stories from Shishmaref, Alaska's Climate Frontline. (n.d.). Retrieved from https://soundcloud.com/warmregardspodcast/stories-from-shishmaref-alaskas-climate-frontline
[53] Why is it important to eat vegetables? (n.d.). Retrieved from https://www.choosemyplate.gov/vegetables-nutrients-health

Opportunity to invest in workforce development programs	One potential downside of workforce development is if community members with newfound skills in renewable microgrid operation and management leave the village to pursue employment opportunities elsewhere. If remaining community members are unable to properly operate and maintain the system, they may be forced to renew their dependence on diesel energy, which would undo the public health benefits associated with the project in the first place. In a worst-case situation, the loss of residents may also contribute to weaker social ties or even long-term community dissolution.	In order to prevent the loss of skilled labor, the community might explore a few avenues such as: providing high wages for microgrid operators or incentives for them to stay, creating a training program where skilled residents can teach other rural Alaska Native communities how to operate renewable microgrids, or investing in other revenue generation streams, such as greenhouses.
Noise pollution *Wind turbines only	- An existing challenge associated with wind turbines is the resulting noise pollution, which some have found disruptive and annoying. This can contribute to increased stress and lower quality of life for the surrounding community.[54] - There have also been reports of nausea, dizziness, and fatigue related to wind turbines, though no evidence thus far has connected wind turbines to these symptoms.[55]	Proximity of the turbines to the village should be considered in the planning process. Community socialization meetings should also be conducted in order to promote understanding of the system and field any concerns that residents may have.

3.5 | PROJECT COSTS

Microgrid Cost Estimate

A full cost estimate for a microgrid should include the following phases (from *Cost Estimating for Advanced Microgrids,* Sandia National Laboratories):

- *Installation Costs* – costs to procure and install all equipment involved in conceptual designs including construction firm overhead costs

[54] Jeffery, R. D. (2013). Adverse health effects of industrial wind turbines. *Canadian Family Physician,59*(5), 473-475. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3653647/

[55] Jeffery, R. D. (2013). Adverse health effects of industrial wind turbines. *Canadian Family Physician,59*(5), 473-475. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3653647/ and Whitmore, J. (2015, February 11). No evidence wind farms directly impact health: NHMRC. Retrieved from https://theconversation.com/no-evidence-wind-farms-directly-impact-health-nhmrc-37470

- *Design and Engineering Costs* – costs for detailed A&E firm design plans, and engineering involved in installation, testing and final implementation of conceptual design. Estimated to be 25% of the total installation costs
- *Contingency Costs* – Additional 25% contingency added to account for unanticipated costs associated with the conceptual design such as base or city planning related costs.
- *Overall Construction Costs* – Sum of installation, design and engineering as well as contingency costs. Approximately 1.5X of installation costs

Costs for the install of various generation facilities could vary significantly; diesel generators could be moved from the existing site, whereas solar or wind equipment would need to be purchased new. We assume, however, that the cost of installing an electric distribution system are comparable independent of the generation source, and do not conduct a full analysis of each of these elements in this stage, but rather focus on the relative cost of generation sources. For reference, estimated microgrid costs per the *Cost Estimating* study are as follows:

Equipment	Equipment and Installation costs ($K)	Construction OH (20%) ($K)	Design OH (12.5%) ($K)	Engineering OH (12.5%) ($K)	Total Costs ($K)	Total Costs with Contingency (25%) ($K)
Microgrid Breaker	100.0	20.0	12.5	12.5	145.0	181.3
Underground Feeder	530.0	106.0	66.3	66.3	768.5	960.6
Microgrid Controls	375.0	75.0	46.9	46.9	543.8	679.7
Misc Equip	250.0	50.0	31.3	31.3	362.5	453.1
Total w/o Generation	1255.0	251.0	156.9	156.9	1819.8	2274.7
Generation						
1600 kW New Generation	1200.0	240.0	150.0	150.0	1740.0	2280.0
Total w/generation	2455.0	491.0	306.9	306.9	3559.8	4554.7

<u>Estimates for Generation by Source</u>

Costs of renewable energy sources vary by estimate. Basic estimates are included below:

Type	Price	Source	Feasibility
Solar	**$0.50 per kWh** in Shishmaref. Low cost ($6/W), base case ($9/W), and high cost	*Solar Prospecting in Alaska: An Economic Analysis of Solar Photovoltaics in the Last Frontier State.* Paul Schwabe, National	“This would not leave a lot of wiggle room - if it ends up falling in base or high price range, **the cost of electricity per kWh will exceed the**

	($12/W) for a 100-kW PV system. Includes $6/W in capital costs and $40 per kWh/year in operation and maintenance costs. (Figure A).[56]	Renewable Energy Laboratory, Department of Energy, Office of Indian Energy.	**current cost** of electrical power in Shishmaref"
Wind	$265,000 /$440,000 per turbine, plus $3,000 / $4,500 in annual O&M costs. (Figure B).	*Wind-Diesel Hybrid Options for Remote Villages in Alaska*. Mia Devine, University of Massachusetts Amherst; E. Ian Baring-Gould, National Renewable Energy Laboratory; Brent Petrie, Alaska Village Electric Cooperative.	"As the least-cost small-scale renewable energy technology currently available, wind energy is a **serious option in reducing the use of diesel and the exposure to fuel price volatility**."
Wind-Diesel	Based on a loan interest rate of 6% and a general inflation rate of 3%, the levelized cost of energy is **$0.13 per kWh.** (Up to $5,000 per kW of rated wind power)	*Wind-Diesel Hybrid Options for Remote Villages in Alaska*.	"The economic benefits of a wind-diesel system result from fuel savings, a potential reduction in diesel O&M and overhaul costs, and the potential value of excess wind energy generated. The use of wind energy also delays the need for additional fuel storage tanks."
Baseline Costs under current diesel generation system	Operation & Maintenance: $2.80 to $9.20 per hour.	*Wind-Diesel Hybrid Options for Remote Villages in Alaska*.	Local O&M capacity should be considered -- current systems are maintained and operated by local workers, while alternatives likely require high-skilled labor.
	Rates per kWh (Dec. 2014): Residential: $0.65 (before PCE) PCE Rate: $0.44		Commercial and government/NGO rates are not subsidized.

[56] Schwabe, P. (2016, February). *Solar Energy Prospecting in Remote Alaska*(Rep.). Retrieved https://www.energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf

	Effective (after PCE): $0.21		
	Fuel cost: Variable. $5.37/gallon in 2013.		Volatile over time (Figure C). PCE subsidy currently insulates residential consumers from volatility by absorbing fuel price increase. (Figure D).

Figure A.

Table 1. Cost Estimates for a 100-kW PV System

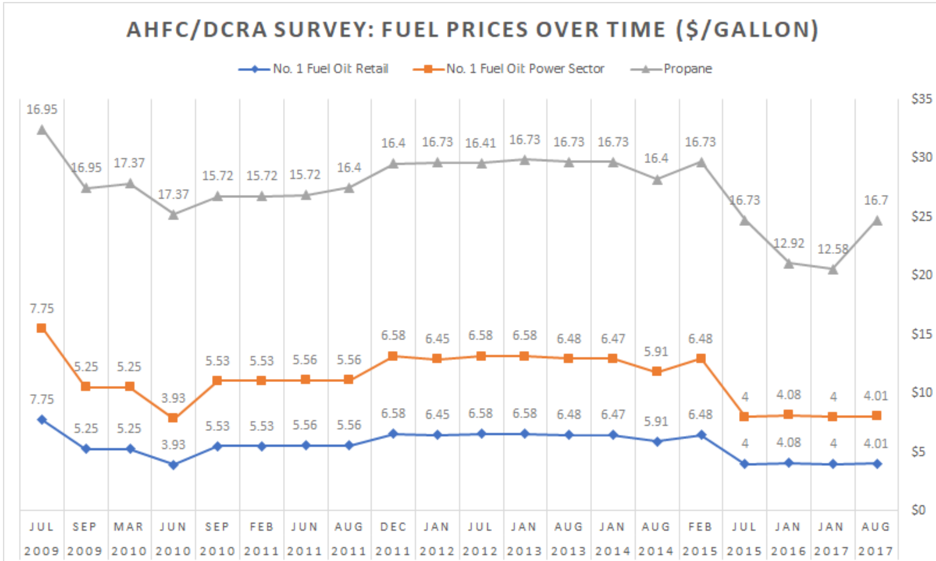
Village	Case	Lower 48 Cost Multiple	Capital Costs ($/W)	O&M Costs ($/kW/yr)
All	Low Cost	2 X	$6	$40
	Base Case	3 X	$9	$60
	High Cost	4 X	$12	$80

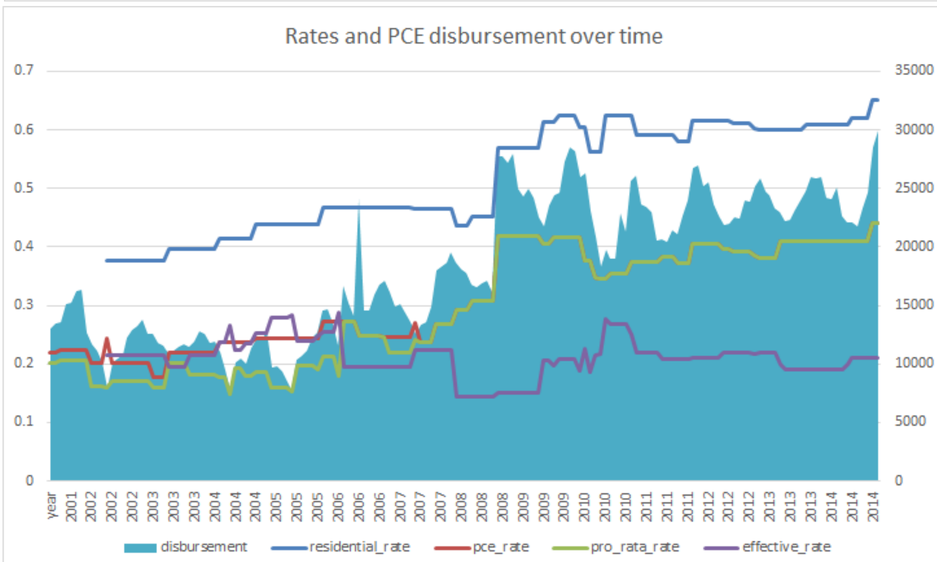
Figure B.

Table 4. Cost of Wind Turbines

	AOC 15/50	NW100
Wind Turbine & Tower	$ 90,000	$ 230,000
Shipping	$ 25,000	$ 35,000
Installation	$ 50,000	$ 75,000
Foundation	$100,000	$100,000
Total (each)	$265,000	$ 440,000
Annual O&M	$3,000	$4,500

Figure C.





A key question when evaluating any cost is whether the electric price cited includes the PCE diesel subsidy -- if so, it is not fair to directly compare renewable costs to subsidized diesel prices, as Alaska taxpayers are still liable for the PCE cost. The subsidy, which came to $301,988 for fiscal year 2016 for Shishmaref alone, represents a significant running cost to support rural energy provision in Shishmaref. It is possible, although unclear, whether this subsidy is accounted for in the following study, which shows negative benefit-cost ratios for installing most renewable energy sources: [57]

[57] Alaska Affordable Energy Model: Shishmaref. (n.d.). Retrieved from http://model-results.akenergyinventory.org/current/Shishmaref/potential_projects.html

Technology/Project	NPV benefits	NPV cost	NPV net benefit	Benefit cost ratio
Residential Energy Efficiency	$5,187,468	$3,131,289	$2,056,179	1.7
Non-residential Energy Efficiency	$1,517,284	$1,323,647	$193,637	1.1
Water and Wastewater Efficiency	$125,911	$383,018	$-257,107	0.3
Wind Power (Modeled)	$1,146,291	$3,567,280	$-2,420,989	0.3
Solar Power	$47,974	$231,775	$-183,802	0.2
Transmission and Interties	N/A	N/A	N/A	N/A
Diesel Efficiency	$614,501	$3,028,170	$-2,413,669	0.2
Biomass for Heat (Cordwood)	N/A	N/A	N/A	N/A
Biomass for Heat (Pellet)	N/A	N/A	N/A	N/A
Residential ASHP	$-4,137,628	$6,839,966	$-10,977,595	-0.6
Non-Residential ASHP	$-895,182	$1,261,278	$-2,156,460	-0.7

Cost effective projects have a benefit cost ratio greater than 1.0.

Most studies we looked at do appear to account for the subsidy. However, a back-of-the-envelope analysis (using the capital costs for wind and solar installation estimated by the Alaska Affordable Energy Model[58], not accounting for cost of capital) our team conducted seems to indicate that installation of wind generation would have a positive value, with a payback period of 10-16 years if the PCE subsidy were re-allocated towards amortization of the initial capital outlay.

3.6 | POTENTIAL FUNDING SOURCES

Based on initial reviews, the following programs present potential funding to support project elements.

Program Name & Purpose	Eligibility Requirements	Project Element	Amount
Power Cost Equalization Endowment Fund (Provide for a long-term, stable financing source for power cost equalization which provides affordable levels of electric utility costs in otherwise high-cost service areas of Alaska)	• Opportunities may exist to leverage PCE to encourage private investment in renewable energy	Wind, Solar	n/a
Bureau of Indian Affairs Energy and Mineral Development Program	• Hydro • Solar • Wind	Wind, Solar	Based on appropriated

[58]Shishmaref: Estimated electricity generation costs per year. (n.d.). Retrieved from http://model-results.akenergyinventory.org/current/Shishmaref/wind_power.html

(Grants for projects that assess, evaluate, or otherwise promote the productive use or development of energy and mineral resources on Indian lands)	• Geothermal • Biomass		amounts
Bureau of Indian Affairs Division of Capital Investment (Loans available for operating capital, equipment purchases, building construction and lines of credit)	• Federally recognized Alaska Native groups • Individually enrolled members of such groups	Produce growing and selling operation	$500k for individuals , more for tribes
Native American Business Development Institute (NABDI) Grant (Enable Alaska Native village or regional village corporation to conduct feasibility studies on the viability of an economic development project, opportunity, enterprise, business, or technology)	• Alaska tribes are allowed to apply if the project would occur on land trust lands • Funds only available for feasibility studies, not business plans	Produce growing and selling operation	none
60Hertz (Provides paths to energy sovereignty through financing and operations & maintenance solutions))	• n/a	Wind, Solar	n/a
USDA Microloan Programs (Provides financing for small, beginning farmer, niche and non-traditional farm operations)	• Need some farm experience (internships /apprenticeship programs acceptable); those with low experience are encouraged to have a mentor	Produce growing and selling operation	$50k
Wells Fargo (Five-year commitment to American Indian/Alaska Native communities to address unique economic, social, and environmental needs)	• Contributions made to organizations with tax-exempt status or qualified tribal and governmental agencies, including public school systems	Renewable energy, clean water, housing development, or workforce development	$50 million total funding available

3.7 | GHG CONSIDERATIONS AND ADDITIONALITY

Assessment Boundary

The microgrid proposal is perhaps the most straightforward in terms of determining GHG emissions reductions and offsets. The chief project activity in any microgrid project will be the construction and operation of a hybrid renewable electricity generation infrastructure. As with previous projects, it is assumed that Shishmaref will relocate, and the baseline cases will involve the utilization of an energy infrastructure similar to the existing (i.e. all diesel generators). In this case, the project assessment boundary encompasses the GHG emissions reduced though replacement of diesel burning for electricity generation with renewables — some combination of wind and solar.

Baseline Case

The baseline scenario in this case assumes that the relocated community of Shishmaref constructs an energy infrastructure similar to their existing, powered entirely by diesel-burning generators. In this case, because data exists on existing electricity consumption for the village, a reasonable estimate of GHG emissions associated with diesel burning can be created. In addition to these primary effects, there would also be secondary effects in a baseline scenario related to construction of the infrastructure. Note that the intensity of activity associated with construction of diesel-based system may be lower, as equipment could feasibly be moved from the existing village site (rather than shipped longer distance, as would be the case for novel renewable infrastructure). For this reason, the baseline scenario resembles a continuation-of-use case.

Additionality

GHG reductions are generated over the baseline scenario through a reduction in the use of diesel, caused by an increased penetration of renewable energy sources. In the hybrid microgrid scenario, it would be again feasible to estimate GHG emissions and primary effects related to project activities: the anticipated annual electricity generated by renewables and used by the scenario could be converted into an amount of diesel not used (and, therefore, GHG emissions avoided). Secondary effects might also occur through a decrease in the frequency of barge deliveries of diesel, assuming a high-penetration renewables scenario. In an actual implementation, primary effect GHG emissions reductions could be measured by looking at actual electricity demand data and the generation mixture of the microgrid.

Appendix B

Package 2*:* A “Foothold” Community at West Tin Creek Hills (JBER Barracks)

This package explores the re-use of temporary barracks to establish a “foothold” community at West Tin Creek Hills. Retrofitted barracks, estimated at 75% of the cost of new construction, could move forward the relocation timeline by lowering the cost barrier of the move, as well as potentially unlock funding sources that require established residents (as discussed in the implementation plan).

We conclude that, while feasible, further analysis of Package 1 presents minimal opportunity for added value by our team. Barracks relocation has already been evaluated and cleared as a reasonable option by several in-depth feasibility studies, including detailed cost analyses and retrofitting plans. Here, we propose several alternative retrofitting options to minimize diesel dependence, and put forward several contingencies for consideration. We recommend that the Shishmaref community continue to consider this option given the detailed information available, as well as take advantage of lessons learned from the Mertarvik relocation.

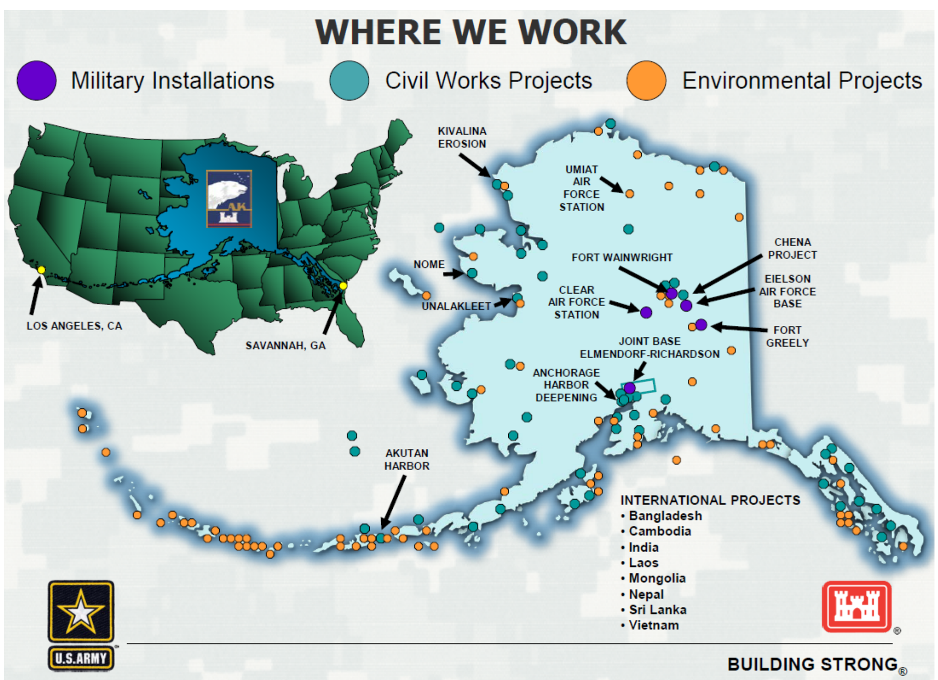
As noted in our implementation plan, our focus, instead is on creating a toehold community in order to increase funding opportunities for the overall relocation. As such, the following feasibility report on the use of barracks is rendered moot.

Criteria	**Description**
Legal	*Little to no constraints, land already conveyed to Shishmaref Native Corporation*
Design	*Barracks are sufficient but a limited solution; site is adequate but lacks access road*
Public Health	*Improved and relocated housing will provide multiple health benefits*
Cost	*Barracks cost 75% of new construction, less depending on labor source*
Funding	*Multiple loans and grants available, depending on timing*
GHG	*GHG reductions are possible, but difficult to estimate given uncertain baseline scenario*

Photo source: [link]

1.1 | PACKAGE DESCRIPTION

Package 1 consists of moving temporary barracks from the Joint Base Elmendorf-Richardson in Anchorage (where they are no longer in use) to the relocation site at West Tin Creek Hill. This option is currently being pursued by both Newtok and Shishmaref. There are a total of 72 units available at JBER, including those allocated to the Newtok relocation, although additional units may be available at other military sites.



Shishmaref has faced a catch-22 situation in which the village is unable to access some funding sources (for example, school construction) without a relocated population, but is unable to relocate without funding. In a best-case scenario, these barracks would serve as low-cost "pioneer" housing, meaning self-sufficient units served by micro-infrastructure rather than the grid, and would establish a foothold at the new site. This would both allow Shishmaref to access more funding sources and accelerate the moving process, which is highly time-sensitive due to the potential for storm damage.

The barracks are "long rows of modular dorms, single-story units attached end to end."[59] Each module has three bedrooms, a bathroom, and a kitchenette -- in Newtok, each single-family home will require 2 modules to make 1,790 square foot, 4-bedroom dwelling.[60] This setup could be modified to create smaller or larger units, depending on desired household configurations, as has been proposed in Mertarvik.

The barracks, which have been used for 10 years by the millitary so far, are expected to have a remaining lifetime of approximately 30-40 years; they are expected to be used for the length of that period.

This project would consist of several phases:

- Disassembly and packing of barracks at the JBER site.

- Shipping: While the barracks were developed for easy transport, under the currently identified Newtok scenario, only 13 4-bedroom units (26 modules) can be shipped per barge. Stacking may allow this number to be doubled, as proposed in the Mertarvik Barracks Relocation Phase 2 report (2017).

- Site preparation: The 2017 Shishmaref Relocation Site Feasibility Study performed by AECOM found soil quality to be sufficient for new construction. However, foundation requirements for the barracks may be different; in particular, gravel availability could be a binding constraint if administrative barriers to accessing the rock source at Ear Mountain cannot be resolved quickly.

- Setup: There are several options for labor sources for installation and retrofitting, including local community members (possibly with CCHRC assistance, as in the case of the Mertarvik model homes), National Guard or other military assistance[61] as part of training programs, or contracted labor. Using local labor could provide co-benefits in terms of capacity-building, as community members develop potentially valuable skills in

---

[59]Waldholz, R. (2017, December 8). To house a village, Newtok looks to unlikely source: Army surplus. *Alaska Public Media*. Retrieved from https://www.alaskapublic.org/2017/12/08/to-house-a-village-newtok-looks-to-unlikely-source-army-surplus/

[60] Waldholz, R. (2017, December 8). To house a village, Newtok looks to unlikely source: Army surplus. *Alaska Public Media*. Retrieved from https://www.alaskapublic.org/2017/12/08/to-house-a-village-newtok-looks-to-unlikely-source-army-surplus/

[61]Laycock, M. (2010, July 20). Arctic Construction: Marines build road for new village over Alaskan tundra. Retrieved from http://www.marforres.marines.mil/Marine-Reserve-News-Photos/Marine-Reserve-News/Article/521433/arctic-construction-marines-build-road-for-new-village-over-alaskan-tundra/

construction, installation, and weatherization (building a "skilled local workforce[62]" has been a critical element of Newtok's strategy). There is also a potential that community work hours could be counted as an "in-kind" contribution towards the 25% Denali Commission match requirement (as in AKEA weatherization project[63]).

- Retrofitting: At minimum, this will require weatherization. New roofs may be required; if barracks are installed before grid infrastructure systems are in place, micro-infrastructure installation for electricity, water and sanitation, waste disposal, and heating will also be needed. This leads to an estimated $300,000 per unit cost.

  State assistance could reduce this cost to Shishmaref: AHFC offers individual low-income weatherization at no cost based on income criteria[64] that are met by at least half of Shishmaref's households (a very conservative estimate, given that the median household income of 30,000 in 2016[65] is already significantly below the 1-person cutoff of $59,430 although average household size was 4[66]).

This project presents several possible advantages:

Cost: Since the base is giving the barracks away for free, the village would not have to pay acquisition cost -- costs of disassembly, transport, site preparation, reassembly, and retrofitting will come to about 75% cost of new construction. The Denali Commission will fund approximately 75% of the cost of shipping the first 13 barracks; however, a 25% local match is required.

Fit: A focus on safe housing is in line with the priorities identified by the Shishmaref Community in the 2015 Strategic Management Plan (September 2016), which identifies gaps in the village's existing housing stock and sets a goal of creating 100 more housing units in order to address "overcrowding, energy efficiency, affordability, and poor structural conditions." The plan prioritizes "access to safe, quality, and affordable housing."

There are several questions that this project should address, however:

Will this option provide adequate housing? The temporary barracks have been in use for over 10 years, and were never intended as permanent housing. Whether they will meet the Shishmaref community's standards for acceptable quality should be evaluated before moving

---

[62] *Relocation Report: Newtok to Mertarvik*(Rep.). (2011, August). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/Mertarvik_Relocation_Report_final.pdf

[63] *Village Energy Efficiency Program*(Rep.). (2012). Retrieved http://www.akenergyauthority.org/Content/Efficiency/EEC/Documents/Shishmaref_FinalReport_VEEP.pdf

[64] FY 2017 Income Limits for Alaska. (2017). Retrieved from https://www.ahfc.us/files/5814/9521/1018/Income_limits_for_Alaska_FY2017.PDF

[65] https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml

[66] https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml

forward with this option. Unlike in Newtok, it appears that many community members in Shishmaref would prefer to remain in their current homes even if relocated.

Would an implementation plan for this option add value? Barrack relocation is already being actively pursued by community and state leaders for both Shishmaref and Newtok, and has been evaluated in at least 2 in-depth feasibility studies. It is unclear that there is sufficient value-add potential in our team's further evaluation of this option.

Will this option actually be low-cost? The potential savings due to using barracks, estimated at 25% of new construction cost, could easily evaporate if unexpected delays or complications arise. There are uncertainties around the actual costs of site preparation, retrofitting, and infrastructure installation. Issues such as administrative or transportation delays, construction cost overruns, and unforeseen technical challenges during installation could quickly inflate costs beyond initial estimates. Whether the cost of retrofitting and pioneer micro-infrastructure will outweigh the savings in materials and construction cost, and the sensitivity of these savings to delays and overruns, should be evaluated in the case that this alternative is pursued further.

Possible contingencies that could cut into savings include:

Time sensitive availability: Since JBER is seeking to relocate the barracks as soon as possible, they may not be available indefinitely. How quickly the new site can be prepared to receive the shipment (see below) is a critical question. Additionally, it is unclear whether there are enough barracks at the JBER site to satisfy demand for both Mertarvik and West Tin Creek Hills: the Mertarvik Barracks Relocation Plan Phase 2 calls for using all JBER modules for Newtok's relocation. Costs of relocation and retrofitting for barracks from other sites, if they are even available, may be very different from the JBER barracks.

Possibility of misaligned phasing: To receive barracks shipments, the site must have some level of preparation, including a barge landing and access roads, site pads, and foundations. This will require:

- Access to material (most importantly, gravel) for construction of roads and site pads;
- Availability of labor and technical capacity to construct foundations;
- Timely construction of access roads, which could pose a coordination challenge if another government agency is responsible for this element.

Even in the case that the barracks are retrofitted as pioneer homes with self-sufficient water and heating/electric generation, some basic community infrastructure for water pumping, waste management, and washing will need to be in place before barracks are liveable even at a basic foothold standard.

Construction delays/site issues: Technical delays due to transportation and construction issues are largely unpredictable. While the West Tin Creek Hills site was evaluated for soil suitability by

AECOM during the site feasibility study, the possibility of issues due to the high soil ice content remains. Additionally, shipping delays due to weather and barge availability

Skilled labor: Assembly of the barracks and retrofitting will require a sufficient quantity of skilled labor on-site over time, as well as management oversight. While training community members in retrofitting could be an opportunity to develop local skills, this will also depend on the local demand for this type of work. Additionally, phasing must be planned as training must take place before barracks delivery. Labor costs will increase substantially (estimated at 2X) if outside construction workers must be contracted in place of local labor.

1.2 | LEGAL ANALYSIS

The land has already been conveyed to Shishmaref, so they will likely not encounter many legal hurdles.

In 1971 Congress passed the Alaska Native Claims Settlement Act (ANCSA), 43 U.S.C. §§ 1601-1628. Among other things, ANCSA was used to extinguish the title of Alaska Natives to millions of acres of land. Under ANCSA, Alaska Natives retained about forty-four million acres, but this land is generally held in fee simple by state-chartered private business corporations whose shareholders are Alaska Natives.

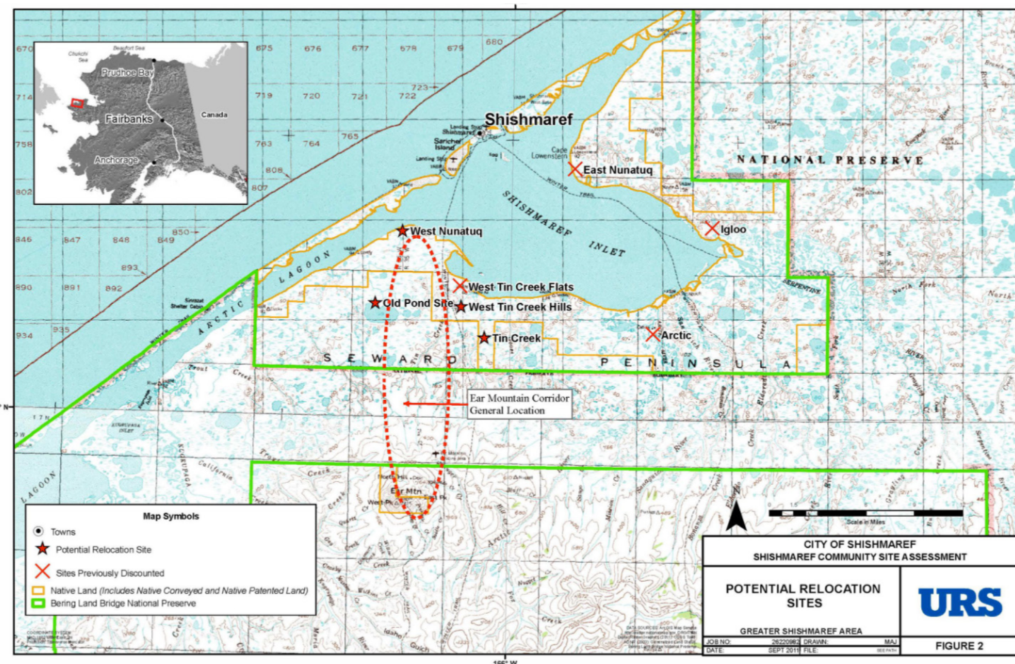
The Shishmaref community has already considered the question of land ownership, as seen in the feasibility study conducted by the Alaska Department of Commerce:

Land ownership and management significantly influences land availability for community relocation, access and easements that might be required. Formal land ownership in the Shishmaref region has been affected by Alaska Native Allotment Act of 1906, Statehood, the Alaska Native Claims Settlement Act of 1971 (ANCSA), and the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). Prior to Statehood, the federal government owned all the land in the Territory of Alaska. The majority of that land at the time was under management of the Bureau of Land Management (BLM). Statehood provided an entitlement for transfer of federal land to state government. However, selection and transfer of lands to the State were affected by the subsequent passage of ANCSA and ANILCA.

ANCSA established regional and village Alaska Native corporations, and allowed those corporations to select land from the federal government. The Bering Strait Regional Corporation and the Shishmaref Native Corporation were established, allowing them to select subsurface and surface lands from the federal government. Native corporation lands generally include the barrier islands in the vicinity of Shishmaref, and coastal lands around Shishmaref Inlet. In addition, Section 14 (c)(3) of ANCSA allows the transfer of lands from village corporation to municipalities for community related needs.

Around that time, Alaska Natives were given the choice to become a shareholder in a Native corporation or complete applications for Native Allotments. Native allotments are considered trust lands under the direction of Bureau of Indian Affairs. Native Allotments within the city limits of Shishmaref and in the vicinity are primarily located on barrier islands, along the shoreline of Arctic Lagoon, and Shishmaref Inlet, and along rivers and creeks that feed into the Inlet[67].

As seen on this map of the region[68], the relocation site of West Tin Creek Hills is within the native lands that have been conveyed to the Shishmaref Native Corporation and therefore can be relocated to without having to create agency access permits.



The other legal aspect of this package is adequate contracting to acquire the barracks. Although the barracks are free, the Shishmaref Native Corporation would nonetheless have to enter into a contract with the military base in order to agree on the terms of the donation. This contract may cover number of barracks donated and agreements on how to transport them - but may also consider having provisions for the quality of the barracks, any exclusivity of use of the barracks, as well as discussion over what happens if the barracks are damaged during transport.

Of course, these sorts of contract considerations would also apply to the transportation company as well as those retrofitting or installing the barracks. Beyond that there are few legal restraints on this package.

---

[67]AECOM Technical Services, Alaska (2016). City of Shishmaref, Alaska Sarichef Island. Relocation Site Selection Feasibility Study February 2016. [online] Anchorage, Alaska, pp.3-5. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Site_Selection_Feasibility_Study_FINAL_022316.pdf

[68] AECOM Technical Services, Alaska (2016). City of Shishmaref, Alaska Sarichef Island. Relocation Site Selection Feasibility Study February 2016. [online] Anchorage, Alaska, pp.3-5. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Site_Selection_Feasibility_Study_FINAL_022316.pdf

1.3 | DESIGN CONSTRAINTS

The NCRS survey for potential relocation sites has identified West Tin Creek Hill as the most feasible relocation site for the Shishmaref community. West Tin Creek Hill is located approximately two miles from Tin Creek. It can be accessed via the creek, or through the development of an access road to the Shishmaref Inlet. The proposed site has 12-16 inches of gray silt soil down to permafrost; surrounding hills are ice-rich which will increase development costs. However, according to the AECOM Shishmaref Relocation Feasibility Study (SRFS), there is better soil and depth for infrastructure and development potential due to the deep thawed layers at West Tin Creek Hill.

According to the SRFS, West Tin Creek Hill, has soil and land which is acceptable for development and relocation for an 800-person community. Additionally, the site is not subject to flooding hazards or to erosion, though there is concern for streambank erosion due to forecasted boat traffic. Secondly, because West Tin Creek Hill is closer in proximity to Ear Mountain (a rock and gravel source), foundations for homes and other building materials may be more accessible than the current site of the village of Shishmaref. In sum, West Tin Creek Hills is 160 acres of developable contiguous land with a complementary combination of shape and elevation.

There are an estimated 153 occupied homes within the existing community: these would have to be addressed and replicated. In terms of quantity, the JBER barracks option does not satisfy the needs of the community. An approach for full relocation would have to include a mixture of home types.

Because the barracks model has been adopted by the community of Newtok, there are not outstanding or comparable disadvantages for Shishmaref to also assume this model. Pending feasibility of other measures, the implementation study would address a community design and mlayout of the amount of space the barracks require and how housing could be arranged to create a community. Furthermore, there are no design constraints in regards to weatherization because of the success of the Newtok model.

The only design constraint is in access to and transportation of barracks to the proposed site of West Tin Creek Hill: the access road leading from the Shishmaref inlet would have to be constructed and completed prior to any preliminary engineering, foundation building, or relocation of barracks.

1.4 | PUBLIC HEALTH IMPACTS

Baseline Health

Currently, the housing in Shishmaref is inadequate for community needs. Given the harsh conditions and difficulty of transporting building material to Shishmaref, there isn’t enough housing and multigenerational extended families end up occupying the same home. This has led to significant overcrowding, which the Alaska Housing Assessment defines as less than 300 square feet per person in a home. According to an annual BSRHA survey, Shishmaref needs

100 new homes in order to comfortably accommodate its residents.[69] Several studies have linked overcrowding within homes to increased rates of anxiety and depression,[70] poorer school performance among children,[71] increased sleep disruption, and greater stress and tension among occupants.[72] Overcrowding also has also resulted in less space for storing subsistence food and emergency supplies.[73] Additional homes are also desired by the community, as evidence in their relocation assessment where nearly all households identified that they would like to split up into two or more homes.[74]

Another challenge is that most homes in Shishmaref have structural problems. Due to poor ventilation and air circulation, many homes experience problems with mold and mildew. Most homes also have issues with electrical wiring, water and sewer, and flooring. Unfortunately, opportunities for weatherization are limited as some residents have incomes that are too high for weatherization grants, but still do not have enough money to afford it on their own.[75] Buildings are also often exposed to high humidity and condensation, which can also lead to deterioration of the structure. This is especially challenging in homes that do not have washing facilities and hang wet clothes inside to dry, which can create a breeding ground for mold.[76] According to the CDC, indoor mold exposure is associated with upper respiratory tract symptoms, cough, and wheeze in otherwise healthy individuals and exacerbation of asthma symptoms in those with the condition.[77] The final cause for concern is the lack of adequate sanitation. Shishmaref is an unserved area, meaning that less than 55% of the community has piped water (in fact, only the school, clinic, washeteria, and teacher housing has piped water).[78] Typically, 15 gallons of water per person per day is required to remain clean and healthy, but given that residents must haul their water from the washeteria, most people use an average of 2

---

[69] *Shishmaref Local Economic Development Plan 2013-2018*(Rep.). (2012). Nome, AK: Kawerak.
[70] *Regoeczi, W. C. (2008). Crowding in Context: An Examination of the Differential Responses of Men and Women to High-Density Living Environments. Journal of Health and Social Behavior,49(3), 254-268. doi:10.1177/002214650804900302*
[71] Solari, C. D., & Mare, R. D. (2012). Housing crowding effects on children's wellbeing. *Social Science Research,41*(2), 464-476. doi:10.1016/j.ssresearch.2011.09.012
[72] *Full house? How overcrowded housing affects families*(Rep.). (2005). Retrieved http://england.shelter.org.uk/__data/assets/pdf_file/0004/39532/Full_house_overcrowding_effects.pdf
[73] *Shishmaref Strategic Management Plan*(Rep.). (2016, September). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/1_Shishmaref_SMP_September_2016.pdf
[74] *Shishmaref Local Economic Development Plan 2013-2018*(Rep.). (2012). Nome, AK: Kawerak.
[75] *Shishmaref Local Economic Development Plan 2013-2018*(Rep.). (2012). Nome, AK: Kawerak.
[76] *Shishmaref Strategic Management Plan*(Rep.). (2016, September). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/1_Shishmaref_SMP_September_2016.pdf
[77] *Facts about mold and dampness. (2017, September 5). Retrieved from https://www.cdc.gov/mold/dampness_facts.htm*
[78] *Shishmaref Local Economic Development Plan 2013-2018*(Rep.). (2012). Nome, AK: Kawerak.

gallons per person a day.[79] This has led to a host of problems, such as the spread of skin and respiratory conditions, particularly among children.[80]

Poor infrastructure coupled with an increased frequency of extreme weather events has also led to an elevated risk of accidents and injury. Four homes in Shishmaref have already collapsed due to flooding and erosion, injuring residents and putting them at significant risk of mortality.[81] A 2016 community-based surveillance study of Alaska found that unintentional injury was more likely to occur during months when participants reported unseasonable environmental conditions.[82] Therefore, as extreme weather events occur with greater frequency, it can be expected that there will be continued damage to homes and resulting injuries in Shishmaref.

Conceptual Model and Public Health Impacts

Assuming that the barracks are 1) adequate for long-term habitation, 2) retrofitted to meet community needs, and 3) able to supplement current housing shortage in Shishmaref, we can

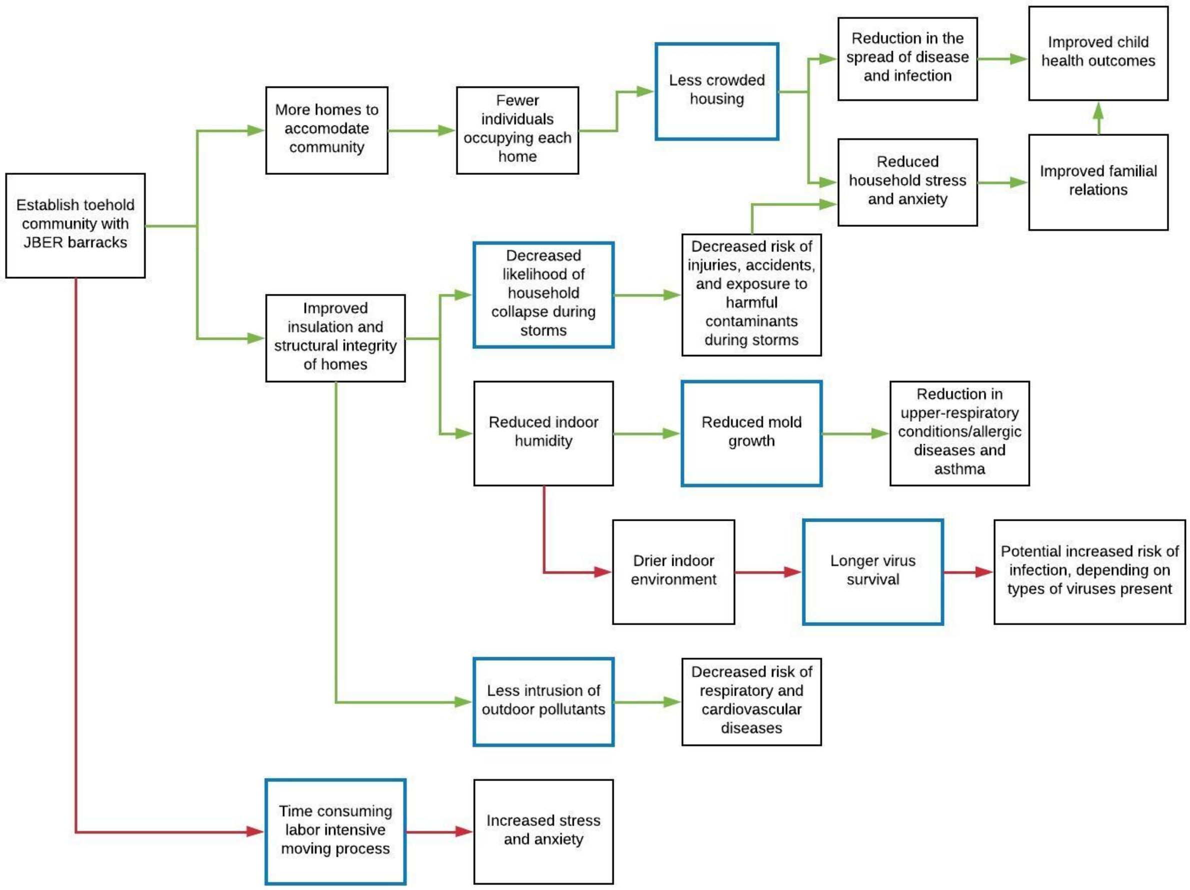
[79] *Shishmaref Strategic Management Plan*(Rep.). (2016, September). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/1_Shishmaref_SMP_September_2016.pdf

[80]Hennessy, T. W., Ritter, T., Holman, R. C., Bruden, D. L., Yorita, K. L., Bulkow, L., . . . Smith, J. (2008). The Relationship Between In-Home Water Service and the Risk of Respiratory Tract, Skin, and Gastrointestinal Tract Infections Among Rural Alaska Natives. *American Journal of Public Health,98*(11), 2072-2078. doi:10.2105/ajph.2007.115618

[81] United States Army Corps of Engineers, Alaska District (2004). Shishmaref Partnership: Shishmaref Relocation and Collocation Study. Preliminary Costs of Alternatives. [online] Seattle, WA: Tetra Tech, Inc. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/USACE_relocation%20plan_shishmaref.pdf

[82]Yoder, S. (2018, January 8). *Assessment of the Potential Health Impacts of Climate Change in Alaska*(Rep.). Retrieved http://www.epi.alaska.gov/bulletins/docs/rr2018_01.pdf

expect the following impacts of this project.



Key: Green = Intended Benefit; Red = Unintended Consequence; Blue = Project Impact

Project Impact	Anticipated Health Effect	Opportunities to Maximize Public Health Benefits
Less crowded housing	- With fewer occupants within close proximity of one another, the spread of respiratory and skin infections currently present in many households will likely decrease. - If households no longer accommodate an undesirable number of family members, there will likely be a decrease in household stress and anxiety and improved familial relations - There is a significant body of research indicating that household crowding can lead to poor health and wellbeing outcomes for children later in life. With less crowding, you can expect improved school	In our conversation with Annie, a community representative from Shishmaref, we learned that the community would like to move as many of their own homes as possible. Therefore planning the moving process hand-in-hand with each family and supplementing with the JBER barracks for the homes that cannot withstand the move would likely ensure that the community is happiest with utilizing the barracks. In addition, while a piped water system may not be immediately possible in the toehold community, any interventions to increase water access and reduce contact with sanitary waste would address the cause for many of the skin and respiratory infections that children in particular are affected by.

	performance among children, fewer behavioral issues, and improved mental health outcomes.[83]	
Decreased likelihood of household collapse during storms	If the community is no longer located in an area that is highly vulnerable during storms and are in more structurally sound homes, then the risk of household collapse and the resulting injury and exposure to contaminants will likely decrease. Therefore, the stress and anxiety associated with extreme weather events will likely decrease. This may also have positive downstream effects on familial and child health.	As mentioned above, working with the community to identify homes that are not structurally sound to move will ensure that all of the homes in the new community are safe for inhabitants. In addition, while the West Tin Creek Hills site is not currently an area of concern in regards to sea level rise and flooding, the harsh weather conditions should be heavily considered when retrofitting the barracks to maximize their longevity.
Reduced mold growth	With improved household ventilation, indoor conditions will not have the opportunity to become as humid, which will decrease the likelihood of mold growth. This will likely reduce the onset or exacerbation of lower-respiratory infections which is particularly important for vulnerable populations like children, elderly, and those with asthma.	Given that much of the indoor humidity stems from people hanging wet clothes to dry, opportunities to minimize impact should be explored. This may include encouraging families to dry clothes away from living/bedroom areas or even creating a space outside the home for families to dry their clothes (perhaps an addition to the washateria).
Less intrusion of outdoor pollutants	With improved infrastructure and better insulation, there will likely be a decrease in intrusion of pollutants like NOx, SOx, and particulate matter from diesel emissions. All of these pollutants are strongly associated with negative respiratory and cardiovascular health effects, therefore protecting families from such emissions will likely decrease the risk of associated diseases.	Exploring renewable energy opportunities, as discussed in Package 1, could completely displace the use of diesel and its resulting emissions and provide the most significant positive health impacts.
Longer virus survival	Research has demonstrated that indoor environments that are too dry may provide a more habitable environment for certain viruses. The infectivity of influenza virus, for example, decays at around 40% humidity or above.[84] While this is not a major concern, a potential	Improving household access to water and therefore improving sanitation practices may decrease likelihood of infection from such viruses.

[83] Children's HealthWatch (2011). Overwcrowding and Frequent Moves Undermine Children's Health. Retrieved from https://www.issuelab.org/resources/13900/13900.pdf

[84] Byber, K., Flatz, A., Norbäck, D., Hitzke, C., Imo, D., Schwenkglenks, M., ... & Mutsch, M. (2016). Humidification of indoor air for preventing or reducing dryness symptoms or upper respiratory infections in educational settings and at the workplace. *The Cochrane Library*.

	unintended consequence of dryer indoor environments is creating a breeding ground for certain pathogens.	
Time consuming and labor intensive moving process	Given that the community is moving due to environmental concerns, the process of leaving the island that they have inhabited for generations may be a traumatic and stressful experience for community-members. The harsh conditions and remote location may also draw out the moving process, which can cause continuous stress and uncertainty for community members.	The increased stress associated with moving must be weighed against the counterfactual scenario, which is the continuation of extreme weather events that are destroying their homes. Without action, they may eventually be forcibly displaced, causing them to be separated or integrated into another community not of their choosing. Flood-related displacement is also associated with depression, anxiety, and PTSD within one year after the event,[85] therefore a proactive move on the community's terms will likely reduce the likelihood of more significant trauma down the road. And finally, as mentioned many times, it is critical that the community be directly involved in the moving process. Ensuring that their voices are heard and needs are met is the best way to ensure a successful move.

Further Considerations

Many of the public health benefits demonstrated in the conceptual model are contingent on the fact that the homes are deemed acceptable by the community and that they are retrofitted to withstand the harsh conditions in West Tin Creek Hills. Therefore in order to maximize public health benefits, significant financial investment must be made in the housing infrastructure, otherwise they may end up occupying homes that are only marginally better than current conditions.

1.5 | COSTS

Two feasibility studies were conducted within the past year on using JBER barracks for the Newtok - Mertarvik community. These cost estimates are used as base costs. Building on these, cost estimates for major project phases are included below.

<u>Labor Costs</u>

Utilizing labor sources besides contractors -- in this case, military assistance or Tribe labor -- could lead to both cost savings and co-benefits in terms of training value. Feasibility studies estimate a per-unit cost savings of $34,880/unit for military assistance, which has been a strategy used in previous Alaska projects to provide both community assistance and training value.

[85] Tong, S. (2017). Flooding-related displacement and mental health. *The Lancet Planetary Health*, *1*(4), e124-e125.

Savings per unit for Tribe labor were estimated at $22,550/unit in Mertarvik due to the lower wage rate of $41/hour relative to skilled construction labor. Whether this savings would be balanced out by a relative loss of efficiency in building as workers learn new skills should be considered -- management overhead cost will of course increase with time. On the other hand, the higher multiplier effect of local labor is an important factor, as local wages are more likely to be re-invested in the community's economy and stimulate further local opportunity. This would also of course depend on local demand for construction jobs.

Depending on the relative training value of disassembly/demolition at JBER site, labor assistance could be split more efficiently by using military assistance at JBER and Tribe labor at the new village site.

Preparation (on-site at JBER)

The cost of interior demolition at JBER is estimated at approximately $5000 for each unit at a labor rate of $75/hr (BR Phase 2). The total cost of preparation and transport (including the demolition cost) is estimated at $19,700/unit. It could be more efficient to utilize military assistance in this phase if possible.

Transportation

Transportation cost per module (per BR Phase 2 estimate) : $28,814 + $11,342 (storage). This is accounting for the transport barge moving 28-30 modules at a time using stacking, as specified in BR Phase 2 for Mertarvik.

Site Preparation

Note: Given the specific needs for weatherization in Climate Zone 8, alternative costs under this section to be filled in as necessary per consultations with Alaska-based providers.

Item	**Alternative**	**Base cost (*Barracks Relocation Phase 2, Sept. 2017)***
Building pads		$30,000 per pad (Denali commission estimates)
Post and pad foundations	Foam foundation	$20,000 per unit
Access Roads		Fill in
Gravel purchase *(if excavation at Ear Mountain is unsuccessful within the delivery timeline)*		Fill in: *From riprap purchase estimate*

Phase: Retrofitting

Item	**Alternative**	**Base cost (2017 Mertarvik Barracks report)***

Replace bedroom windows with egress compliant type.	Passive house energy-conserving windows	*(Included in total)*
Replace stairs for egress compliance.	n/a	
Install underfloor soffit in lieu of insulated crawl space skirting.	n/a	
Remove and replace gas fired heating system and water heaters with diesel based systems.**		
Removal of sprinkler, fire alarm and emergency lighting systems (required for dorms, not residential houses).	n/a	
Removal or modification of plumbing systems and installation of appropriate system for the new village.		
Convert electrical systems from 3-phase to 1-phase power to suit the proposed community electrical system		
New roof installation (on-site)		
	Total	$337,410/unit***
Thermal envelope upgrades		+ $34,600/unit = **$372,010/unit**

**Not including thermal upgrades to exterior walls; including thermal upgrades to windows and doors, roof insulation, and underfloor insulation.*
*** "The existing heating systems, natural gas fired furnaces with ductwork, will be removed in the demolition work. New heating systems will be installed in each unit, consisting of diesel fired Toyo-stove direct fired units with a small fuel tank located on the exterior." (BR Phase 2)*
**** Including arctic entry installation and new roofing.*

Other costs
This section does not include infrastructure costs, such as grid connection or water supply and sanitation systems, which we assume would be comparable for barracks retrofit and new construction.

Overhead and management costs will of course increase with a longer project timeline.

1.6 | POTENTIAL FUNDING SOURCES

The following funding sources, most of which are more traditional grant or loan products, have been identified that could potentially meet the needs of Package 1. Depending on validated cost structures, timelines, and legal restrictions, these funds would need to be carefully reviewed and aligned to specific segments of the final implementation plan.

Grant Program Name & Purpose	Eligibility Requirements	Project Element	Amount
Bureau of Indian Affairs Division of Capital Investment (Loans available for operating capital, equipment purchases, building construction and lines of credit)	• Federally recognized Alaska Native groups • Individually enrolled members of such groups	Community worker skill-building (if incorporated)	$500k for individuals, more for tribes
Multi-Family Housing Loan Guarantees (Works with qualified private-sector lenders to provide financing to qualified borrowers to increase supply of affordable rental housing)	• Lenders automatically approved if active in HUD, Fannie Mae, Freddie Mac, Ginnie Mae, Federal Home Loan Bank members, and state or local housing finance agencies	Housing (construction and improvement of multi-family rental housing, buying and improving land, providing necessary infrastructure)	n/a
AHFC Nonconforming Program (Provides alternative avenue for funding for projects who do not qualify for traditional lending options)	• Unconventional utilities, lack of central heating, unconventional foundation system • Home must be structurally sound	Housing	n/a
Mutual Self-Help Housing Technical Assistance Grants (Recipient community members provide labor while grant funds outside technical assistance)	• Government non-profit organizations • Federally recognized tribes • Private non-profit organizations	Housing construction technical and supervisory assistance, recruit more families and assist with loan applications	n/a
AHFC Weatherization Assistance for Low Income Persons (Provides funding for low income persons to increase energy efficiency of dwellings owned or occupied by those individuals, reduce total residential expenditures, and improve health and safety)	• Dwelling units and residential buildings which are to be destroyed, abandoned, or converted to another purpose within 12 months are ***not*** eligible for funding	Housing features, water heaters, energy conservation efforts	n/a (meeting with AHFC indicated that funds are dwindling)
Housing Preservation Grants (Provides grants for the repair or rehabilitation of housing occupied	• Federally recognized tribes • Proven experience to perform repair	Housing rehabilitation	n/a

by low and very low income people)	• Population <20,000		
Alaska Housing Finance Corporation Renovation Loans (Purchase renovation, improvements on a home already owned, refinancing home renovations into new loan)	• Alaska residents	Housing renovations	95% of appraised value
Rural Housing Site Loans (Provides two types of loans to purchase and develop housing sites for low- and moderate-income families)	• Federally-recognized tribes	Housing site development	n/a
AHFC Manufactured Home Program (Provides funding specifically for manufactured homes for low-income individuals)	• Barracks would need to be designated as manufactured homes	Housing	$100k-$175k
Multi-Family Housing Direct Loans (Funds may be used for construction, improvement, and purchase of multi-family rental housing for low-income families)	• Renting structure overseen by other entities (individuals, trusts, associations, non-profits, for-profits, state and local governments, and tribes)	Housing	n/a
Single Family Housing Direct Home Loans (Provides low- and very-low-income applicants obtain housing by providing payment assistance to increase applicant's repayment ability)	• <35,000 population • Applicants must be without decent, safe, and sanitary housing • Applicants must be able to obtain a home loan from other resources	Housing	n/a
Single Family Housing Guaranteed Loan Program (Funds may be used for repairs and rehabilitation when associated with the purchase of an existing dwelling, site preparation costs, and relocation)	• Income levels • Applicants must be able to incur loan obligation	Housing	n/a
Single Family Housing Repair Loans & Grants (Provides loans to very-low-income homeowners to repair, improve, or modernize their homes)	• <35,000 population • Income eligibility	Housing	Max is $20,000
Alaska Municipal Bond Bank Authority (Public corporation established to aid authorized Alaskan borrowers in	• Cities, boroughs, municipalities • Authorized to make loans to Joint Action Agencies and	Schools, water and sewer systems, public buildings,	~$150m

financing capital improvement projects)	Regional Health Organizations	harbors, docks	
Grants for Rural and Native Alaskan Villages (Helps remote Alaskan villages provide safe, reliable drinking water and waste disposal systems for households and businesses)	• <10,000 population • Median household income less than 110 percent of statewide household income • 25% matching funds • Applications accepted year round	Water and waste disposal systems	n/a
Grants for Rural and Native Alaskan Villages (Helps remote Alaskan villages provide safe, reliable drinking water and waste disposal systems for households and businesses)	• Rural hub of population 10,000 or less • Median household income less than 110 percent • Grant used for waterborne communicable disease • Individual residents are hauling water to or human waste from their homes	Water and waste disposal	n/a but can pay up to 75 percent of project costs (with 25 percent matching local contributions)
Water & Waste Disposal Grants to Alleviate Health Risks on Tribal Lands and Colonias (Provides low-income communities access to safe, reliable drinking water and waste disposal facilities and services)	• Federally recognized tribes	Water and waste disposal	Potential to fund 100 percent of project needs, if funds are available
Water & Waste Disposal Loan & Grant Program (Provides funding for clean and reliable drinking water systems, sanitary sewage disposal, sanitary solid waste disposal, and storm water drainage)	• Federally-recognized tribes • Population <10,000	Water and waste disposal	n/a
Water & Waste Disposal Loan Guarantees (Helps private lenders provide affordable financing to qualified borrowers to improve access to clean, reliable water and waste disposal systems for households and businesses in rural areas)	• Federally-recognized tribes • Population <10,000	Water and waste disposal	n/a
Water & Waste Disposal Predevelopment Planning Grants (Assists low-income communities with initial planning and development of applications for	• Federally-recognized tribes • Population <10,000	Water and waste disposal	Max of $30k or 75 percent of pre-developme

USDA Rural Development Water and Waste Disposal direct loan/grant and loan guarantee programs)			nt planning costs
Emergency Community Water Assistance Grants (Helps eligible communities prepare, or recover from, an emergency that threatens the availability of safe, reliable drinking water)	● Flood ● Disease outbreak ● Other natural disasters ● *No disaster declaration required	Water	Up to $500k for water source, intake, or treatment facility

1.7 | GHG CONSIDERATIONS AND ADDITIONALITY

Assessment Boundary

In all evaluation scenarios, it is assumed that the community of Shishmaref will relocate and utilize an energy infrastructure similar to that in the original community, with diesel as the primary fuel for electricity and heating. Evaluation of GHG reductions would focus on the results from deploying JBER barracks as housing, compared to the construction and operation of other form of housing on the relocated site — but would not assume any changes to the infrastructure that supplies energy (i.e. no increased penetration of renewables).

GHG sources would be ongoing combustion emissions associated with burning diesel to generate electricity and heat, as well as other emissions associated with the process of construction (including retrofitting of housing units, transport of materials and assembly on site). Housing energy efficiency measures, such as better insulation, included in this package reduce the amount of diesel necessary to be used as fuel; modular systems or retrofitting processes could reduce emissions associated with construction.

Baseline Case

Specifying the baseline case is complicated by the possible set of scenarios for housing in a relocated village. Shishmaref could choose to move their existing housing stock, as has been done previously. Homes moved from the original site would possess varying degrees of weatherization — houses in good enough condition to be transported would be newer and generally higher performing, although even some older houses have undergone weatherization processes (retrofits and operational changes).

If Shishmaref were to construct new homes, baseline case operational performance would depend on the type of home type chosen. There is a range of anticipated performance and GHG emission reductions associated with various types: the CCHRC's prototypes are more advanced and high-performing[86]; houses built on a template by the Bering Strait Regional Housing Authority might be less high-performing.

[86] Cold Climate Housing Research Center (2017, February 10). Mertarvik Housing Master Plan.

GHG emissions from construction processes are similarly varied. Modular prototypes, like those designed by CCHRC[87] might reduce emissions and time on site but would produce emissions from factory-based manufacturing; more traditional house types would have little factory time but significant time on site. The physical moving of houses from Shishmaref to its relocated site would feature less construction, but might create emissions from vehicle traffic.

In most baseline case scenarios, a plausible GHG emission estimate associated with operation could be calculated by adapting existing utility data as well as through analysis of similar projects elsewhere in Alaska. It is likely that the amount of GHGs produced from occupancy in most housing scenarios could be reasonably modeled from past history; the CCHRC's housing prototype could be evaluated based on actual results and predictive models. GHG emissions related to construction would be more difficult to assess, and would depend on a variety of assumption related to logistics, materials and labor practices.

Additionality

Additionality in this context hinges on both energy efficiency improvements to the JBER barracks over whatever is used in the baseline scenario, as well as changes to related construction process. GHGs offsets would be derived from how the design of the barracks reduce ongoing energy use (primarily for heating), as well as the fact that shipping pre-built units to site would lead to a one-time reduction in the intensity of activities (both on- and off-site) required for construction. GHG reductions caused by the usage of barracks for housing would therefore include both primary and secondary effects.

The GHG reductions associated with project activities could be calculated through performance simulations, based on proposed design details for the retrofit envelope. Actual reductions could be measured by monitoring energy usage (as would likely be done in any case by the electric utility). GHG emissions (and reductions) related to construction activities would, however, be more difficult to assess.

[87] Cold Climate Housing Research Center (2017, February 10). Mertarvik Housing Master Plan.

Package 3: Opportunities for Private Investment to Create Capital for Sustained Community Investment Efforts

This package explores alternative financing sources, including private-sector options, that the community could access prior to relocation. Constraints and opportunities posed by each are evaluated, focusing in particular on innovative sources and structures that have been under-evaluated by previous studies focusing on government funding.

For multiple reasons, this option is not considered independently feasible: the project would be too small in size to generate a substantial return for investors; at this time, there are not many identifiable potential partners willing to invest in a small scale project; aggregating communities in Alaska leads to hurdles of structuring an investment that would deliver consistent returns from all communities. Due to the uncertainties of the proposed project, there is difficulty in pitching a source of return to investors. Similarly, since we are unsure of what projects the relocated village could realistically undertake, we cannot make guarantees of any energy reductions to our investors.

Criteria	**Description**
Legal	*Village's 501(c)(3) status enables a number of investment methods or grants*
Design	*Few immediate design constraints given package scope*
Public Health	*Few specific public health impacts given package scope*
Cost	*Package would need to negotiate high administrative costs and village credit rating*
Funding	*Few private investors exist with interest and suitability*
GHG	*Specific GHG reductions and offsets difficult to determine given project scope*

2.1 | PACKAGE DESCRIPTION

For the Alaska Native Village of Shishmaref, and many other Alaska Native Villages threatened by flooding and erosion due to climate change, securing the necessary capital to fund relocation efforts has proven to be difficult and complex. Due to shifts in the political landscape, existing legal and policy restrictions, and general bureaucratic complications, it has been consistently challenging to identify, apply for, and secure the federal or state funds, most of which are grants, necessary for relocation efforts to move forward at a pace that supports the needs of the communities. While the Denali Commission has taken on coordinating village relocation activities in Alaska, the absence of a formal federal or state entity responsible for overseeing relocation efforts with appropriate levels of designated funding means that the process is inherently disjointed and decentralized. This makes coordinating the acquisition and disbursement of funds in alignment with an evolving set of priorities and projects extremely difficult. Until a formal oversight body with adequate funding is established, relocation planning and plan implementation will continue to be extremely challenging.

Despite a lack of formal channels, villages have employed creative strategies in attempts to access significant pots of federal money. In 2017, the village of Newtok attempted to access funding available under through the Robert T. Stafford Disaster Relief and Emergency Assistance Act by requesting then-President Barack Obama to declare the erosion and thawing permafrost in Newtok as a federal disaster.[88] However, the request was denied on the grounds that the nation's disaster laws do not apply to slow-moving impacts resulting from climate change.[89] Until there is reason to believe that federal actors are willing to interpret the Stafford Act in a way that includes coverage for slow-moving disasters, it is unlikely that communities like Newtok and Shishmaref will be able to gain traction in their efforts to access large sums of federal money.

In addition to challenges related to accessing federal funding, relocation efforts face an inherent catch-22. While it would be ideal for village relocations to happen as soon as possible, projects of this level of complexity, scope, and scale inherently require timelines of five to 10 years, if not longer. During this extended time frame, the current village infrastructure does not cease to require investment to withstand normal- and climate change-related wear and tear. However, many funders - government and otherwise - are unwilling to invest in future village locations unless there is proof of movement, and oftentime movement isn't feasible until initial investments can be made in the existing community. This complicated tension makes securing funding for investments to improve existing infrastructure or projects supporting relocation unnecessarily challenging, and inhibits progress that only further delays efforts to address the impacts climate change is having on the livelihoods of these villages.

Outside of grant funding, Shishmaref faces significant challenge in utilizing traditional methods for accessing capital from private entities, such as traditional loans or mortgages, because of

[88] Robert T. Stafford Disaster Relied and Emergency Assistance Act., Pub. L. No. 93-288 (2016).
[89] Waldholz, R. (2017, January 18). Obama denies Newtok's request for disaster declaration. *Alaska Public Media*. Retrieved from https://www.alaskapublic.org/2017/01/18/obama-denies-newtoks-request-for-disaster-declaration/

the financial status of the majority of community members. As a village of 573 people, the poverty rate is 42.8%, the median household income is just over $29k, and the median property value is just below $87k.[90] According to a resources developed in January of 2017 by the United States Department of Agriculture entitled the *Alaska Rural Homeownership Resource Guide*, “mortgage financing is not often done in Alaska villages due to the lack of cash in the local economy, the high cost of construction, and the lack of familiarity with debt.”[91] Additional upfront costs related to mortgage initiation and management can also be prohibitive. While a range of subsidized and guaranteed loan and mortgage programs exist to serve rural Alaskan villages, these capital mechanisms also fall victim to the catch 22 related to relocation.

For these reasons and others, we determined that it would be valuable to explore the feasibility of securing private investment capital that could be used to support immediate or long-term needs related to either investment in current infrastructure or projects at the new location given that both play an important role in facilitating Shishmaref’s long-term viability as a community. In the case of Newtok’s relocation to Mertarvik, only 0.1 percent of approximately $30 million in funding they had received (as of 2011) has come from non-governmental sources.[92] Conversations with individuals working closely on the Newtok relocation plan indicated that further exploration into potential private funding sources and mechanisms could be valuable in assisting Shishmaref, along with other villages facing the task of relocation, in expediting the process and overcoming significant barriers related to the approach taken to securing funding thus far.

The community of Shishmaref can explore a few different options in structuring and unlocking private funding sources. For example, investors around the country conduct social impact investing into companies, organizations, funds, and projects that generate social and economic impact along with a financial return. This market has been growing over the last few years and there is opportunity to create a relocation plan that considers renewable energy, sustainable agriculture, and other conservation mechanisms that would create a social and environmental impact while at the same time providing a financial return to the investors which would make the projects viable investments.

If we envision the investor to be a private equity firm, a mutual fund, or any other corporate status entity, an attractive return on the investments can be structured in the form of tax credits - the U.S. tax code provides for a Business Energy Investment Tax Credits (26 USC § 48), Renewable Energy Production Tax Credits (26 USC §45), or Residential Renewable Energy Tax Credits which can lead to up 30% of credit for investing entities.[93]

---

[90] Data USA. (2018). Shishmaref, AK. [online] Available at: https://datausa.io/profile/geo/shishmaref-ak/ [Accessed 6 May 2018].
[91] United States Department of Agriculture (2017, January). Alaska Rural Homeownership Guide. [online] Available at: https://www.rd.usda.gov/files/Alaska%20Rural%20Homeownership%20Guide%2001_11_17_v2.pdf
[92] *Relocation Report: Newtok to Mertarvik* (Rep.). (2011, August). Retrieved https://www.commerce.alaska.gov/web/Portals/4/pub/Mertarvik_Relocation_Report_final.pdf
[93] 26 U.S. Code § 48 - Energy credit.

Finally, the investments can be structured in more conventional manners that link the financial return to a revenue source for the investors. The potential revenue sources could be tied to securitization of payments for materials to build the new community. This is an especially attractive opportunity for mutual funds, whose investing profiles tend to lean towards risk-averse, stable, at-market returns. Nonetheless, structuring financing in this manner could add more strain to the residents of the community as they will be responsible for ultimately financing their own relocation - either personally by buying and paying interest on eco-friendly materials for their houses or collectively through the Shishmaref corporation's community fund, the money for which is generated via taxes.

There are certain pools of investors that could be interested in taking on and investing in projects such as these. For example, banks, mutual funds, and wealth managers can serve as a conduit to provide their individual clients with opportunities to invest in projects that further their own social and environmental goals. Similarly, large institutional foundations and private equity funds can leverage their assets in order to meet their social impact goals as well. Given the parameters of this project and the limited revenue generating opportunities, the key task would be to identify specific institutions and entities that would invest for below-market rates of return, as most funds tend to pursue market-competitive or market-bearing returns due to fiduciary duty restrictions.

Moreover, private equity firms and mutual funds can work as partners with identified clients that are corporations with social impact mandates. It is possible to structure the transaction with unregulated entities providing a seed investment or other tangible products that could be of use to the relocated community, for which the funds could provide additional financing but not take on the primary risk of the investment that the unregulated entity would. The main advantage to this is that unregulated entities are not restricted by stringent fiduciary obligations.

Challenges Related to Risk as Perceived by Funders and Lenders

The investors would have to price in several risks in their return models for such a project. The most cited risk for funds is business management and execution[94] - the investors would need to rely on the Alaskan government and, more locally, the Shishmaref tribal government to execute and manage the relocation efficiently and in a manner that meets all their internal targets and deadline in order to maximize their investments. Similarly, there is significant liquidity and exit risk with this project as the invested money would be tied up in the relocation for the duration of the entire relocation process before the investors would start to receive a return once the new community is up and running. Most importantly, however, there is a financing risk in that the the new community may not be able to deliver on energy reduction (or other) targets at all which would leave the investors with none, or not enough, tax credits.

[94] What You Need to Know About Impact Investing (2018); Retrieved from https://thegiin.org/impact-investing/need-to-know/#what-is-impact-investing.

2.2 | LEGAL CONSTRAINTS

The Native Village of Shishmaref council is the legal remnant of the Native traditional government who are organized and recognized as a tribal government under the Indian Reorganization Act of 1934. The Native Village of Shishmaref is organized as a public non-profit recognized by the federal government[95]. As a result of its non-profit 501(c)(3) status, The Native Village of Shishmaref is not only an attractive investment opportunity for funds looking for a return, but it is also qualified to receive several grants that are only available to 501(c)(3) such as the Rasmussen Foundation Grants offered to 501(c)(3)s dedicated to organizations committed to improving the quality of life for Alaskans.

Moreover, because of its non-profit status, the Native Village can accept donations for its relocation that the donating entity can deduct from its taxable income as donations made to 501(c)(3)s are tax deductibles - this opens up funding sources from private foundations, businesses, and individuals!

Turning now to the tax credits, the Business Energy Investment Tax Credit provides the following chart of tax credits available for investors (as per 26 U.S.C. § 48):

Technology	2018	2019	2020	2021	2022	Future Years
PV, Solar Water Heating, Solar Space Heating/Cooling, Solar Process Heat	30%	30%	26%	22%	10%	10%
Hybrid Solar Lighting, Fuel Cells, Small Wind	N/A	N/A	N/A	N/A	N/A	N/A
Geothermal Heat Pumps, Microtubines, Combine Heat and Power Systems	N/A	N/A	N/A	N/A	N/A	N/A
Geothermal Electric	10%	10%	10%	10%	10%	10%
Large Wind	18%	12%	N/A	N/A	N/A	N/A

As seen above, there are very specific types of energy projects that investors could pursue in order to get a tax credit. The most substantial being the 30% credit for solar powered systems - meaning that investors would be able to deduct 30% of their investment in the technology as a tax credit against their taxable income.

Finally, the community residents have the opportunity to take out basic loans for their relocation, even though they may not normally qualify for them, thanks to the Community Reinvestment Act (1977) which is intended to encourage depository institutions to help meet the credit needs of the communities in which they operate, including low- and moderate-income neighborhoods, consistent with safe and sound banking operations.[96] 12 CFR parts 25, 228, 345, and 195.

---

[95] AECOM Technical Services, Alaska (2016). City of Shishmaref, Alaska Sarichef Island. Relocation Site Selection Feasibility Study February 2016. [online] Anchorage, Alaska, pp.3-5. Available at: https://www.commerce.alaska.gov/web/Portals/4/pub/Shishmaref_Site_Selection_Feasibility_Study_FINAL_022316.pdf [Accessed 6 May 2018].

[96] Community Reinvestment Act. (2017, September 1). Background & Purpose. Retrieved from https://www.ffiec.gov/cra/history.htm.

2.3 | DESIGN CONSTRAINTS

The implementation of this package requires creative design of delivery packages that involve community participation. An assessment of communities and villages statewide in Alaska could inform a model that could serve not just Shishmaref, but work statewide. A built-in agency or partner that facilitates the fund could solve barriers in communication and coordination, as well as delivery of funding.

There are not significant foreseeable design constraints for this package, aside from the limitations tied to certain funding sources, for example if a housing provider is willing to contribute funding, it may be contingent on specific materials used, or limit the community to certain models.

2.4 | PUBLIC HEALTH IMPACTS

Since the scope of this project does not focus on specific interventions but rather securing private investment for relocation, it is difficult to quantity the public health impacts outside of those related to moving. More specific benefits will depend on what types of funding are acquired and where the community deems it is most valuable to utilize the funding. As a result, the analysis for this package will focus on the broader community health benefits associated with moving.

Baseline Health

In addition to the baseline health parameters related to housing and energy infrastructure discussed in the previous two packages, the community is also grappling with the overall social and mental health effects associated with sea level rise and unanticipated flood events. Due to their remote and low-lying location, a single storm can threaten their lives because there is no evacuation route to get them to higher ground.[97] As a result, many community members have reported elevated stress and anxiety related to concerns around safety and security, as well as sense of loss due to changing sociocultural and environmental conditions.[98]

Public Health Impacts

Assuming that private investment is secured and depending on where funding in funneled, the following public health benefits may be achieved (expanding on public health benefits discussed in previous packages):

- **Reduced psychosocial stress** associated with the imminent threat of sea level rise and unexpected flood events; ability to invest in improved housing, energy, and other infrastructure that meets community needs.

---

[97] Toomey, D. (2016, June 23). Unable to Endure Rising Seas, Alaskan Villages Stuck in Limbo. *Yale Environment 360*. Retrieved from https://e360.yale.edu/features/sea_level_rise_alaska_native_newtok_shishmaref_kivalina

[98] Schwerdtle, P., Bowen, K., & McMichael, C. (2018). The health impacts of climate-related migration. *BMC medicine*, *16*(1), 1.

- **Fewer accidents and injuries** associated with household collapse during extreme weather events.[99]
- **Improved overall health outcomes** associated with reduced stress, improved housing infrastructure, transition away from dependence on diesel, and investment in social services like health care.
- **Greater household financial security** associated with investment in workforce development and long-term decline in energy prices from improved housing and transition to renewable energy.

2.5 | PROJECT COSTS

This section will evaluate costs involved with private-sector financing options, not final project costs associated with these. Cost of this alternative will vary depending on the financing structure selected. Major cost categories include:

Loan repayment

Loans or bonds, whether undertaken by individuals or issued by the community through a bond offering, will involve an ongoing, fixed cost to cover loan interest and amortize loan principal over time. Depending on the structure and amount, this may impose a strain on fixed- or low-income households. The degree of burden this places on payers will depend on whether it is a new payment flow on top of current payments (e.g. paying for a new water system where there is none currently), replaces another payment or payment stream (e.g. paying back materials over time rather than paying a housing mortgage), or is gradually amortized to provide long-term savings (e.g. paying back the capital costs of a wind farm rather than ongoing fuel tariffs).

Price of credit risk

Shishmaref, like many rural Alaskan communities, will likely have difficulty finding financing at affordable rates due to the community's high credit risk. Yields for other Alaska municipal bonds currently range from 1.43- 2.45%[100], although few small communities appear to have offered bonds. GIven the community's small tax base and relatively low median income, as well as limited alternative cash flows with which to back a bond offering, a traditional bond offering will likely be infeasible. Tactics to mitigate this cost are discussed at the end of this section.

Administrative costs

The administrative cost of initiating and managing of a complex financing structure could be high. Costs include underwriting, financing fees (depending on intermediaries), and fees and salaries of personnel responsible for the process. This cost will also vary depending on local capacity to manage this process, which is likely to be lower as the financing structure becomes more complex, requiring specialized skills. This "complexity cost" is a common feature of environmental finance projects, and can render even projects with above-market ROIs infeasible.

---

[99] McLaughlin, J., & Castrodale, L. (2018). Assessment of the Potential Health Impacts of Climate Change in Alaska.

[100] Alaska Municipal Bonds (2018). Retrieved from http://alaska.municipalbonds.com/bonds/recent/

If refinancing is required in the future, this cost will increase substantially. Ensuring compliance with government regulations will also add another dimension to administrative costs.

Cost of default

The risk involved in defaulting on a loan payment is, understandably, an important community concern. In particular, the possibility of repossession of critical assets could impose an additional cost of social/psychological stress in addition to any financial hit. The level and form of this cost will depend on the guarantor, loan type (recourse vs. nonrecourse), and negotiated contract. For instance, in some cases a municipal default on a loan held by the state can lead to a loss of state aid until the principal is recouped.

Other costs

Loss of existing funding sources: Depending on the financing structure, some projects that involve a substantial move towards relocation could involve risking eligibility for other funding, such as for infrastructure improvements at current site. SImilarly, installing new renewable energy capacity could mean sacrificing current Power Cost Equalization diesel subsidies that ensure consistent and low energy prices.

Opportunity cost: The cost of further delay, especially if this alternative requires a complex financial structure involving numerous stakeholders, could be a major factor given the precariousness of Shishmaref's location. This should be evaluated relative to possibly quicker alternatives, such as government-funded construction or barracks relocation.

There are several financing cost reduction strategies available to Shishmaref:

- *Loan guarantees* reduce the interest rate on a loan by reducing the credit risk to the borrower, and as such bringing down the rate of return the borrower will demand.

- *Enhancing repayment capacity* through other means. Especially in the case of non-traditional bonds, which are "paid back" through environmental or social improvements, improving Shishmaref's capacity to meet targets through training or technical assistance could improve the community's capacity for repayment (whether financial or not).

- *Concessional-rate bonds,* such as those purchased by the Alaska Municipal Bond Bank Authority, can provide financing at below-market rates. AMBBA's structure, whereby the public corporation "generates funding by selling bonds on the national market, and using the proceeds to purchase bonds from authorized borrowers within the State" is designed to allow communities like Shishmaref to borrow finance capital projects at better rates, paying principal and interest to AMBBA rather than to private bondholders.[101]

[101] Department of Revenue: Alaska Municipal Bond Bank Authority. (2012). Retrieved from http://treasury.dor.alaska.gov/ambba/

2.6 | POTENTIAL FUNDING SOURCES

Based on our analysis, we determined that only a very short list of private sector investors would even consider engaging in a project of this size, risk, and potential return. Nonetheless, the firms with the highest likelihood of meeting our project's criteria are listed below.

Project Partners	Eligibility Requirements	Project Element	Amount
Moss Adams Tax Credit Exchange (Provides a marketplace for selling new market tax credits to potential buyers)	• n/a	Funding mechanism	n/a
Alaska Growth Capital (Provide access to capital as a lender that can act quickly for actors who have a hard time obtaining, or are not yet ready for, traditional bank financing)	• Borrowers who are finding bank financing difficult • Growth companies with adequate cash flow but limited collateral • Underserved rural markets	Funding mechanism	$0.5-$10mil
Ecotrust (Uses New Markets Tax Credits to build long-term community and environmental wealth in underserved rural communities)	• n/a	Funding mechanism	n/a
Travois (Secures financing for affordable housing developments through Low Income Housing Tax Credits)	• Focuses exclusively on promoting housing and economic development for Alaska Native communities	Funding mechanism	n/a
ConocoPhillips (Largest energy producer in Alaska)	• Potential project partner for natural gas exports from the community	Funding mechanism	TBD

2.7 | GHG CONSIDERATIONS AND ADDITIONALITY

Assessment Boundary

The possibility of GHG emission reductions associated with private investment efforts depend entirely on the type of relocation-related projects funded. Any possible GHG reductions must be assessed within the reasonable and comprehensive scope of the relevant project; it is however important to ensure that any GHGs offsets produced by a specific investment are not double counted (i.e. used again under the scope of the project itself). A vehicle for private investment might result in a number of projects that reduce GHG emissions — for example, a housing weatherization program or new energy infrastructure — in which case the overall assessment boundary would cover each individual project.

Baseline Case
Given that access to adequate capital is a critical bottleneck for many projects related to Shishmaref's relocation, it can be argued that the baseline scenarios are in effect "do nothing". Without the capital provided by the proposed vehicle for private investment, these projects would not happen. Depending on the projects involved, however, the baseline scenario could involve the continued GHG emissions of the village in its present state, or GHG emissions resulting from more ad-hoc forms of relocation.

Additionality
On the assumption that private investment provides capital critical to the implementation of a set of relocation projects, all project activities might be additional over their corresponding baseline case of no action. Without specifying project types enabled by investment, it is difficult to describe primary or secondary effects in detail.

Appendix C
Financial Models

Assumptions for all scenarios

ANNUAL REVENUES (from energy information (1))		
PCE		$315,580
Unsub tariffs		$501,000
Res tariffs after subsidy		$157,790
	total	$974,369

ANNUAL COSTS		
Transmission (cost/mile + miles, brian's estimate)	$4,000,000	10
Total (capital + project dev for 10 turbines, from some paper?)	8,000,000	
O&M annual baseline (HOMER)	88,000	
Project lifetime (yrs, HOMER)	25	

SCENARIO 1

Medium viability: concessional loan

Loan interest/ Bond rate	4%
PCE escalation	2%
Tariff escalation	2%
GHG payments	0
O&M escalation	1%

SCENARIO 1 OUTCOMES

Amortization Period	17 years
NPV @3%	$8,872,375
NPV @7%	$1,628,529
IRR	8%
Total savings (not discounted)	$15,387,626

GROWTH SITUATION

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs	*Principal*	$13,160,000	$12,657,280	$12,112,990	$11,525,027	$10,891,198	$10,209,213	$9,476,680	$8,691,103	$7,849,876	$6,950,278	$5,989,473	$4,964,496	$3,872,256
	Amortization (max possible)		$502,720	$544,291	$587,963	$633,829	$681,985	$732,533	$785,577	$841,227	$899,597	$960,806	$1,024,977	$1,092,239
	Loan interest=	*0.04*	$526,400	$506,291	$484,520	$461,001	$435,648	$408,369	$379,067	$347,644	$313,995	$278,011	$239,579	$198,580
	Total Debt Service		**-$1,029,120**	**-$1,050,582**	**-$1,072,482**	**-$1,094,830**	**-$1,117,633**	**-$1,140,901**	**-$1,164,644**	**-$1,188,871**	**-$1,213,592**	**-$1,238,817**	**-$1,264,556**	**-$1,290,819**
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Total Revenues (res sub+ unsub), 2% esca*		$801,540	$817,571	$833,922	$850,601	$867,613	$884,965	$902,664	$920,718	$939,132	$957,914	$977,073	$996,614
	PCE (2% escalation)		$315,580	$321,891	$328,329	$334,896	$341,594	$348,425	$355,394	$362,502	$369,752	$377,147	$384,690	$392,384
	GHG offsets (15,000)		0											
	Net cash flows		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs	*Principal*	$2,709,530	$1,472,950	$159,006	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Amortization (max possible)	$1,162,727	$1,236,580	$1,313,944	$159,006	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Loan interest=	$154,890	$108,381	$58,918	$6,360	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Debt Service	**-$1,317,617**	**-$1,344,961**	**-$1,372,862**	**-$6,360**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Total Revenues (res sub+ unsub), 2% esca*	$1,016,547	$1,036,877	$1,057,615	$1,078,767	$1,100,343	$1,122,350	$1,144,796	$1,167,692	$1,191,046	$1,214,867	$1,239,165	$1,263,948	$1,289,227
	PCE (2% escalation)	$400,231	$408,236	$416,401	$424,729	$433,223	$441,888	$450,725	$459,740	$468,935	$478,313	$487,880	$497,637	$507,590
	GHG offsets (15,000)													
	Net cash flows	$0	$0	$0	$1,394,970	$1,430,379	$1,460,018	$1,490,261	$1,521,119	$1,552,604	$1,584,730	$1,617,509	$1,650,955	$1,685,080
														$15,387,626

NPV Calculation

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs		-12,000,000												
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Tariffs (unsub, 2% escalation)*		$801,540	$817,571	$833,922	$850,601	$867,613	$884,965	$902,664	$920,718	$939,132	$957,914	$977,073	$996,614
	PCE (2% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
Cash flow		-12,000,000	1029119.6	1044270.4	1059733.016	1075513.772	1091619.121	1108055.643	1124830.052	1141949.199	1159420.07	1177249.793	1195445.64	1214015.029

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs														
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Tariffs (unsub, 2% escalation)*	$1,016,547	$1,036,877	$1,057,615	$1,078,767	$1,100,343	$1,122,350	$1,144,796	$1,167,692	$1,191,046	$1,214,867	$1,239,165	$1,263,948	$1,289,227
	PCE (2% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
Cash flow		1232965.525	1252304.85	1272040.877	1292181.64	1312735.333	1333710.317	1355115.119	1376958.44	1399249.152	1421996.311	1445209.15	1468897.091	1493069.744

NPV	7%	$1,628,528.66
	3%	$8,872,374.83
Total Savings		$19,077,654.88

SCENARIO 2: BEST CASE

Loan interest/bond rate	4%
PCE escalation	3%
Tariff escalation	3%
GHG payments (annual)	15000
O&M escalation	1%

SCENARIO 2 OUTCOMES

Amortization Period	15 years
NPV @3%	$9,125,964
NPV @7%	$1,791,897
IRR	9%
Total savings (not discounted)	$20,940,352

SCENARIO 2

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs	*Principal*	$13,160,000	$12,642,280	$12,071,068	$11,443,226	$10,755,461	$10,004,315	$9,186,164	$8,297,202	$7,333,440	$6,290,692	$5,164,571	$3,950,476	$2,643,584
	Amortization (max possible)		$517,720	$571,212	$627,842	$687,766	$751,145	$818,151	$888,962	$963,762	$1,042,748	$1,126,121	$1,214,095	$1,306,892
	Loan interest=	*0.04*	$526,400	$505,691	$482,843	$457,729	$430,218	$400,173	$367,447	$331,888	$293,338	$251,628	$206,583	$158,019
	Total Debt Service		**-$1,044,120**	**-$1,076,903**	**-$1,110,685**	**-$1,145,495**	**-$1,181,364**	**-$1,218,324**	**-$1,256,408**	**-$1,295,650**	**-$1,336,085**	**-$1,377,749**	**-$1,420,678**	**-$1,464,911**
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Tariffs (3% escalation)*		$801,540	$825,586	$850,354	$875,864	$902,140	$929,205	$957,081	$985,793	$1,015,367	$1,045,828	$1,077,203	$1,109,519
	PCE (3% escalation)		$315,580	$325,047	$334,798	$344,842	$355,188	$365,843	$376,819	$388,123	$399,767	$411,760	$424,113	$436,836
	GHG offsets (15,000)		15000	15150	15301.5	15454.515	15609.06015	15765.15075	15922.80226	16082.03028	16242.85058	16405.27909	16569.33188	16735.0252
	Net cash flows		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs	*Principal*	$1,238,840	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Amortization (max possible)	$1,404,744	$1,238,840	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Loan interest=	$105,743	$49,554	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Debt Service	**-$1,510,487**	**-$1,288,394**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Tariffs (3% escalation)*	$1,142,804	$1,177,089	$1,212,401	$1,248,773	$1,286,236	$1,324,823	$1,364,568	$1,405,505	$1,447,670	$1,491,101	$1,535,834	$1,581,909	$1,629,366
	PCE (3% escalation)	$449,941	$463,439	$477,342	$491,663	$506,413	$521,605	$537,253	$553,371	$569,972	$587,071	$604,683	$622,824	$641,508
	GHG offsets (15,000)	16902.37545	17071.39921	17242.1132	17414.53433	17588.67967	17764.56647	17942.21214	18121.63426	18302.8506	18485.87911	18670.7379	18857.44528	19046.01973
	Net cash flows	$0	$269,053	$1,605,832	$1,655,685	$1,707,051	$1,759,974	$1,814,503	$1,870,684	$1,928,568	$1,988,207	$2,049,652	$2,112,959	$2,178,184

NPV Calculation

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs		-12,000,000												
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Tariffs (unsub, 2% escalation)*		$801,540	$817,571	$833,922	$850,601	$867,613	$884,965	$902,664	$920,718	$939,132	$957,914	$977,073	$996,614
	PCE (2% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)		15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Cash flow		-12,000,000	1044119.6	1059270.4	1074733.016	1090513.772	1106619.121	1123055.643	1139830.052	1156949.199	1174420.07	1192249.793	1210445.64	1229015.029

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs														
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Tariffs (unsub, 2% escalation)*	$1,016,547	$1,036,877	$1,057,615	$1,078,767	$1,100,343	$1,122,350	$1,144,796	$1,167,692	$1,191,046	$1,214,867	$1,239,165	$1,263,948	$1,289,227
	PCE (2% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Cash flow		1247965.525	1267304.85	1287040.877	1307181.64	1327735.333	1348710.317	1370115.119	1391958.44	1414249.152	1436996.311	1460209.15	1483897.091	1508069.744

NPV	7%	$1,791,896.6
	3%	$9,125,964.4
Total Savings		19,452,655

SCENARIO 3: WORST CASE

Loan interest/bond rate	7%
PCE escalation	0%
Tariff escalation	1%
GHG payments (annual)	0
O&M escalation	2%

SCENARIO 3

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Costs	*Principal*	$13,160,000	$13,052,080	$12,930,351	$12,793,800	$12,641,346	$12,471,828	$12,284,009	$12,076,562	$11,848,066	$11,597,005	$11,321,751	$11,020,567	$10,691,591	$10,332,832	$9,942,161	$9,517,298
	Amortization (max possible)		$107,920	$121,729	$136,551	$152,455	$169,517	$187,819	$207,448	$228,495	$251,062	$275,254	$301,184	$328,976	$358,758	$390,671	$424,864
	Loan interest=	*0.07*	$921,200	$913,646	$905,125	$895,566	$884,894	$873,028	$859,881	$845,359	$829,365	$811,790	$792,523	$771,440	$748,411	$723,298	$695,951
	Total Debt Service		**-$1,029,120**	**-$1,035,375**	**-$1,041,675**	**-$1,048,021**	**-$1,054,411**	**-$1,060,847**	**-$1,067,328**	**-$1,073,855**	**-$1,080,427**	**-$1,087,044**	**-$1,093,707**	**-$1,100,415**	**-$1,107,170**	**-$1,113,970**	**-$1,120,815**
	O&M (2% escalation)		**-$88,000**	**-$89,760**	**-$91,555**	**-$93,386**	**-$95,254**	**-$97,159**	**-$99,102**	**-$101,084**	**-$103,106**	**-$105,168**	**-$107,272**	**-$109,417**	**-$111,605**	**-$113,837**	**-$116,114**
Revenues	*Tariffs 1% escalation)*		$801,540	$809,555	$817,651	$825,827	$834,086	$842,427	$850,851	$859,359	$867,953	$876,632	$885,399	$894,253	$903,195	$912,227	$921,350
	PCE (0% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Net cash flows		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Costs	*Principal*	$9,055,802	$8,555,065	$8,012,294	$7,424,501	$6,788,488	$6,100,834	$5,357,881	$4,555,709	$3,690,130	$2,756,659	$1,750,498	$666,514	$0	$0	$0
	Amortization (max possible)	$461,495	$500,737	$542,771	$587,793	$636,013	$687,653	$742,954	$802,171	$865,579	$933,471	$1,006,161	$1,083,984	$666,514	$0	$0
	Loan interest=	$666,211	$633,906	$598,855	$560,861	$519,715	$475,194	$427,058	$375,052	$318,900	$258,309	$192,966	$122,535	$46,656	$0	$0
	Total Debt Service	**-$1,127,706**	**-$1,134,643**	**-$1,141,626**	**-$1,148,654**	**-$1,155,728**	**-$1,162,847**	**-$1,170,012**	**-$1,177,223**	**-$1,184,479**	**-$1,191,780**	**-$1,199,127**	**-$1,206,519**	**-$713,170**	**$0**	**$0**
	O&M (2% escalation)	**-$118,436**	**-$120,805**	**-$123,221**	**-$125,686**	**-$128,199**	**-$130,763**	**-$133,379**	**-$136,046**	**-$138,767**	**-$141,542**	**-$144,373**	**-$147,261**	**-$150,206**	**-$153,210**	**-$156,274**
Revenues	*Tariffs 1% escalation)*	$930,563	$939,869	$949,267	$958,760	$968,348	$978,031	$987,811	$997,690	$1,007,666	$1,017,743	$1,027,921	$1,038,200	$1,048,582	$1,059,068	$1,069,658
	PCE (0% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Net cash flows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$500,785	$1,221,437	$1,228,964

NPV Calculation

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Costs		-12,000,000															
	O&M (2% escalation)		**-$88,000**	**-$89,760**	**-$91,555**	**-$93,386**	**-$95,254**	**-$97,159**	**-$99,102**	**-$101,084**	**-$103,106**	**-$105,168**	**-$107,272**	**-$109,417**	**-$111,605**	**-$113,837**	**-$116,114**
Revenues	*Tariffs 1% escalation)*		$801,540	$809,555	$817,651	$825,827	$834,086	$842,427	$850,851	$859,359	$867,953	$876,632	$885,399	$894,253	$903,195	$912,227	$921,350
	PCE (0% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow		-12,000,000	1029119.6	1035375	1041675.354	1048020.76	1054411.308	1060847.085	1067328.169	1073854.631	1080426.538	1087043.947	1093706.909	1100415.467	1107169.657	1113969.505	1120815.03

		16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Costs																
	O&M (2% escalation)	**-$118,436**	**-$120,805**	**-$123,221**	**-$125,686**	**-$128,199**	**-$130,763**	**-$133,379**	**-$136,046**	**-$138,767**	**-$141,542**	**-$144,373**	**-$147,261**	**-$150,206**	**-$153,210**	**-$156,274**
Revenues	*Tariffs 1% escalation)*	$930,563	$939,869	$949,267	$958,760	$968,348	$978,031	$987,811	$997,690	$1,007,666	$1,017,743	$1,027,921	$1,038,200	$1,048,582	$1,059,068	$1,069,658
	PCE (0% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow		1127706.243	1134643.145	1141625.729	1148653.978	1155727.865	1162847.354	1170012.398	1177222.939	1184478.91	-$1,564,879	1199126.814	1206518.553	1213955.334	1221437.031	1228963.504

NPV	7%	$134,743.7
	3%	$5,634,913.0
Total Savings		12,952,219

Appendix C - Financial Modeling

Assumptions for all scenarios

ANNUAL REVENUES (from energy information (1))

PCE		$315,580
Unsub tariffs		$501,000
Res tariffs after subsidy		$157,790
	total	$974,369

ANNUAL COSTS		(miles)	
Transmission (cost/mile + miles)	$4,000,000		10
Total (capital + project dev for 10 turbines)	8,000,000		
O&M annual baseline (HOMER)	88,000		
Project lifetime (yrs, HOMER)	25		

SCENARIO 1

Medium viability: concessional loan

Loan interest/ Bond rate	4%
PCE escalation	2%
Tariff escalation	2%
GHG payments	0
O&M escalation	1%

SCENARIO 1 OUTCOMES

Amortization Period	17 years
NPV @3%	$5,809,890
NPV @7%	-$272,138
IRR	7%
Total savings (not discounted)	$13,236,031

NO GROWTH SITUATION

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs	*Principal*	$11,372,000	$10,943,500	$10,479,313	$9,977,631	$9,436,567	$8,854,150	$8,228,324	$7,556,939	$6,837,755	$6,068,431	$5,246,524	$4,369,485	$3,434,655
	Amortization (max possible)		$428,500	$464,187	$501,682	$541,064	$582,417	$625,827	$671,384	$719,184	$769,324	$821,907	$877,039	$934,830
	Loan interest=	*0.04*	$454,880	$437,740	$419,173	$399,105	$377,463	$354,166	$329,133	$302,278	$273,510	$242,737	$209,861	$174,779
	Total Debt Service		**-$883,380**	**-$901,927**	**-$920,855**	**-$940,169**	**-$959,879**	**-$979,993**	**-$1,000,517**	**-$1,021,462**	**-$1,042,835**	**-$1,064,644**	**-$1,086,900**	**-$1,109,610**
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Total Revenues (res sub+ unsub), 2% esca*		$655,800	$668,916	$682,294	$695,940	$709,859	$724,056	$738,537	$753,308	$768,374	$783,742	$799,417	$815,405
	PCE (2% escalation)		$315,580	$321,891	$328,329	$334,896	$341,594	$348,425	$355,394	$362,502	$369,752	$377,147	$384,690	$392,384
	GHG offsets (15,000)		0											
	Net cash flows	*-$11,372,000*	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs	*Principal*	$2,439,257	$1,380,397	$255,052	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Amortization (max possible)	$995,397	$1,058,861	$1,125,345	$255,052	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Loan interest=	$137,386	$97,570	$55,216	$10,202	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Debt Service	**-$1,132,784**	**-$1,156,431**	**-$1,180,561**	**-$10,202**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Total Revenues (res sub+ unsub), 2% esca*	$831,713	$848,347	$865,314	$882,620	$900,273	$918,278	$936,644	$955,377	$974,484	$993,974	$1,013,853	$1,034,131	$1,054,813
	PCE (2% escalation)	$400,231	$408,236	$416,401	$424,729	$433,223	$441,888	$450,725	$459,740	$468,935	$478,313	$487,880	$497,637	$507,590
	GHG offsets (15,000)													
	Net cash flows	$0	$0	$0	$1,194,982	$1,230,309	$1,255,947	$1,282,108	$1,308,803	$1,336,042	$1,363,837	$1,392,198	$1,421,137	$1,450,666
														$13,236,031

NPV Calculation

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs		-12,000,000												
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Tariffs (unsub, 2% escalation)*		$655,800	$668,916	$682,294	$695,940	$709,859	$724,056	$738,537	$753,308	$768,374	$783,742	$799,417	$815,405
	PCE (2% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
Cash flow		-12,000,000	883379.6	895615.6	908105.12	920853.3184	933865.4576	947146.9063	960703.1413	974539.7499	988662.432	1003077.003	1017789.394	1032805.657

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs														
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Tariffs (unsub, 2% escalation)*	$831,713	$848,347	$865,314	$882,620	$900,273	$918,278	$936,644	$955,377	$974,484	$993,974	$1,013,853	$1,034,131	$1,054,813
	PCE (2% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
Cash flow		1048131.966	1063774.62	1079740.042	1096034.788	1112665.545	1129639.133	1146962.511	1164642.779	1182687.179	1201103.098	1219898.072	1239079.792	1258656.099

NPV	7%	-$272,138
	3%	$5,809,890
Total Savings		$14,409,559

SCENARIO 2: BEST CASE

High viability

Loan interest/bond rate	4%
PCE escalation	3%
Tariff escalation	3%
GHG payments (annual)	15000
O&M escalation	1%

SCENARIO 2 OUTCOMES

Amortization Period	15 years
NPV @3%	$6,063,480
NPV @7%	-$108,770
IRR	7%
Total savings (not discounted)	$16,896,108

SCENARIO 2

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs	*Principal*	$12,000,000	$11,581,620	$11,118,094	$10,606,749	$10,044,778	$9,429,237	$8,757,035	$8,024,929	$7,229,518	$6,367,232	$5,434,331	$4,426,888	$3,340,791
	Amortization (max possible)		$418,380	$463,526	$511,346	$561,971	$615,541	$672,202	$732,106	$795,411	$862,285	$932,902	$1,007,442	$1,086,097
	Loan interest=	*0.04*	$480,000	$463,265	$444,724	$424,270	$401,791	$377,169	$350,281	$320,997	$289,181	$254,689	$217,373	$177,076
	Total Debt Service		**-$898,380**	**-$926,791**	**-$956,069**	**-$986,241**	**-$1,017,332**	**-$1,049,371**	**-$1,082,387**	**-$1,116,409**	**-$1,151,466**	**-$1,187,591**	**-$1,224,816**	**-$1,263,173**
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Tariffs (3% escalation)*		$655,800	$675,474	$695,738	$716,610	$738,109	$760,252	$783,059	$806,551	$830,748	$855,670	$881,340	$907,781
	PCE (3% escalation)		$315,580	$325,047	$334,798	$344,842	$355,188	$365,843	$376,819	$388,123	$399,767	$411,760	$424,113	$436,836
	GHG offsets (15,000)		15000	15150	15301.5	15454.515	15609.06015	15765.15075	15922.80226	16082.03028	16242.85058	16405.27909	16569.33188	16735.0252
	Net cash flows		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs	*Principal*	$2,171,726	$915,172	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Amortization (max possible)	$1,169,065	$1,256,554	$915,172	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Loan interest=	$133,632	$86,869	$36,607	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Debt Service	**-$1,302,697**	**-$1,343,423**	**-$951,779**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Tariffs (3% escalation)*	$935,014	$963,064	$991,956	$1,021,715	$1,052,366	$1,083,937	$1,116,456	$1,149,949	$1,184,448	$1,219,981	$1,256,581	$1,294,278	$1,333,106
	PCE (3% escalation)	$449,941	$463,439	$477,342	$491,663	$506,413	$521,605	$537,253	$553,371	$569,972	$587,071	$604,683	$622,824	$641,508
	GHG offsets (15,000)	16902.37545	17071.39921	17242.1132	17414.53433	17588.67967	17764.56647	17942.21214	18121.63426	18302.8506	18485.87911	18670.7379	18857.44528	19046.01973
	Net cash flows	$0	$0	$433,608	$1,428,627	$1,473,181	$1,519,088	$1,566,390	$1,615,128	$1,665,346	$1,717,088	$1,770,400	$1,825,329	$1,881,924

NPV Calculation

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs		-12,000,000												
	O&M (1% escalation)		**-$88,000**	**-$88,880**	**-$89,769**	**-$90,666**	**-$91,573**	**-$92,489**	**-$93,414**	**-$94,348**	**-$95,291**	**-$96,244**	**-$97,207**	**-$98,179**
Revenues	*Tariffs (unsub, 2% escalation)*		$655,800	$668,916	$682,294	$695,940	$709,859	$724,056	$738,537	$753,308	$768,374	$783,742	$799,417	$815,405
	PCE (2% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)		15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Cash flow		-12,000,000	898379.6	910615.6	923105.12	935853.3184	948865.4576	962146.9063	975703.1413	989539.7499	1003662.432	1018077.003	1032789.394	1047805.657

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs														
	O&M (1% escalation)	**-$99,161**	**-$100,152**	**-$101,154**	**-$102,165**	**-$103,187**	**-$104,219**	**-$105,261**	**-$106,314**	**-$107,377**	**-$108,450**	**-$109,535**	**-$110,630**	**-$111,737**
Revenues	*Tariffs (unsub, 2% escalation)*	$831,713	$848,347	$865,314	$882,620	$900,273	$918,278	$936,644	$955,377	$974,484	$993,974	$1,013,853	$1,034,131	$1,054,813
	PCE (2% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Cash flow		1063131.966	1078774.62	1094740.042	1111034.788	1127665.545	1144639.133	1161962.511	1179642.779	1197687.179	1216103.098	1234898.072	1254079.792	1273656.099

NPV	7%	-$108,770.1
	3%	$6,063,479.6
Total Savings		14,784,559

SCENARIO 3: WORST CASE

Low viability

Loan interest/bond rate	7%
PCE escalation	0%
Tariff escalation	1%
GHG payments (annual)	0
O&M escalation	2%

SCENARIO 3

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs	*Principal*	$12,000,000	$11,956,620	$11,905,406	$11,845,779	$11,777,119	$11,698,763	$11,610,004	$11,510,082	$11,398,186	$11,273,448	$11,134,939	$10,981,665	$10,812,564
	Amortization (max possible)		$43,380	$51,214	$59,628	$68,660	$78,355	$88,759	$99,922	$111,896	$124,738	$138,509	$153,274	$169,101
	Loan interest=	*0.07*	$840,000	$836,963	$833,378	$829,205	$824,398	$818,913	$812,700	$805,706	$797,873	$789,141	$779,446	$768,717
	Total Debt Service		**-$883,380**	**-$888,178**	**-$893,006**	**-$897,865**	**-$902,754**	**-$907,673**	**-$912,622**	**-$917,602**	**-$922,611**	**-$927,650**	**-$932,719**	**-$937,818**
	O&M (2% escalation)		**-$88,000**	**-$89,760**	**-$91,555**	**-$93,386**	**-$95,254**	**-$97,159**	**-$99,102**	**-$101,084**	**-$103,106**	**-$105,168**	**-$107,272**	**-$109,417**
Revenues	*Tariffs 1% escalation)*		$655,800	$662,358	$668,982	$675,671	$682,428	$689,252	$696,145	$703,106	$710,137	$717,239	$724,411	$731,655
	PCE (0% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)		0	0	0	0	0	0	0	0	0	0	0	0
	Net cash flows		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs	*Principal*	$10,626,497	$10,422,248	$10,198,515	$9,953,904	$9,686,926	$9,395,986	$9,079,377	$8,735,276	$8,361,728	$7,956,645	$7,517,793	$7,042,778	$6,529,044
	Amortization (max possible)	$186,067	$204,249	$223,733	$244,611	$266,978	$290,940	$316,608	$344,102	$373,548	$405,083	$438,853	$475,014	$513,735
	Loan interest=	$756,879	$743,855	$729,557	$713,896	$696,773	$678,085	$657,719	$635,556	$611,469	$585,321	$556,965	$526,245	$492,994
	Total Debt Service	**-$942,946**	**-$948,104**	**-$953,291**	**-$958,507**	**-$963,752**	**-$969,025**	**-$974,327**	**-$979,658**	**-$985,017**	**-$990,404**	**-$995,818**	**-$1,001,260**	**-$1,006,729**
	O&M (2% escalation)	**-$111,605**	**-$113,837**	**-$116,114**	**-$118,436**	**-$120,805**	**-$123,221**	**-$125,686**	**-$128,199**	**-$130,763**	**-$133,379**	**-$136,046**	**-$138,767**	**-$141,542**
Revenues	*Tariffs 1% escalation)*	$738,972	$746,362	$753,825	$761,363	$768,977	$776,667	$784,434	$792,278	$800,201	$808,203	$816,285	$824,448	$832,692
	PCE (0% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Net cash flows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	-$6,529,044

		26	27	28	29	30	31	32	33	34	35	36
Costs	*Principal*	$5,973,851	$5,374,273	$4,727,175	$4,029,205	$3,276,777	$2,466,052	$1,592,925	$653,004	-$358,412	-$1,446,351	-$2,616,193
	Amortization (max possible)	$555,192	$599,578	$647,098	$697,970	$752,429	$810,725	$873,127	$939,921	$1,011,416	$1,087,939	$1,169,842
	Loan interest=	$457,033	$418,170	$376,199	$330,902	$282,044	$229,374	$172,624	$111,505	$45,710	-$25,089	-$101,245
	Total Debt Service	**-$1,012,225**	**-$1,017,748**	**-$1,023,297**	**-$1,028,872**	**-$1,034,473**	**-$1,040,099**	**-$1,045,750**	**-$1,051,426**	**-$1,057,126**	**-$1,062,850**	**-$1,068,597**
	O&M (2% escalation)	**-$144,373**	**-$147,261**	**-$150,206**	**-$153,210**	**-$156,274**	**-$159,400**	**-$162,588**	**-$165,840**	**-$169,156**	**-$172,539**	**-$175,990**
Revenues	*Tariffs 1% escalation)*	$841,019	$849,429	$857,923	$866,503	$875,168	$883,919	$892,759	$901,686	$910,703	$919,810	$929,008
	PCE (0% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	0	0	0	0	0	0	0	0	0	0	0
	Net cash flows	$0	-$5,374,273	$0	-$4,029,205	$0	-$2,466,052	$0	-$653,004	$0	$1,446,351	$0

NPV Calculation

		0	1	2	3	4	5	6	7	8	9	10	11	12
Costs		-12,000,000												
	O&M (2% escalation)		**-$88,000**	**-$89,760**	**-$91,555**	**-$93,386**	**-$95,254**	**-$97,159**	**-$99,102**	**-$101,084**	**-$103,106**	**-$105,168**	**-$107,272**	**-$109,417**
Revenues	*Tariffs 1% escalation)*		$655,800	$662,358	$668,982	$675,671	$682,428	$689,252	$696,145	$703,106	$710,137	$717,239	$724,411	$731,655
	PCE (0% escalation)		$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)		0	0	0	0	0	0	0	0	0	0	0	0
Cash flow		-12,000,000	883379.6	888177.6	893005.98	897864.6918	902753.6797	907672.8802	912622.2219	917601.6252	922611.002	927650.2558	932719.2809	937817.9626

		13	14	15	16	17	18	19	20	21	22	23	24	25
Costs														
	O&M (2% escalation)	**-$111,605**	**-$113,837**	**-$116,114**	**-$118,436**	**-$120,805**	**-$123,221**	**-$125,686**	**-$128,199**	**-$130,763**	**-$133,379**	**-$136,046**	**-$138,767**	**-$141,542**
Revenues	*Tariffs 1% escalation)*	$738,972	$746,362	$753,825	$761,363	$768,977	$776,667	$784,434	$792,278	$800,201	$808,203	$816,285	$824,448	$832,692
	PCE (0% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash flow		942946.1768	948103.7898	953290.6579	958506.6272	963751.5333	969025.2012	974327.4448	979658.0665	985016.8574	990403.5962	995818.0498	1001259.972	-$5,522,314

		26	27	28	29	30	31	32	33	34	35	36
Costs												
	O&M (2% escalation)	**-$144,373**	**-$147,261**	**-$150,206**	**-$153,210**	**-$156,274**	**-$159,400**	**-$162,588**	**-$165,840**	**-$169,156**	**-$172,539**	**-$175,990**
Revenues	*Tariffs 1% escalation)*	$841,019	$849,429	$857,923	$866,503	$875,168	$883,919	$892,759	$901,686	$910,703	$919,810	$929,008
	PCE (0% escalation)	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580	$315,580
	GHG offsets (15,000)	0	0	0	0	0	0	0	0	0	0	0
Cash flow		1012225.175	1017747.897	1023296.972	1028872.086	1034472.91	1040099.099	1045750.296	1051426.125	1057126.194	1062850.097	1068597.407

NPV	7%	-$2,248,543.7
	3%	$1,144,186.0
Total Savings		5,063,670