MICROREACTORS IN ALASKA

Use Case Analysis: Small Rural Community

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Small Rural Community Customer Analysis

Alaska's energy landscape can be roughly divided into two parts: the road system and rural Alaska. Outside of the Railbelt, energy systems across the state are made up of very small micro-grids. Alaska is home to over 100 very small, islanded micro-grids. These micro-grids typically serve communities with fewer than 1,000 residents isolated from the road system with air and, sometimes, barge access.

This analysis is primarily concerned with the remote, rural parts of Alaska in the western, northern, and interior parts of the state. With some exceptions, communities in these regions rely on diesel power generation and lack economies of scale to produce affordable power. This analysis excludes the larger 'hub communities', which are scattered across remote, rural Alaska and are larger in population size (measured in the thousands) and exhibit different energy characteristics.

Population and Demographics

Communities across rural remote Alaska vary widely in size, from fewer than 10 residents to several thousand. Figure 1 maps Alaska community population across Alaska. 'Hub' communities, such as Kotzebue, Bethel, Dillingham, Nome, and Utqiaġvik serve as transportation and administrative centers for surrounding villages with populations numbering in the hundreds. Most of these villages are home to Alaska Native people practicing a subsistence lifestyle with a limited cash economy. These latter communities are the focus of this analysis, rather than the larger hubs which are addressed separately.

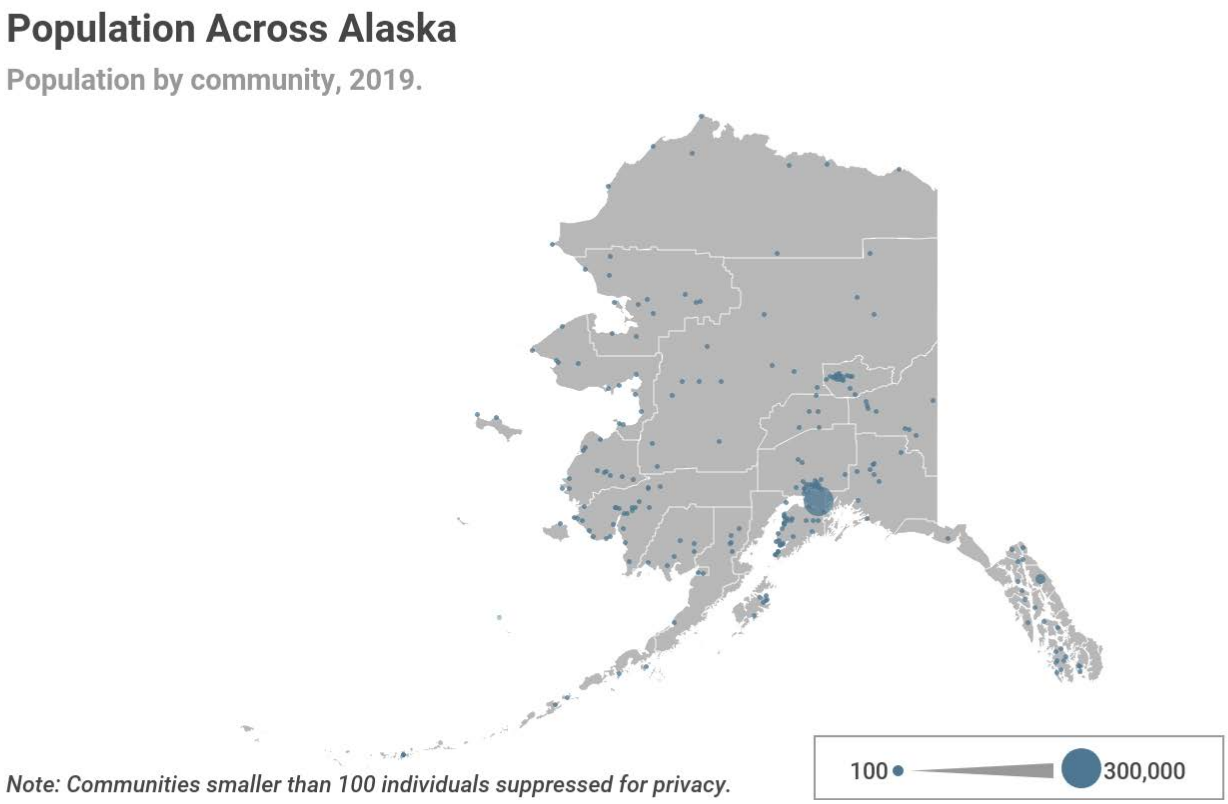

Figure 1: Population density across Alaska
Source: Alaska Department of Labor and Workforce Development (AKDOLWD), 2019.

Because population size is small and labor pools are isolated, the workforce is less diverse than in larger communities on the road system and even rural hub communities. A sample of five communities were taken at random to show population (Figure 2), education (Figure 3), and workforce characteristics (Figure 4) common across rural Alaska.

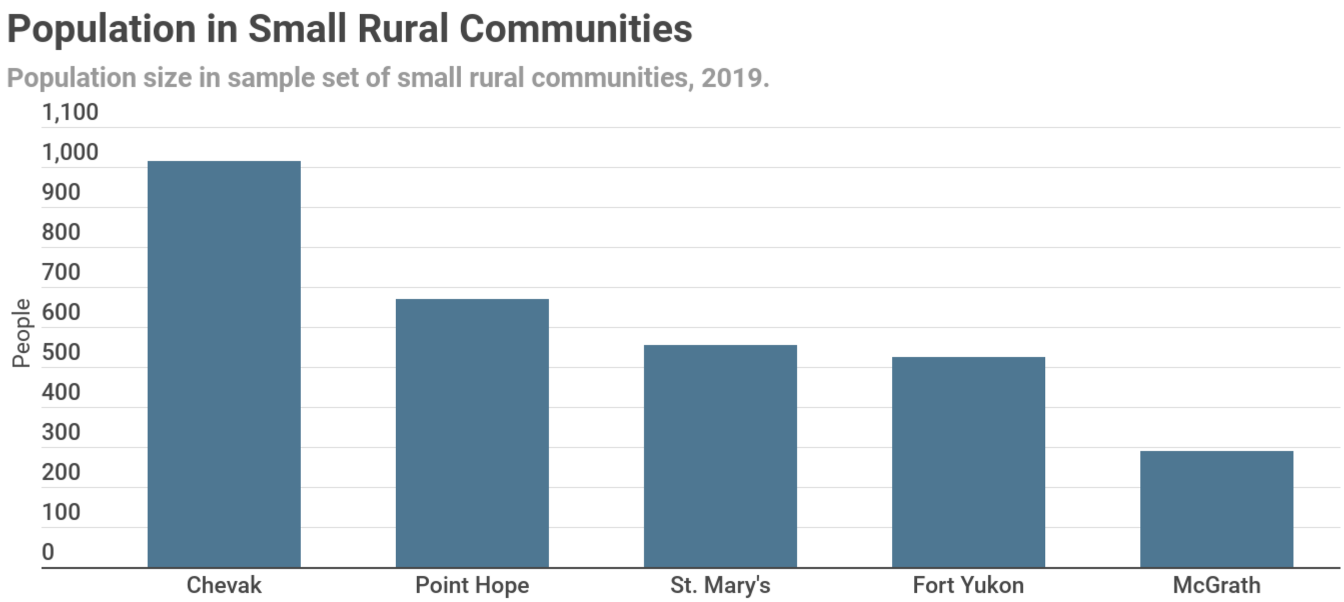

Figure 2: Population size in sample small rural communities
Source: AKDOLWD, 2019.

Rates of educational attainment in rural communities differ significantly from statewide averages. For example, the proportion of the population 25 and older in the sample communities examined here with a high school diploma are significantly higher than statewide. However, the proportion of the population with a bachelor degree is lower than statewide averages, ranging from 2 to 10 percent.[1]

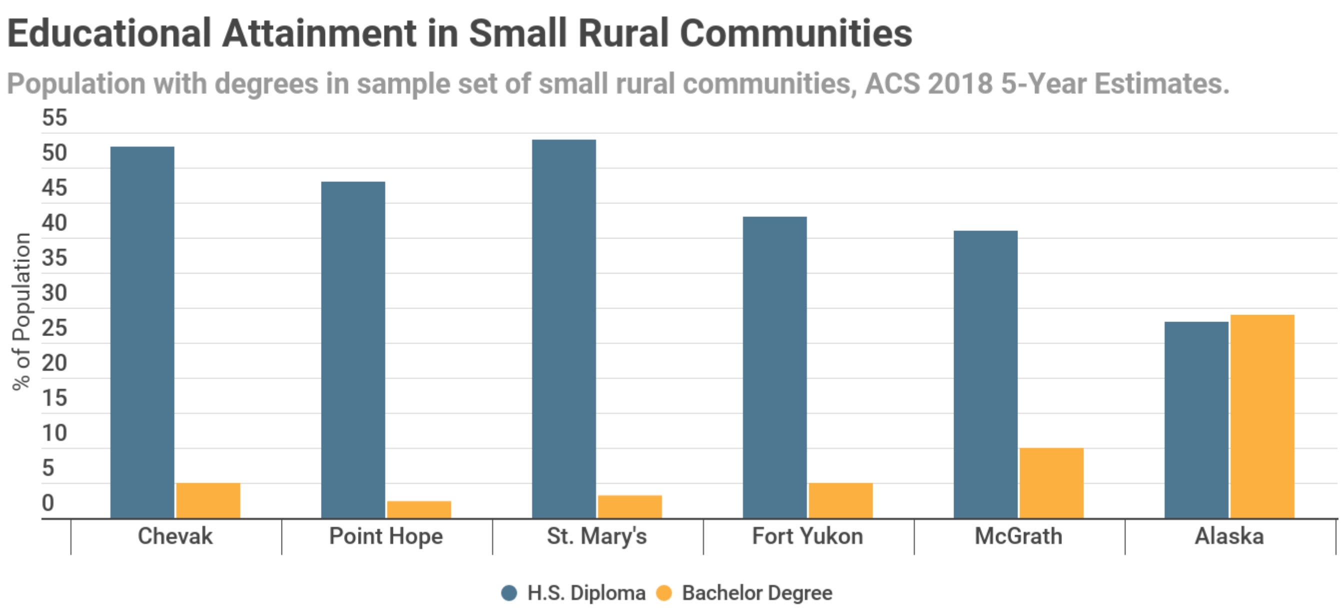

Figure 3: Education Attainment in Sample Small Rural Communities.
Source: American Community Survey (ACS), 2018 Five-Year Estimates.

Cash employment opportunities are limited. Local government, education and healthcare, and trade, transportation, and utilities are the three largest sectors. Subsistence activities play an important economic and cultural role.

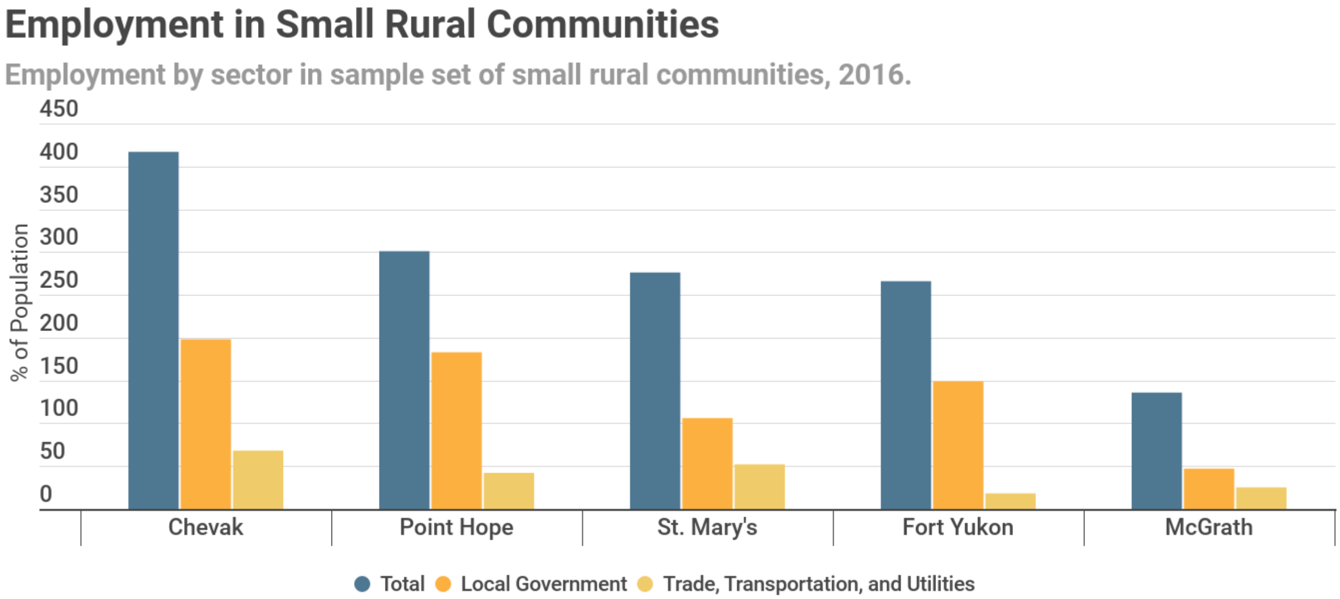

Figure 4: Employment in Sample Small Rural Communities.
Source: ACS 2018 Five-Year Estimates.

Poverty rates in rural Alaskan communities are higher than the statewide average of 10.8 percent. Figure 5 compares poverty rates in the sample set of rural communities. Average household income is significantly lower than the statewide median of $76,000.[2]

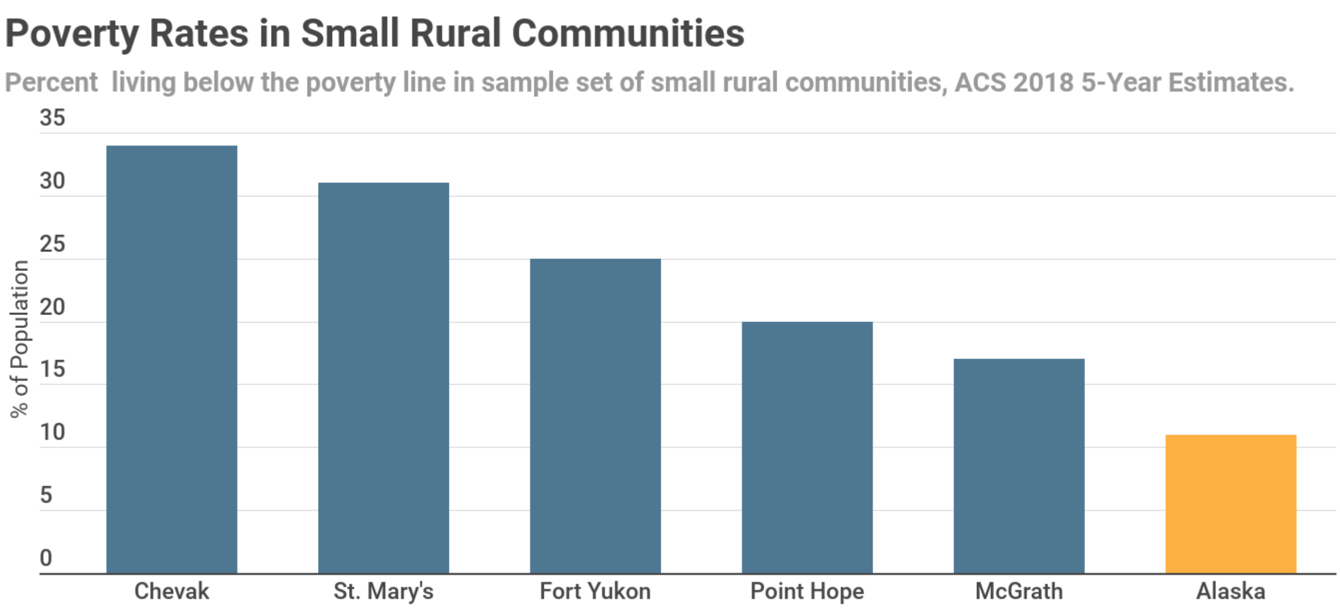

Figure 5: Poverty Rates in Sample Small Rural Communities.
Source: ACS 2018 Five-Year Estimates.

With lower household incomes and high energy costs, households dedicate a large portion of their income to energy costs. Figure 6 compares median household income across a sample set of rural communities.

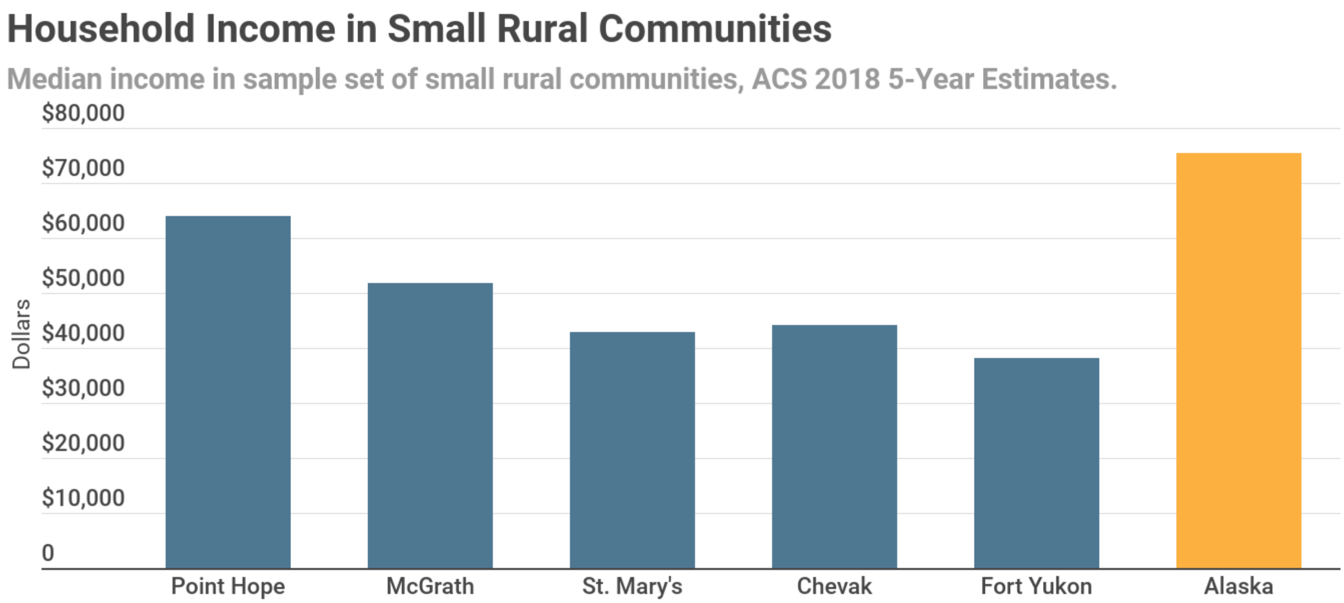

Figure 6: Average Household Income in Sample Small Rural Communities.
Source: ACS 2018 5-Year Estimates.

Energy Systems

Electric

As rural Alaska communities vary in size, so do the size of the energy systems. Electric loads are primarily made up of residential customers and community facilities. Schools, washeterias, and water treatment facilities often make up the largest single energy users.[3] Most communities have health clinics which require constant power.

Eligible communities across rural Alaska participate in the Power Cost Equalization (PCE) program, a State subsidy which lowers the cost of power for residential customers up to the 500 kWh and for eligible community facilities. The program subsidizes qualifying fuel and non-fuel costs, lowering the realized cost of energy for rural Alaskan residents. However, commercial energy users do not qualify for the program and bear the full burden of energy costs in rural communities.[4]

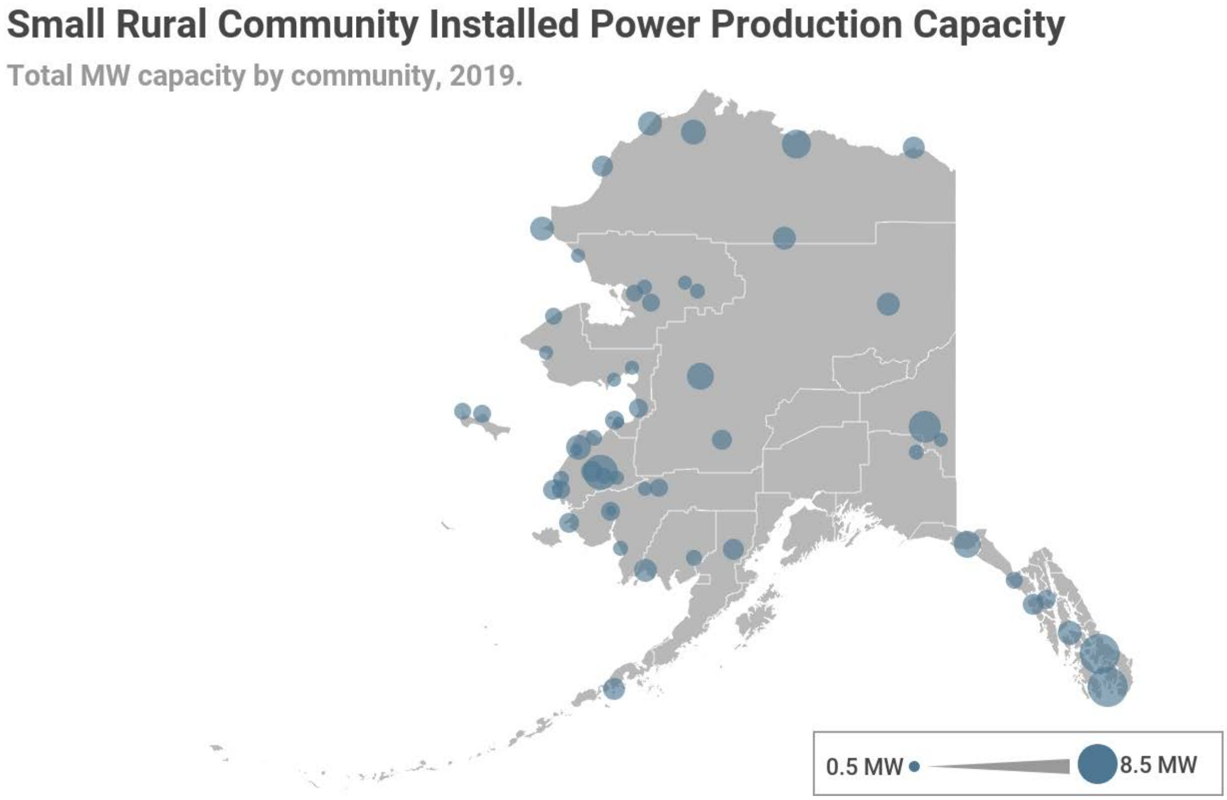

Figure 7: Small Remote Community Generation Capacity.
Source: U.S. Energy Information Agency (EIA), 2019.

Alaska hosts 170 seafood processors, many of which are located across rural Alaska.[5] Processors represent large industrial loads for the communities they are located in. In some cases, processors maintain their own energy systems and in other they are tied into community systems. Processors usually operate seasonally and building a community energy system to accommodate a large seasonal processor would far outsize the capacity of the system for the community's load through much of the year.

These small rural communities are defined separately from rural hub communities largely by their size. In many cases, an energy system with a capacity of 1 MW is considered very large. Figure 7 maps the installed power capacity of rural communities. Figure 8 below compares the installed capacity in the sample set of communities discussed above.

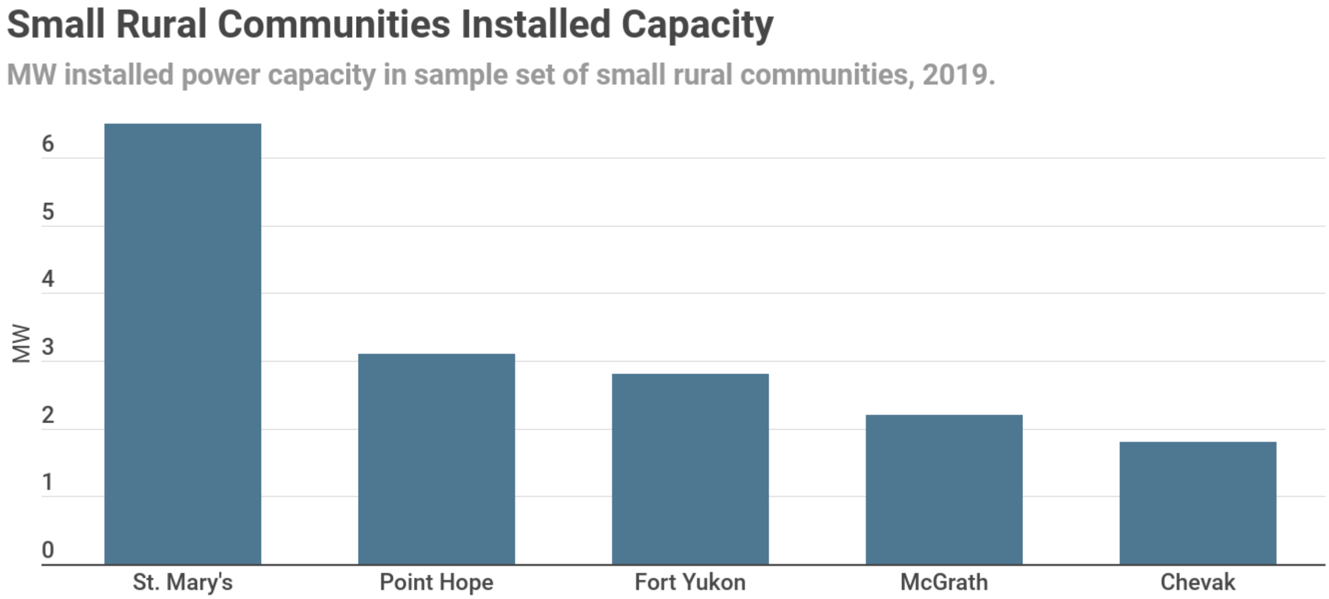

Figure 8: Sample Small Rural Community Installed Capacity.
Source: EIA, 2019.

The ownership models of rural hub utilities vary, and include city ownership, co-op models, tribal ownership, and private ownership. Alaska Village Electric Cooperative serves 58 individual communities across Alaska and is the largest energy coop to deploy the business model of serving multiple islanded communities to spread costs over a larger number of kWh. Table 1 discusses the ownership models of the community utilities from the sample set of communities.

Sample Small Rural Community Utility Ownership Structure	
Community	**Ownership Type**
Chevak	Cooperative
Fort Yukon	Tribal Corporation Owned
McGrath	Tribal Corporation Owned
Point Hope	Local Government
St. Mary's	Cooperative

Table 1: Sample Small Rural Community Utility Ownership Structure.
Source: Regulatory Commission of Alaska, 2019.

Over 30 PCE eligible communities across rural Alaska operate systems monitoring a combination of diesel and other renewable assets, including: wind, solar, and hydro.[6] Systems which can coordinate with engineers and operators in Anchorage and the rest of the U.S. are increasingly prevalent. Other communities operate very simple, dated systems, where routine maintenance can be a challenge. Across Southeast Alaska, many of the communities are primarily powered by mature hydro assets with diesel backup. Western Alaska hub communities are mostly dependent on diesel fuel for power generation. Alaska Village Electric Cooperative operates wind-diesel hybrid systems in 13 of the 58 communities it serves.[7]

Two of the five sample communities discussed above operate systems which utilize a mixture of diesel and non-diesel resources. Both St. Mary's and Chevak operate wind diesel hybrid systems. Figure 9 below shows the annual kWh composition of power generated from diesel and non-diesel sources.

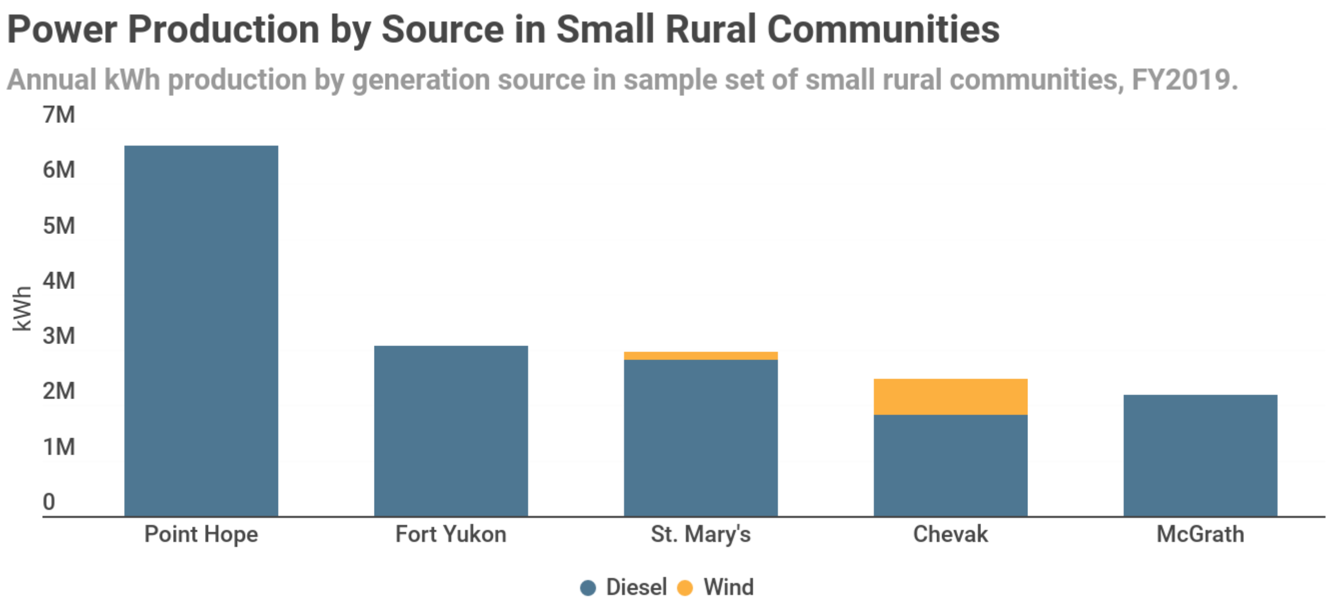

Figure 9: Sample Small Rural Community Power Production by Generation Source.
Source: Alaska Energy Authority (AEA), 2019.

The costs associated with maintaining and operating a diesel system in rural Alaska are notoriously high. Maintenance costs represent a high cost and a technical challenge in some communities.[8] Difficulty with routine maintenance activities is common, largely due to a lack of technical capacity in some communities and access to replacement parts.[9] Fuel costs also represent a large and variable cost for many communities. Fuel deliveries occur once or twice a year, in the summer, and are delivered by barge or plane. [10] Figure 10 compares the average residential rate paid by community customers and Figure 11 compares annual utility power production costs for the sample set of rural communities.

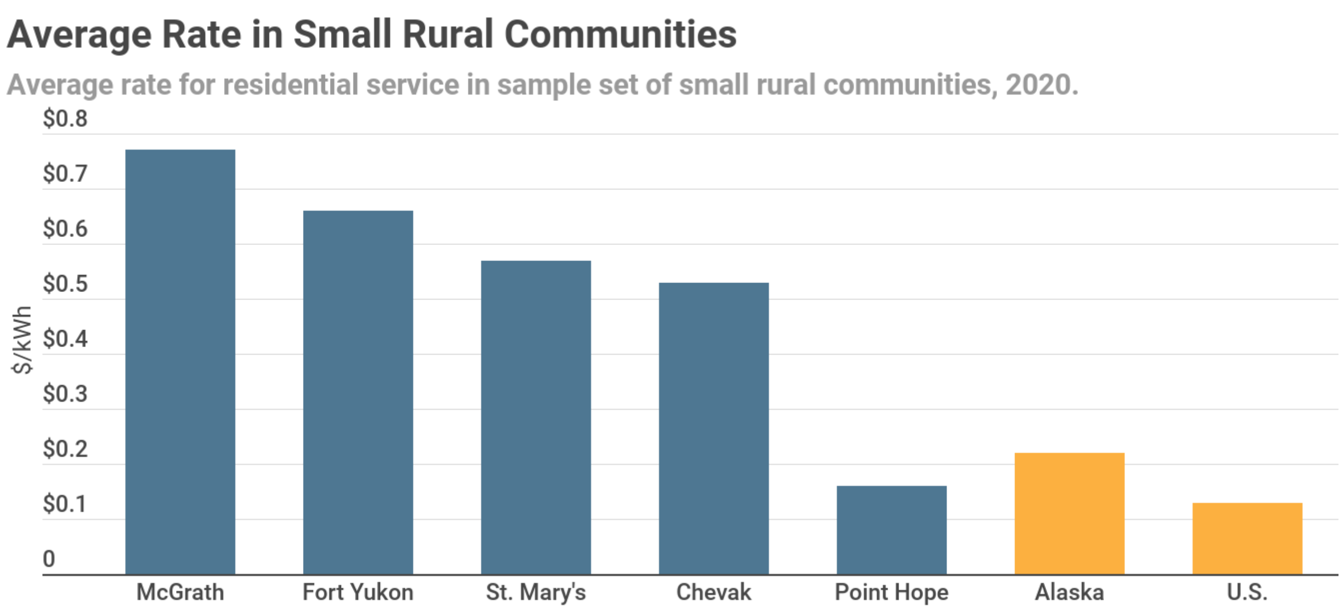

Figure 10: Average Rates for Residential Service in Sample Small Rural Communities.
Source: RCA, 2019.

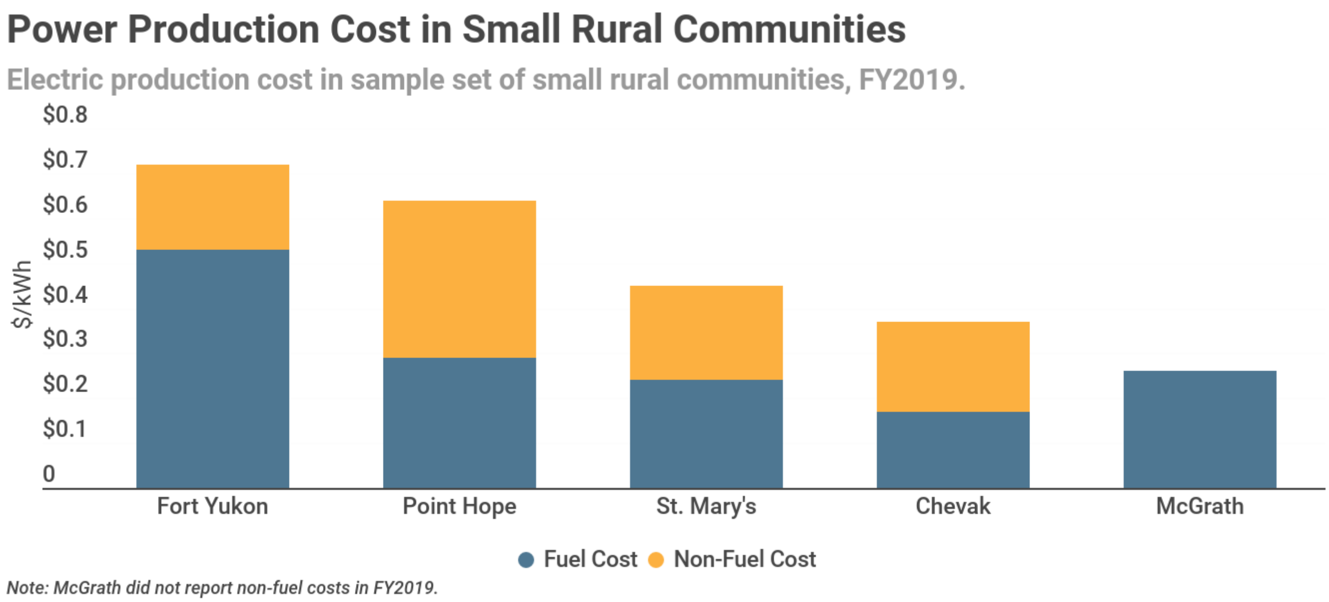

Figure 11: Power Production Costs for Sample Small Rural Communities.
Source: AEA, 2019.

Diesel generation systems' high cost and variability is balanced by the relative dependability and operational ease of such familiar technology. A common refrain across Alaska is "diesel is easy", meaning the comfort level with the technology and supply chain dynamics are solid and understood. In addition to government and tribal support services providing technical assistance to energy providers, supply chain systems have been built throughout the state to serve the multitude of remote diesel systems in servicing, operation, and repair.[11] Similar systems are only now starting to emerge to support other energy systems, such as wind and solar technology.[12]

While diesel is a known technology with widely understood maintenance needs, it should be emphasized that 'operational ease' is a relative term. Breakdowns and maintenance failures of diesel gensets are frequent problems leading to periodic, and sometimes extended, blackouts. The expertise to repair and maintain the engines exists within the state, but not in every small community. Rural villages experiencing breakdowns often require assistance from technicians who must fly to the community to fix a failing system.

Cost of power across rural Alaska communities is extremely variable, and the factors influencing that variability are inconsistent. For example, the chart above shows the breakdown of fuel and non-fuel costs for five remote communities. Figure 12 compares the annual electric production costs for Chevak and St. Mary's, two power systems operated by the same utility in western Alaska. Despite those commonalities the communities have cost structures which differ by approximately $0.10 per kWh. This can be driven by several factors: including the cost of delivered fuel, amortization of generation assets, maintenance costs, costs associated with transmission, and more.[13]

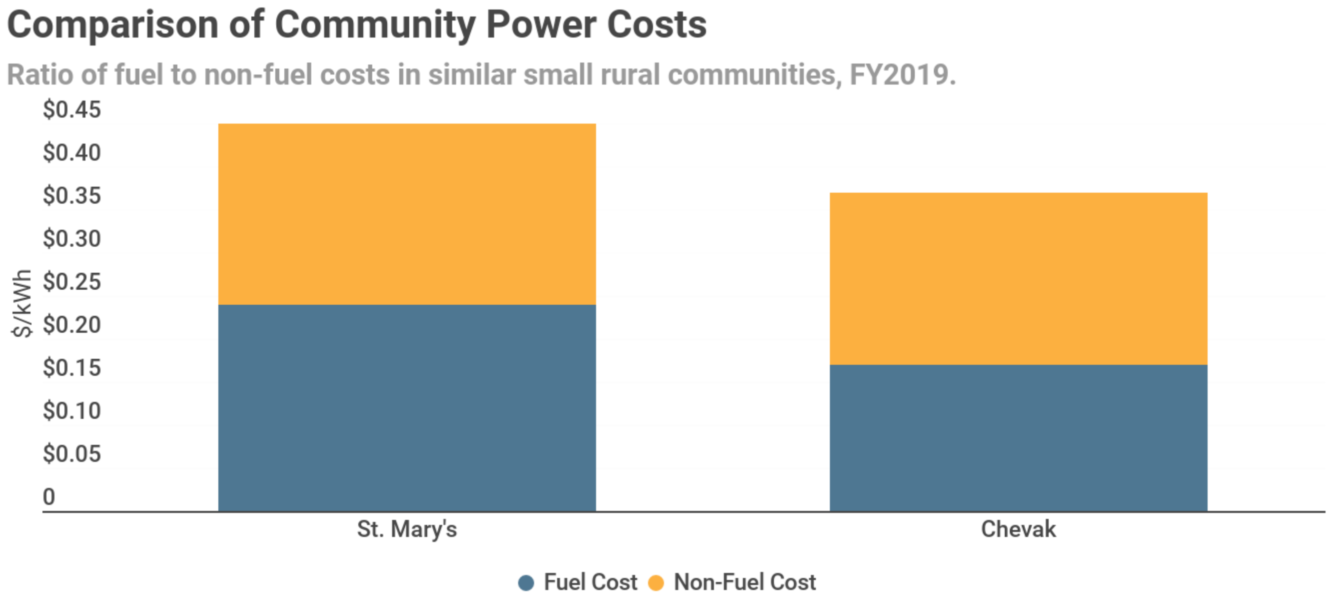

Figure 12: Comparison of Community Power Costs for Small Rural Communities. Source: AEA, 2019.

However, in some cases access to transportation and logistical networks helps drive down operations and maintenance costs. For example, fuel delivered by barge is almost always cheaper than fuel delivered by aircraft.

Heat

Heat remains an area of the energy landscape in rural Alaska that has seen less attention than electric. Heating fuel is the most common heat source across rural Alaska; however, wood and, in some circumstances, coal are also used for residential heating. Larger facilities, such as the city government and public-school systems, purchase heating fuel in bulk, lowering the cost of heat by a certain amount. Residents purchase heating fuel from public or private distributors. Figure 13 presents a sample of heating fuel costs from the communities referenced above.

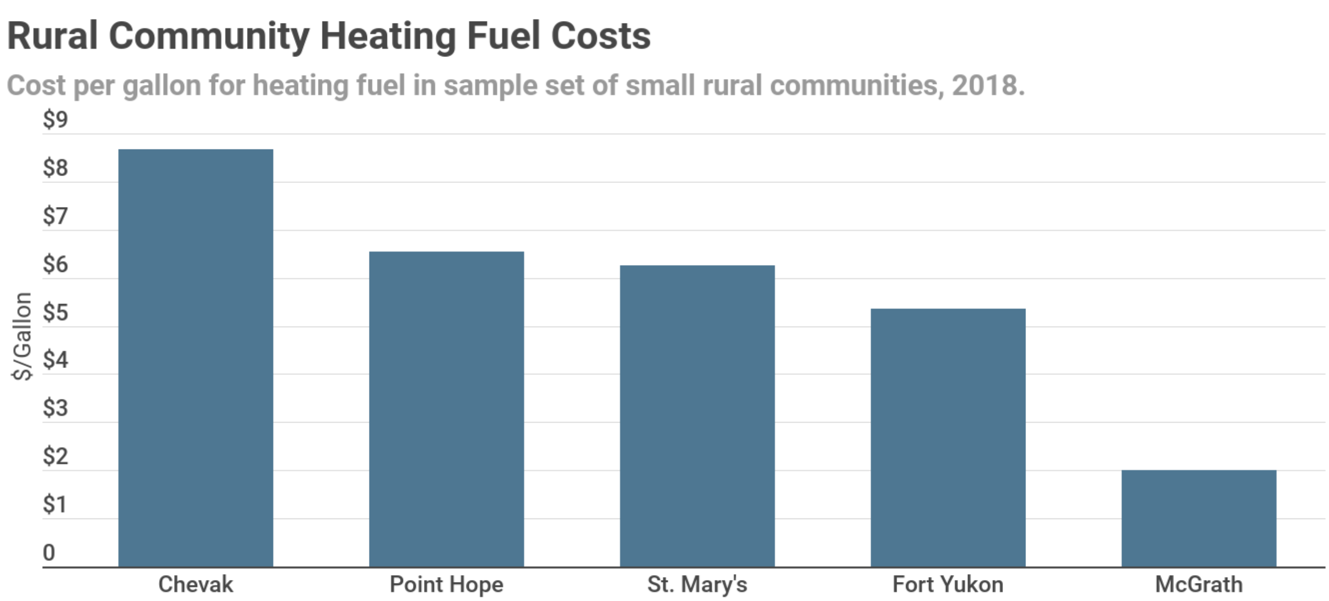

Figure 13: Heating Fuel Cost in Sample Small Rural Community. Source: Division of Community and Regional Affairs (DCRA), 2018.

To provide an example of the costs associated with heating a single residential building, heating fuel in McGrath was recorded at $8.68 per gallon in 2018.[14] The average annual heating degree days in McGrath is 13,916 days.

The most recent reported heating fuel consumption for McGrath showed the community consumed 108,000 gallons of fuel for residential heating purposes.[15] Using those numbers, it cost approximately $937,440 in 2018 to heat residential buildings in McGrath.

Efforts have been made to use recovered heat from diesel generators to heat community buildings, power houses, water treatment facilities, and washeterias. Energy efficiency and weatherization projects across the state have made steps toward heating fuel savings; however, work remains in this area.

District heat infrastructure is limited across rural Alaska. District heat, and water systems, face a number of challenges in rural communities. The first reason for this is the high cost of constructing rural infrastructure. The second is due to extra considerations to accommodate permafrost, which inhibits construction of underground utility corridors.

Investigating Alternatives

Leaders from many rural communities have expressed a vested interest in expanding their renewable and alternative energy generation portfolio. Interest in this comes from several angles.

- **Sustainability:** Climate change is a reality in Alaska, with particular impacts in rural areas. As such, many utilities have set goals to reduce emissions.[16]
- **Dependence on fossil fuels:** Diversification of generation assets increases community resilience by reducing dependence on a single energy source. Even with renewable energy asset integration in some communities, most rural communities are entirely dependent on a single resource -- imported diesel fuel.
- **Maintenance and operation:** Both routine and non-routine maintenance can present a technical challenge for small rural energy producers. Maintenance failures for diesel and non-diesel technology may require technicians to fly in from outside the community, causing repair delays and high costs.
- **Supply chain independence:** Imported diesel presents a logistical and financial hurdle for many utilities. The energy supply chain is dependent on a small number of diesel suppliers who deliver fuel in the non-winter months. Deliveries are subject to the variability in weather and ice conditions.[17]
- **High cost:** Power costs and heat costs are high in rural Alaska. In remote communities, costs per kWh are approximately double costs in urban Alaska. Fuel costs and operations and maintenance costs are two variables which influence the end costs realized by energy consumers. Remoteness, fuel delivery infrastructure, bulk purchasing capability, workforce costs, and more, drive these high costs for community utilities. In the heating realm limited competition in fuel retails create an extra layer influencing heating fuel costs
- **Cost variability:** In addition to the high cost per gallon of diesel fuel used to power the energy system in rural Alaska, diesel costs are also highly variable. That variability presents a hurdle for utility planning.[18]

Many rural utilities are investigating and installing alternative energy sources and detailed energy plans and resource studies exist at both the regional and local levels. One key player, the Alaska Energy Authority (AEA), has appropriated more than $257 million toward investigating and installing renewable energy capacity across rural Alaska through the Renewable Energy Fund (REF). More than 55 projects have been completed with REF funding.[19] However, momentum has stalled due to State of Alaska budget issues.[20]

Progress toward integrating renewable capacity has largely been limited by resource availability, variability, cost, and access to storage technologies. All of these are issues that all utilities struggle with, but are more pronounced at the small scale of rural Alaska utilities.

Microreactor Themes and Perspectives

Due to the variability and availability of renewable resources, full replacement of diesel fuel through renewable integration remains unlikely for the foreseeable future for many communities. In order to entirely replace diesel generation in small rural hub communities, alternatives to traditional renewable resources and advanced technologies will need to be deployed. However, those technologies will need to meet the existing system requirements present in communities across Alaska

The size range for the advanced microreactors being developed is wide. Systems could range from 1 MW(e) to 20 MW(e) with additional potential heat capacity.[21] While these represent extremely small systems for most electrical grids in the US, without finding opportunities for other dispatchable loads (heat and transportation), even a 1 MWe system could be outsized for many rural communities.

Many technical and regulatory specifications of microreactors remain unknown and will be determined as the technology moves through the permitting and testing phases. While the high cost of power in small rural communities makes them an attractive market for deploying emerging energy technology, some of the technical requirements microreactors may make remote operation complex. Microreactors will likely need to include but are not limited to the following characteristics:

- Load-following capabilities.
- Autonomous operations or minimal operating requirements with remote operations capabilities.
- Design specifications accounting for high levels of earthquake activity and permafrost characteristics.
- Minimal construction footprint and security requirements.

Utility operators and energy stakeholders interviewed for this report noted that when making technology decisions, comfort level has historically been an important factor. Microreactors are still in the technology testing stages; therefore, establishing a certain degree of comfort with the technology will be critical for motivating customers. Factors to consider could include:

- A robust understanding of lifetime costs and operational processes.
- Established plans for the life of the reactor: including installation, fueling, and disposal.
- Clear processes for fuel transportation and disposal.
- Emergency preparedness and disaster mitigation planning.
- Processes for technology support and system repair and maintenance.
- Understanding of federal and state regulatory requirements.

Use Case: A Hypothetical Rural Community

Consider a hypothetical rural community along the Yukon River in the interior of Alaska. The town has a population of 200 people, roughly half of which are of working age. The community is predominantly Alaska Native and subsistence activities play an important role in the lives of most residents. The community is able to get fuel delivered by barge twice a year depending on river conditions. Depending on the winter and springtime weather, the community has been known to experience seasonal flooding as the ice breaks up on the river and erosion along the banks of the river. The community has considered relocating, but no significant action has been taken.

The utility is owned by the local tribe and is considering its options for integrating renewables into its energy system; furthermore, the utility is planning for an overhaul of its aging powerhouse. The community has asked its regional energy planning organization for assistance in assessing its options and recently finished an energy resource study.

Economic and Housing Information

Local government is the largest sector of employment in the community, followed by trade, transportation, and utilities, and education and health services. The utility plays an important role in the community as an employer and enabler of other economic activities. There are limited businesses in the community and the bottom line of those businesses is closely tied to electricity availability and costs.

Traditional employment opportunities are limited in the community and the unemployment rate is high. However, subsistence practices play an important cultural and economic role in the community.

Median annual wage in 2019 was approximately $20,000. In addition, roughly 70 percent of the residents meet the criteria for being economically 'distressed'.[22] Twenty-two percent of households are considered 'cost-burdened' or 'very cost-burdened'.[23] Figure 14 compares the percentage of cost burdened household in the community to the statewide average.

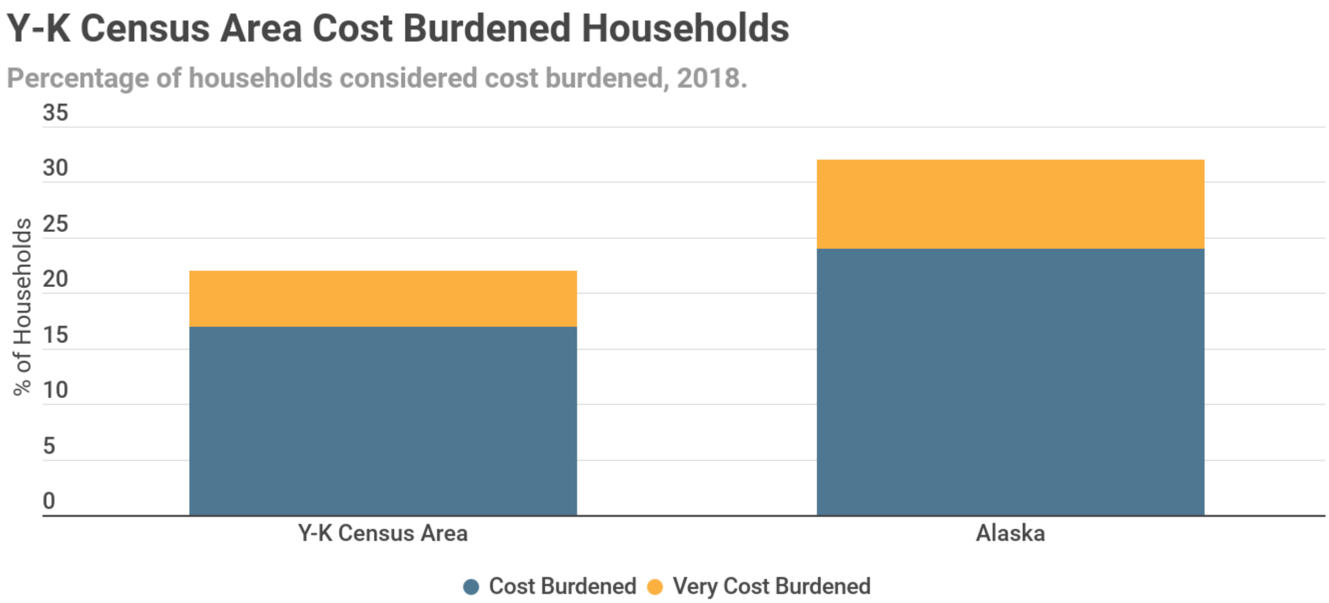

Figure 14: Cost Burdened Householding in the Yukon-Koyukuk (Y-K) Census Area.
Source: AHFC, 2018.

Housing conditions are poorer than state averages. Rates of overcrowding remain higher than the statewide average at 15 percent. Figure 15 compares the regions overcrowding to the statewide average. Conditions in existing housing units are poor. Sixty percent of housing units are considered drafty or very drafty, with 18 percent of the community's homes achieving a one-star energy rating. Almost 40 percent of the homes in the community have incomplete plumbing.[24]

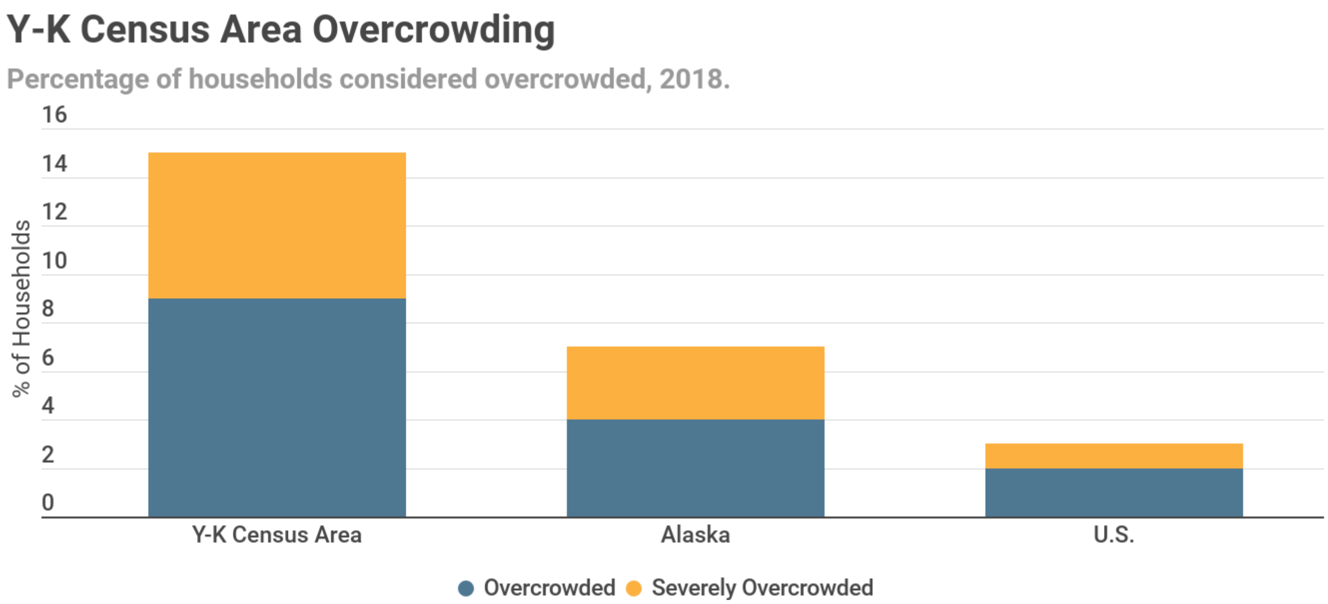

Figure 15: Overcrowding in the Y-K Census Area.
Source: AHFC, 2018

Energy efficiency efforts focused on community buildings and the school has reduced the community's energy load. Energy efficiency retrofits were funded through state and federal grant programs. Figure 16 compares energy efficiency in the region to Alaska as a whole.

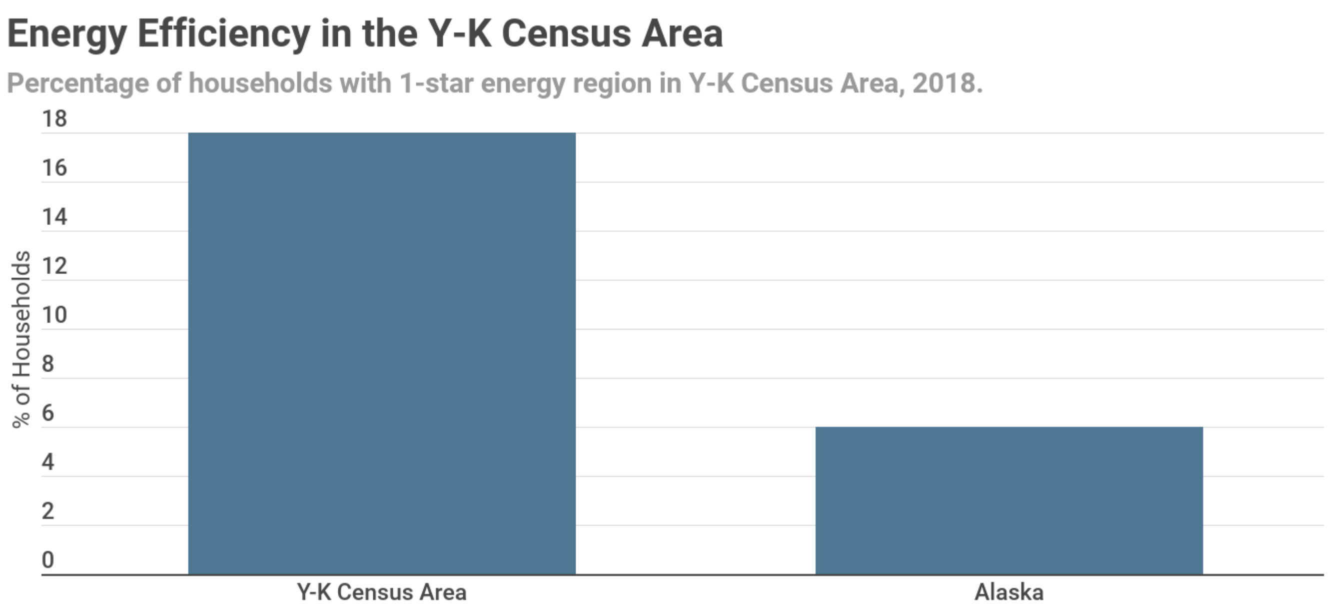

Figure 16: Homes with 1-Star Energy Rating in Y-K Census Area.
Source: AHFC, 2018

Region and Climate

The interior region of Alaska is one of the largest and most diverse regions of Alaska. It spans from the mid-Yukon to the Canadian border. In the Yukon-Tanana subregion, the climate is in the continental climate zone and is characterized by extreme temperatures. Temperatures are warm in the summer and extremely cold in the winters.

Energy System

Electric

The community utility operates an aging diesel system. The utility is planning for a powerhouse replacement in the next five years. The design for the new powerhouse is a modular unit built in Anchorage and shipped to the community. The current system does not operate any heat recovery; however, the new generators will include a heat recovery system which will be used to heat the community washeteria. The utility is working with the Department of Energy Bureau of Indian Affair for technical assistance in designing and executing the project.

The energy study commissioned by the community showed few locally available renewable energy resources. Solar energy systems with installed energy storage assets provide the best renewable energy option for the community; however, solar will only provide partial diesel displacement mostly in the summer months.

The system has a maximum capacity of 2.5 MW with five 0.5 MW generators which can be turned on or off to accommodate system needs at any given time. In 2019, the utility sold 2,000,000 kWh of power. As PCE program participants, power costs are subsidized for residential customers for the first 500 kWh and for approved community facilities. Figure 17 presents the composition of power customers for this sample community.

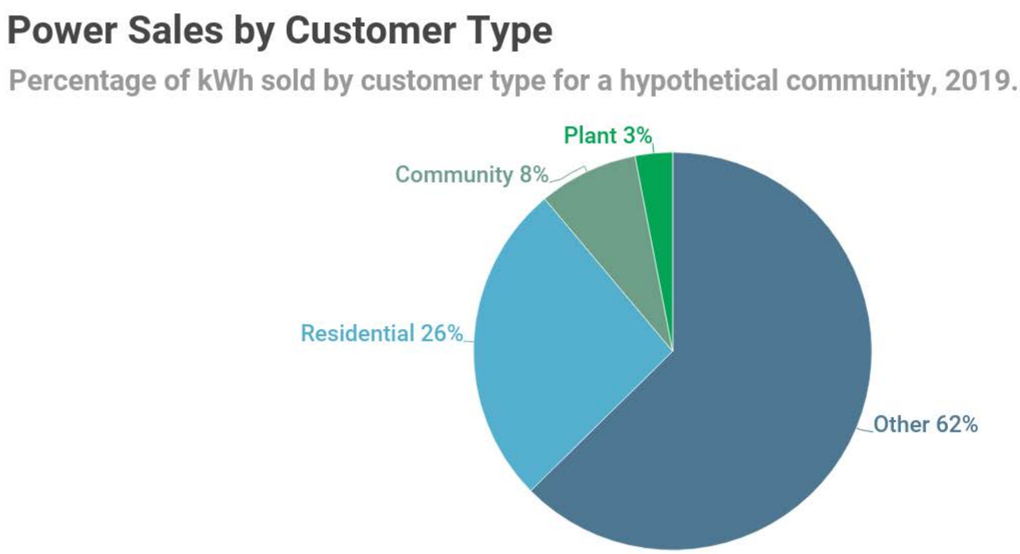

Figure 17: Hypothetical Community Energy Sales by Customer Type.
Source: AEA, 2019

The system is run by three plant operators, with two office staff supporting management activities and billing. A stated challenge the utility grapples with is access to capital when high cost items are needed. The utility generates enough revenue to cover operations and most maintenance costs but is unable to fund large infrastructure projects such as a new generator. The new powerhouse is expected to be funded through a patchwork of grants and loans.

Administrative operations are a challenge. As a small community the labor pool is limited and access to candidates with specific skill sets is limited without in-house training. Finance skill sets specific to utility operations can be a niche, and PCE reporting requirements add a layer for which there are few training programs.

The system primarily serves residential customers, community facilities, and small commercial customers. The community hosts a clinic which requires uninterrupted power. There are no 3-phase energy users and the daily energy demand to the system cycles according to daily and seasonal residential demand patterns.[25]

Power costs in the community are high, even with PCE subsidization. The Table 2 below shows energy cost characteristics for this hypothetical community. Note, Figure 18 shows that the average rate is higher than the cost per kWh experienced by the utility. Rate setting in rural Alaska is not always indicative of the present costs of utility operations. Rate calculations and design occur infrequently, if at all, compared to urban Alaska and the U.S. as a whole. However, the utilities rates remain the best way to gage the costs realized by customers.

Hypothetical Community Energy Cost Characteristics	
Total Power Costs ($/kWh)	$0.65
Non-Fuel Cost ($/kWh)	$0.35
Fuel Cost ($/kWh)	$0.30
Residential Average Rate - Pre-PCE ($/kWh)	$0.75
Residential Average Rate - Post-PCE ($/kWh)	$0.35

Table 2: Hypothetical Community Energy Cost Characteristics.
Source: AEA, 2019

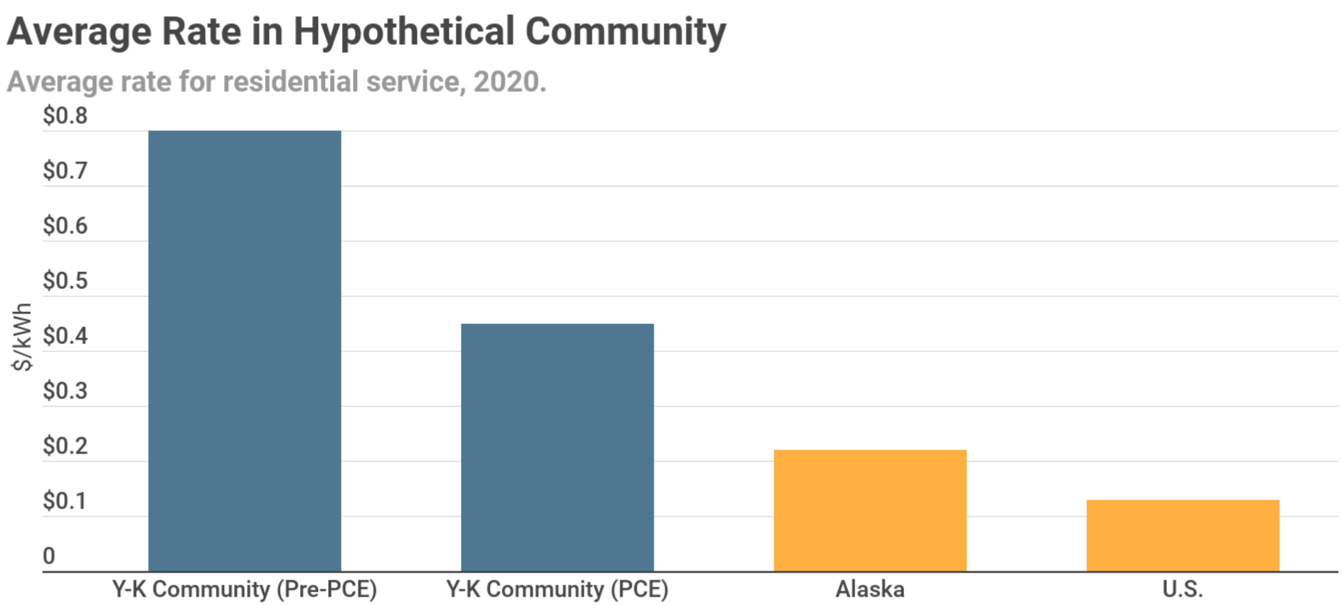

Figure 18: Average Power Rate Comparison.
Source: AEA and EIA, 2019.

Heat

Community heating needs are met through a combination of diesel heating fuel and wood harvested from the surrounding area. Figure 19 presents the makeup of heating fuel usage in the community. The retail rate for heating fuel ranges from $5.50 to $6.50, and the community only has one local fuel retailer. There is some concern over air quality issues from inefficient wood burning.

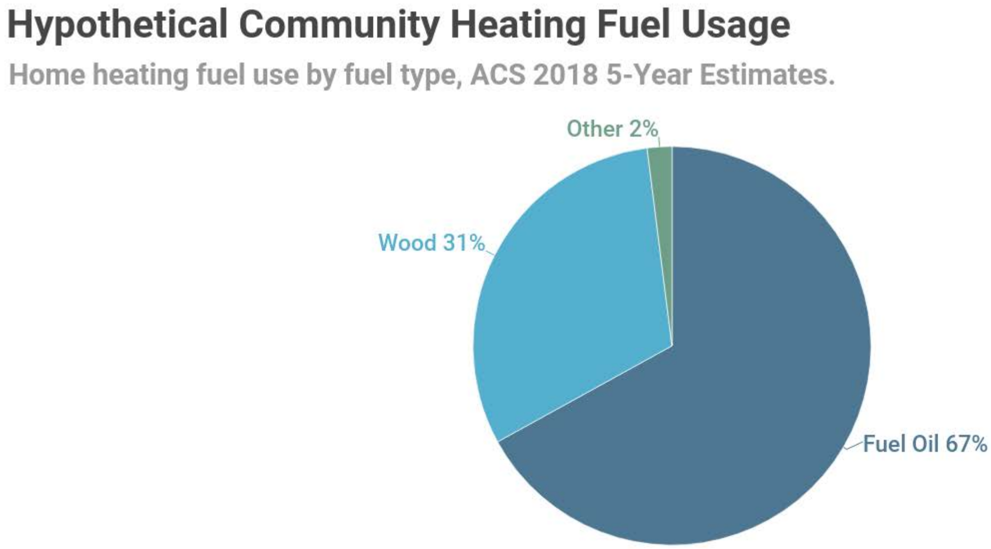

Figure 19: Hypothetical Community Home Heating Fuel Use by Fuel Type.
Source: ACS 2018 5-Year Estimates.

The school operates a biomass boiler which was installed a decade ago and heats the school buildings. Other community buildings, such as the city and tribal offices, washeteria, and others, make bulk fuel purchases at a lower per gallon rate.

Energy Technology Market Drivers

The community electric utility is owned by the local tribe and, therefore, is unregulated. The community participates in the PCE program and makes filings to the State of Alaska to justify allowable costs for the program. Key going concerns for the community and utility management include: cost, operational ease, reliability, and decarbonization, all of which drive operational and technological decisions.

Cost: Costs are one of the clearest drivers of decision-making processes as the community's primary goal is lowering or stabilizing the cost of power. Decisions about generation technology are made through considering the upfront capital costs and long-term operations and maintenance costs and fuel costs (if applicable). Access to capital is a challenge and the utility does not have cash reserves to put toward large infrastructure projects. Funding programs can play a role in some technology decisions and the community has utilized State of Alaska, Department of Energy, Bureau of Indian Affairs, and U.S. Department of Agriculture grant programs and funding mechanisms for past projects.

Technical Capacity: Technical capacity is limited within the community and surrounding areas. Currently, plant operators have the training to operate the installed diesel and conduct routine maintenance activities; however, the skills and confidence required to diagnose and resolve non-routine issues are limited. Therefore, operational ease of any energy system is critical to the success of any energy project. Training to operate new energy systems will likely need to occur no matter the technology integrated, which could place a cost burden on the utility.

Reliability: Reliability is a major going concern for the community. The utility has struggled with outages related to aging transmission infrastructure, an especially critical concern in the winter. The utility operates on a N+1 principle of redundancy, meaning if any one generator needs to be shut off, there is enough redundant capacity to meet peak energy demand. In Interior Alaska, where winter temperatures can frequently reach negative 50 degrees, reliability of the power system is also a critical health concern. Reliable power is tied to healthcare and food systems, as well as local water supply and more in the community.

Sustainability: The community has experienced the adverse effects of climate change through impacts to subsistence resources and erosion; therefore, decarbonization is a strong motivator toward reducing dependence on fossil fuels. However, another strong driver is reduction of the risk of environmental contamination from fuel spills. The community discussed here has limited fuel delivery infrastructure and aging fuel storage tanks. Fuel spills have created a number of contaminated sites in the community which have only been partially cleaned and reclaimed.

Familiarity: Comfort with a given energy technology has been a driver away from renewable energy adoption in the community. One of the benefits of diesel generation technology is that the system technology is well known and broadly utilized; therefore, maintenance and operations issues are well known. The community is wary of the time and financial resources necessary to operate emerging technologies.

Market Fit for Microreactors

Technical Capacity and System Fit

The hypothetical small rural community discussed here operates an extremely small energy system. Without industrial power users, the utility serves an energy load which is largely dependent on residential energy demand characteristics. The advanced nuclear technologies under development would need to accommodate the existing power demands in many small rural communities. This likely includes: load following characteristics, remote or autonomous operation, 'plug-and-play' capabilities suited to the existing distribution infrastructure, minimal operational and security requirements, and a low impact footprint which considers geological activity and permafrost characteristics.

In a small, consolidated community such as the hypothetical one discussed here, there are opportunities for electrification of consistent dispatchable loads. Heat and transportation are two areas that could be electrified. Microreactor developers have noted the recovered heat potential of the systems under development could be used to heat district heating loops. Further excess energy could be used as an electric heat source. Additionally, with an isolated road system, mobility systems could be transferred to electric vehicles and ATVs.

Ownership Models

There are several ownership models for integration which could provide varying levels of technical fit for nuclear reactors: utility operation and integration, contract operation, and power purchase agreement with commercial operators. Each of these models could be viable in a rural setting and each addresses challenges which rural utilities face. However, maintaining local hire and operation of the community's energy system is likely to be an ongoing point of interest, and microreactor operating models should be designed with that in mind. Table 3 compares some of the advantages and disadvantages of different ownership models.

Microreactor System Ownership Model		
Ownership Model	**Advantages**	**Disadvantages**
Utility operation and integration	• Community control • Retention of local hire	• Operational complexity • Need for retraining • High capital cost
Contract operation	• Less operational liability • Specialized support	• High capital costs • Potential loss of local hire
Power purchase agreement	• Specialized support • reduced operational liability • Potential costs spread over lifetime of reactor	• Loss of local hire • Limited community control

Table 3: Microreactor System Ownership Models.

One of the concerns of the hypothetical community discussed here is the operational liability associated with microreactors. The regulatory and operational requirements of microreactors is as yet unknown. Any number of requirements placed by the U.S. Nuclear Regulatory Commissionpercent and by the technology developers could present a hurdle for the community. Unknowns around operational and security requirements and physical requirements could present a hurdle for the community.

Financial Fit

In our hypothetical community in interior Alaska, the rate for electricity is $0.75 per kWh. Only a portion of the realized cost to customers includes variable cost which could be replaced through integrating a microreactor.[26] The cost of power for the utility is a function of generation, distribution and transmission, and administrative costs. Cost replacement could occur for fuel costs and operations and maintenance costs (generation costs). In the community discussed here, 57 percent of the utilities' annual costs are associated with diesel generation and could be replaced by costs related to an alternative energy source.

An additional consideration is that historically, integration of alternative energy technologies in rural Alaska has had little to no impact on the energy costs of residential customers. This is a product of the PCE subsidy calculation. In the community discussed here, energy rates after applying PCE subsidies for residential service is $0.35 per kWh. Potential savings from implementing microreactors would likely only be passed on to residents using in excess of 500 kWh a month and commercial energy users, such as local small businesses.

Given the unknowns and technical hurdles associated with integrating the technology, it is likely that the cost savings would need to be significant for the community. In addition, community education around the impact to energy rates would likely need to be robust.

There is little published cost information on the cost per kWh to provide a robust financial analysis, but initial NEI estimates that the first 50 microreactors deployed could produce energy at costs range as high as $0.40 per kWh in remote communities to $0.10 per kWh in Alaska's Railbelt.[27]

Rudimentary financial modeling using information published by NEI and Alaska energy data, shows that the financial fit of microreactors in remote markets will be sensitive to upfront capital costs and refueling frequency and costs.[28] Financial data on microreactors is still undeveloped, making a thorough analysis for the hypothetical community difficult; however, understanding the key variable helps to reveal potential barriers to technology adoption. Access to capital to fund large infrastructure projects is a stated challenge in the hypothetical community. The community has utilized grants to subsidize infrastructure projects. Future creativity in assembling capital resources may be needed for a microreactor project.

Perception Fit

General understanding of nuclear technology in the hypothetical community discussed here likely mirrors the U.S. on average. Public awareness of nuclear energy has been tied to examples of the worst possible scenarios (i.e. Fukushima and Chernobyl). The utility manager and community leaders have discussed microreactors as a potential energy option but too many unknowns exist for definitive opinions to have developed.

Risk of environmental contamination is a prevalent concern across rural Alaska. Instances of point source environmental contamination in the community discussed here have had an impact on subsistence resources and influenced the community's perception on environmental remediation. Plans for a nuclear reactor would need to consider the entirety of the reactor's lifespan and would need to be in place well in advance: including specifics on safety measures, fuel disposal, cleanup procedures, and more.

It is impossible to generalize all rural communities under a single umbrella of public perception. Different communities have varying experiences with environmental contamination, investment in their energy systems, and attitudes toward energy technology risk. Any one of these factors could influence perceptions toward integrating microreactor.

In a community like the one discussed here, public acceptance of a nuclear project could likely require a broad and thorough education program. Points of education could include understanding of the technology and its difference from traditional nuclear, understanding the environment and physical security risk and mitigation measures, clear planning and agreement around disposal of nuclear waste, processes for fuel delivery and transportation, planning and environmental cleanup measures in case of incidence and more.

Given the community's attitudes toward adopting experimental or early stage energy technologies, there is an apparent aversion toward being the first user of microreactors. Like many rural energy stakeholders, community officials and energy operators may prefer to see the technology tested and deployed in urban Alaska or elsewhere to observe the functionality and success of the technologies before implementing it in communities.

Small Rural Community Energy Value Propositions

Current Value	**Barriers:**
• Heavy dependence on diesel fuels. • High cost of power. • Small consolidated system allowing for heat and power functions. • Strong support of movement away from fossil fuels and energy diversification.	• Availability of workforce and specialized technical skill sets. • Extremely small system size could force a heavy reliance on single technology. • General attitudes toward nuclear among the public and fear of risks. • Concerns over external environmental issues (i.e. earthquakes, erosion, and permafrost melting). • Undetermined regulatory hurdles, and operational and security requirements.
Future Opportunities:	**Challenges:**
• Electrification of consolidated transportation systems. • Distributed district heating. • Electrification of heating systems.	• Access to capital. • Aversions to implementing untried technologies. • Characteristics of small system cycling. • Perception around risk of nuclear contamination and waste disposal.

Table 4: Small Rural Community Energy Value Propositions.

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