MICROREACTORS IN ALASKA

Use Case Analysis: Rural Hub Community

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Table of Contents

Table of Figures

Table of Tables

Rural Hub Community Customer Analysis

Alaska's energy landscape can be roughly divided following two separate characteristics. The majority of Alaskans live on the Railbelt. Outside of the Railbelt, the energy systems across the state are made up of micro-grids which range in size from 0.5 MWe to 85 MWe in installed capacity. Alaska is home to over 100 very small micro-grids serving communities with fewer than 500 residents isolated from the road system with air and, sometimes, barge access.

The larger range of these very small systems include handful rural 'hub' communities, which have larger energy demands and more complex systems. They serve as transportation and administrative centers for surrounding villages, and have populations numbering in the thousands rather than hundreds. These hub communities are scattered across interior, southeast, western, and northern Alaska and range in size from approximately 10 MW(e) to 25 MW(e) of installed capacity.[1] Figure 1 maps the installed power capacity across hub communities.

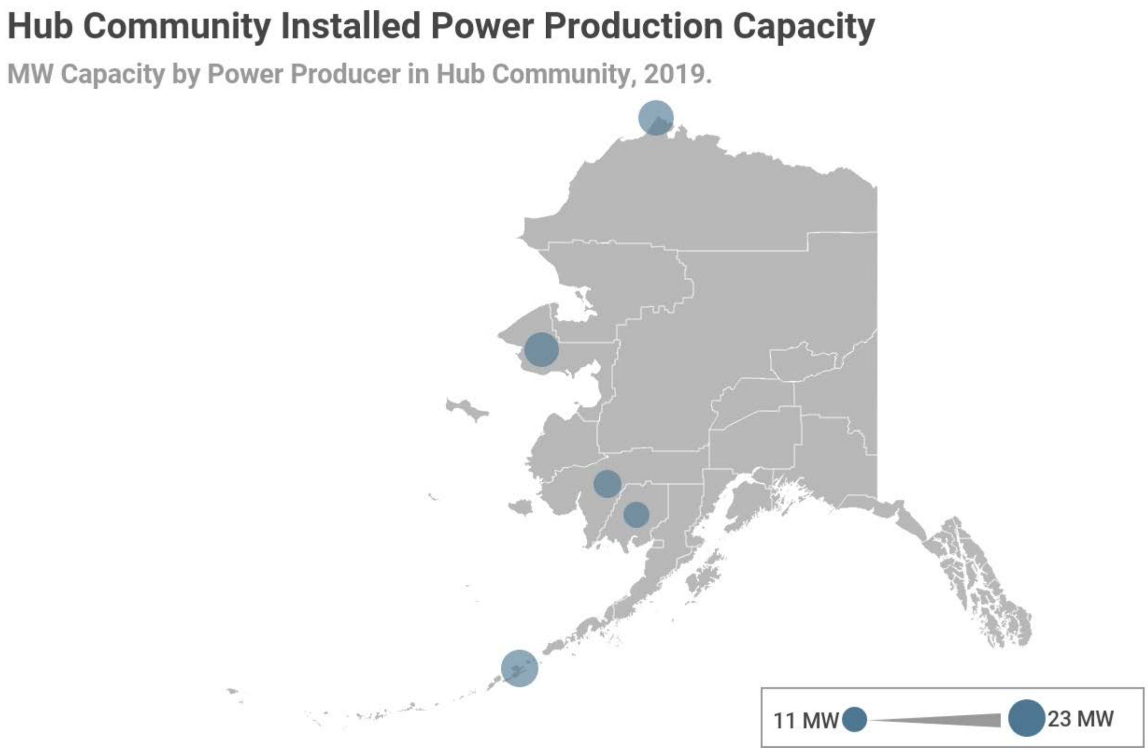

Figure 1: Hub Installed Power Capacity.
Source: Energy Information Agency (EIA), 2019.

Population and Demographics

There is no cohesive definition for a hub community. One of the most common definitions includes population; however, others include criteria for communities to serve as a regional services hub. Table 1 below is a list of some of the rural communities that can be considered regional hubs for the purposes of this analysis.

Hub Community Population	
City	**Population**
Unalaska	4,592
Bethel	6,259
Dillingham	2,327
Nome	3,690
Utqiagvik	4,536
Kotzebue	3,112

Table 1: Hub Community Population Size.
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; however, hub communities do have access to a larger labor pool than the small villages of rural Alaska. Table 2 shows a sample of the largest employment industries in three hub communities: Dillingham, Kotzebue, and Nome.

Hub Community Employment Characteristics	
Industry	**Number of Jobs**
Dillingham - Total	1,023
Educational and Health Services	401
Local Government	201
Trade, Transportation, and Utilities	193
Kotzebue - Total	1,357
Education and Health Services	370
Local Government	312
Trade, Transportation, and Utilities	230
Nome - Total	1,720
Education and Health Services	562
Trade, Transportation, and Utilities	276
Local Government	262

Table 2: Hub Community Employment Characteristics.
Source: AKDOLWD, 2016.

The ‘Trade, Transportation, and Utilities’ sector in each of the above referenced communities is among the top employers. A trend that is present across rural Alaska.

Unemployment rates are slightly higher in hub communities than the state average. Furthermore, poverty rates also tend to be higher than state averages. Figures 2 and 3 compare unemployment and poverty rates in several hub communities.

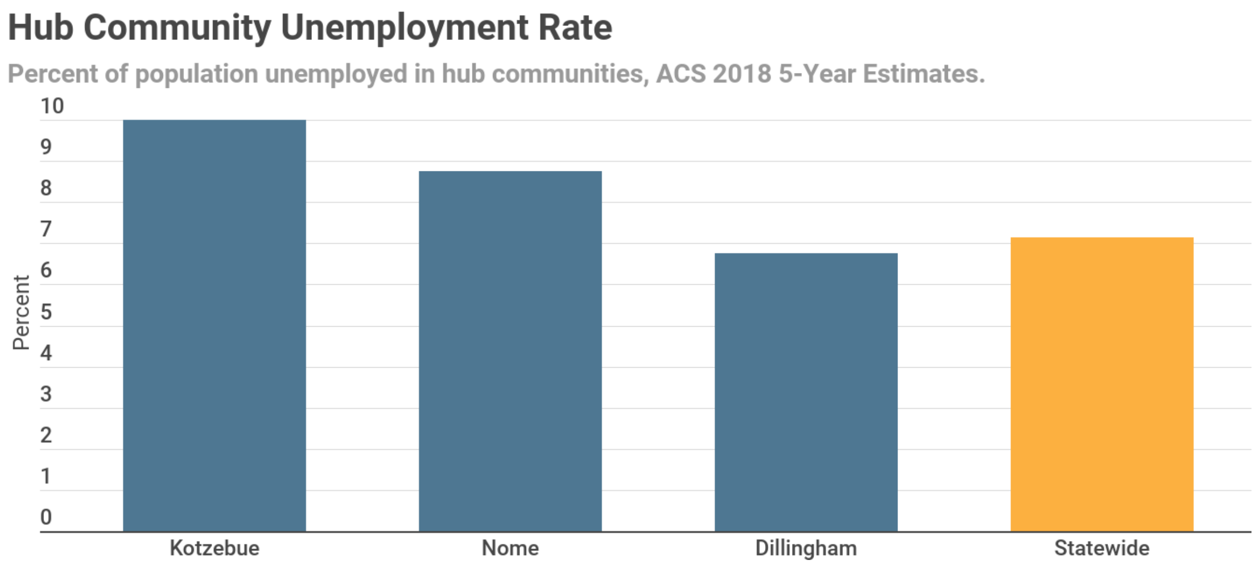

Figure 2: Hub Community Unemployment Rates.
Source: American Community Survey (ACS) 5-Year Estimates, 2018.

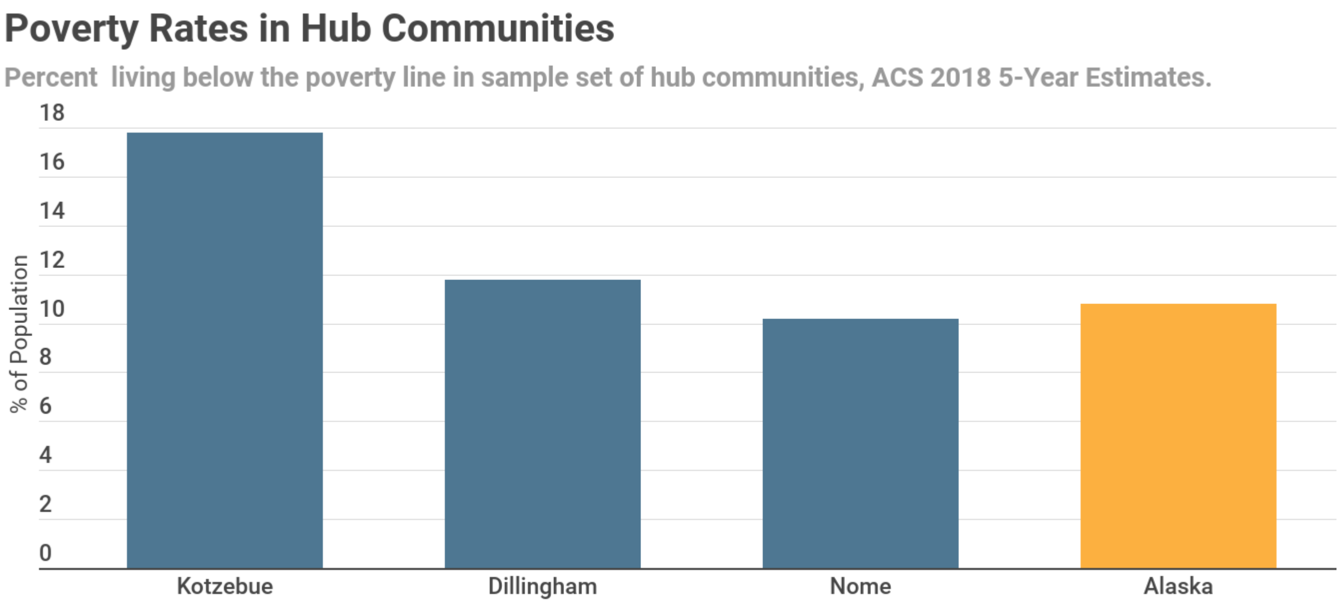

Figure 3: Hub Community Households Below Poverty Line.
Source: ACS 5-Year Estimates, 2018.

Current Energy Systems

Electric

Alaska's hub communities or Rural hub community power systems vary in size depending on the community size and industrial loads. In the previously referenced communities, roughly 35 to 40 percent of community electrical loads are made up of residential customers and community facilities. Table 3 discusses the power characteristics of several hub community utilities.

Hub Community Utility Power Characteristics			
Community	**Ownership Model**	**Power Cost per kWh**	**kWh Sales**
Dillingham	Cooperative	$0.36	18,144,633
Kotzebue	Cooperative	$0.39	19,495,001
Nome	Local Government	$0.31	29,802,574

Table 3: Hub Community Utility Power Characteristics.
Source: AEA, 2019.

Schools and health facilities represent larger community loads with individual energy priorities. Nome, Bethel, Utqiaġvik, Dillingham, and Kotzebue all host hospitals and play a critical role in their respective regional health systems.

Several hub communities host fish processors, which represent large industrial loads for many communities. Most processors operate seasonally, so their energy needs fluctuate annually. Figure 4 compares annual power sales by customer type for several hub communities.

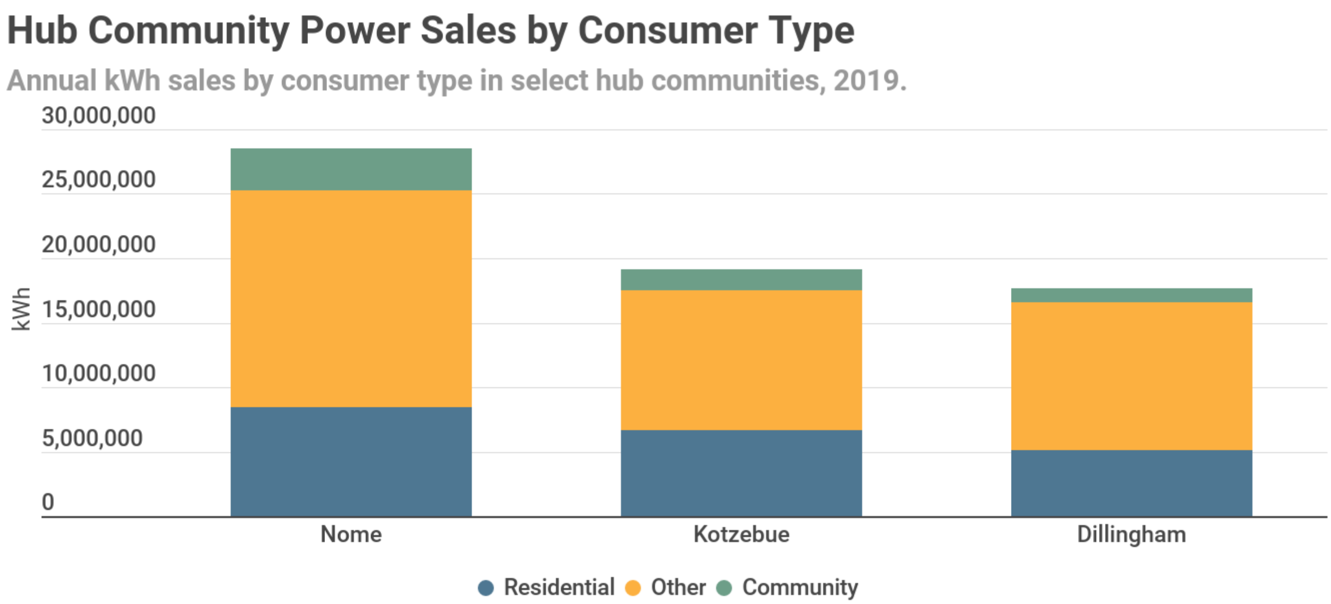

Figure 4: Hub Community kWh Sales by Consumer Type.
Source: AEA, 2019.
**Note: "Other" denotes all other kWh sales, which includes: commercial power users, non-PCE eligible community facilities, and power house usage.*

The ownership models of rural hub utilities vary, and include city ownership, co-op models, tribal ownership, and private ownership. Hub community utilities operate sophisticated systems and monitor a combination of generation assets and energy sources.

Western Alaska hub communities are mostly dependent on diesel fuels for power generation; however, several communities operate wind-diesel hybrid systems. Utqiaġvik, in northern Alaska, utilizes local natural gas resources for power production.

Given that even communities with large renewable resources are required to maintain diesel back-up systems for consistent output, most hub communities are subject to the variability and high costs of diesel fuel. Delivered cost of fuel is variable across hub communities. Figure 5 shows the breakdown in per kWh power production costs by fuel and non-fuel costs. Figure 6 compares hub community utility average residential rates.

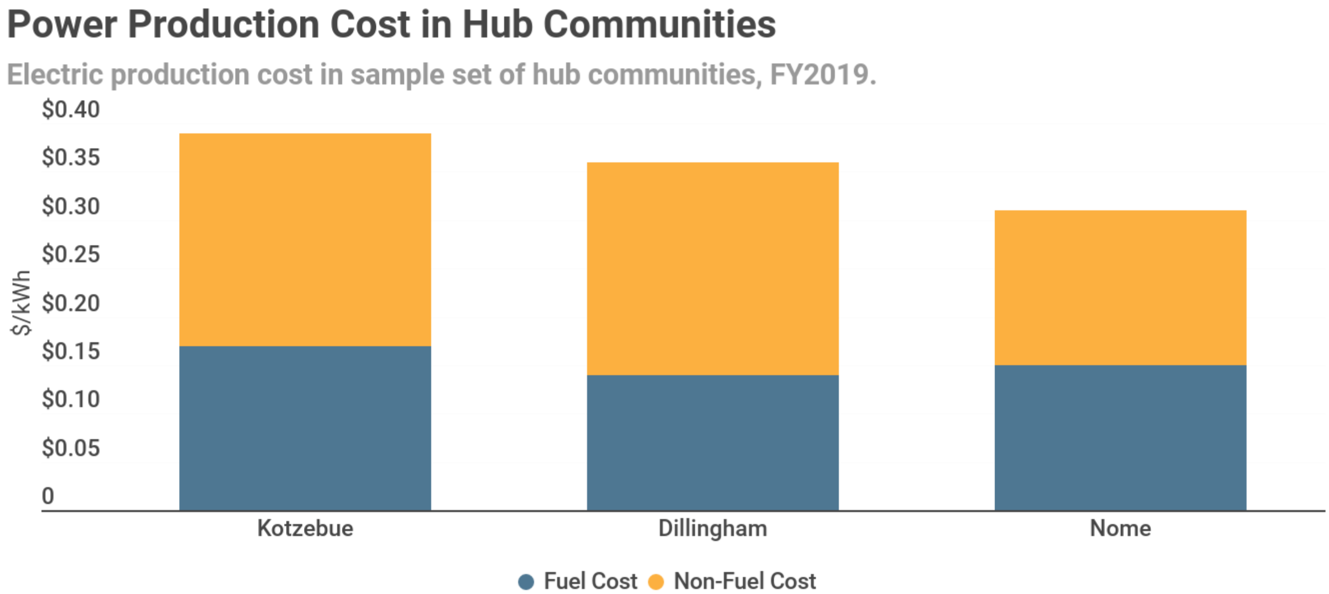

Figure 5: Utility Energy Cost per kWh.
Source: AEA, 2019.

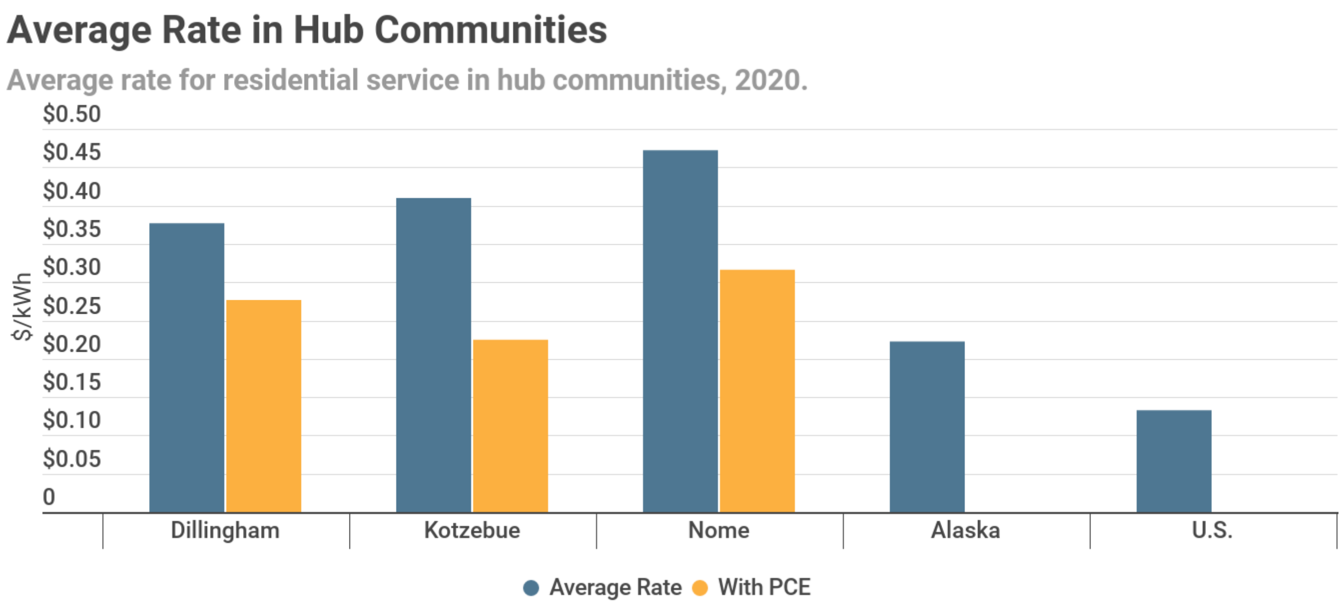

Figure 6: Hub Community Average Residential Rates for Service.
Source: Regulatory Commission of Alaska (RCA) and EIA, 2020.

Heat

Heating-related energy needs is an area of the energy landscape in Alaska that has received less attention than electricity. Across hub communities, heating fuel is used almost ubiquitously to heat homes, community facilities, and commercial facilities. Larger facilities, such as the city government and schools, purchase heating fuel in bulk, lowering the cost by a certain amount. Figure 7 compare heating fuel costs for several hub communities.

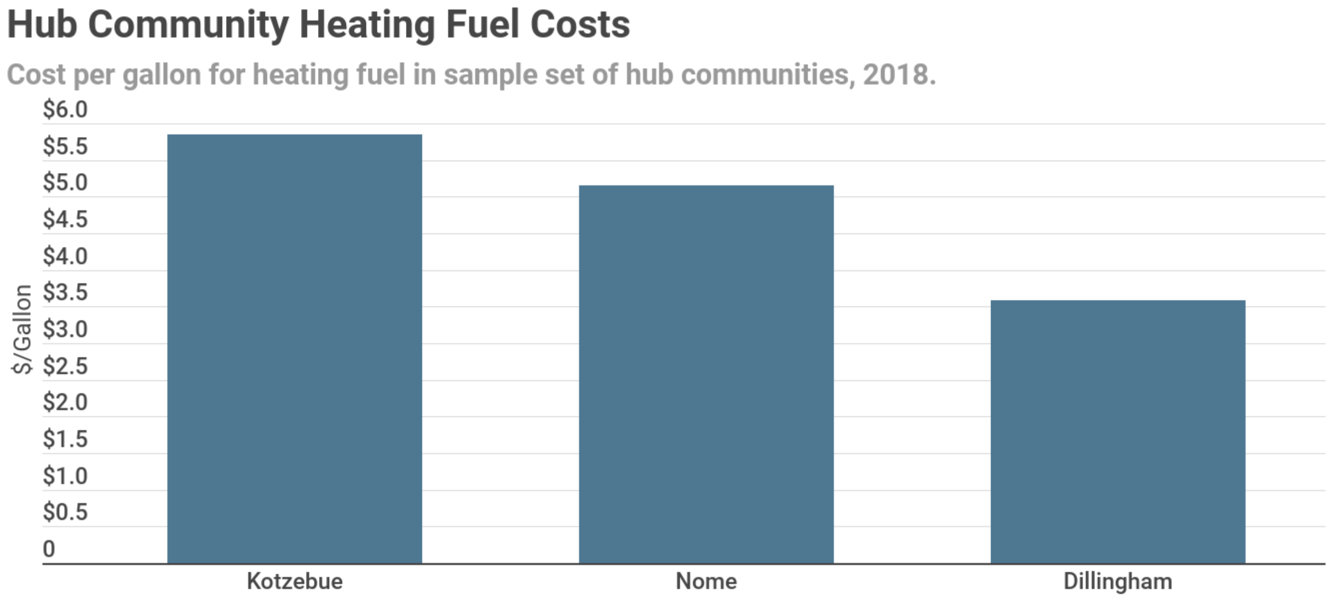

Figure 7: Hub Community Heating Fuel Costs.
Source: Alaska Division of Community and Regional Affairs (DCRA), 2018.

Residents purchase heating fuel from public or private distributors. Depending on available resources, residents in some communities use wood for residential home heating. Figure 8 shows estimated household heating fuel usage by fuel type for Nome and Dillingham.

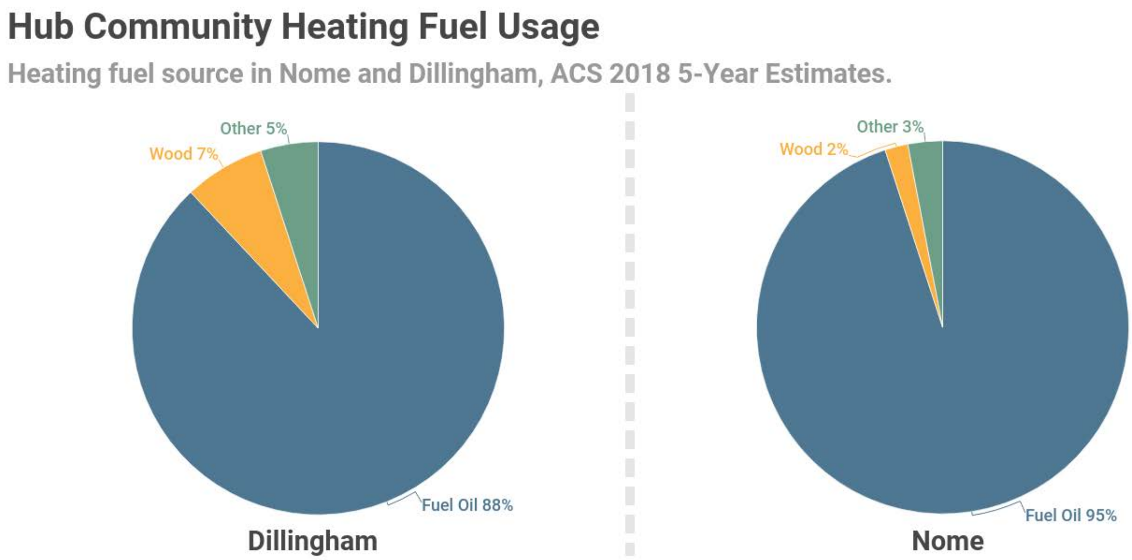

Figure 8: Hub Community Heating Fuel Source.
Source: ACS 5-Year Estimates, 2018.

Some communities have installed heat recovery systems to heat community buildings, power houses, and water treatment facilities. Energy efficiency and weatherization projects across the state have made steps toward heating fuel savings; however, work remains in this area, even in hub communities.[2]

Investigating Alternatives

Many rural hub communities have expressed a vested interest in expanding their renewable and alternative energy generation sources. Interest in this comes from various angles.

- **Decarbonization:** Climate change is a reality in Alaska, with particular impacts in rural areas. As such many utilities have set goals to reducing emissions.
- **Dependence on fossil fuels:** Diversification of generation assets increases community resilience by reducing dependence on a single, imported, energy source. Even with renewable energy asset integration in some hub communities many energy systems are entirely dependent on a single resource—imported diesel fuel.
- **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 enforced by weather conditions and ice conditions.
- **High Cost:** Power and heat costs are high in rural Alaska. In hub communities, energy 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 high costs for hub community utilities. In the heating realm, limited competition in fuel retailers 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.

Microreactor Themes and Perspectives

Due to the variability and availability of renewable resources, full replacement of diesel fuel through renewable integration is unlikely.

With their high cost of power, technical capacity, and average system size and base load, the hub communities would seem to be a likely candidate for an initial customer of microreactors; however, a number of rural hub utilities and energy stakeholders expressed reservations about adopting early stage technologies on a system with less resiliency or backup capacity. Interviewees noted that in the case of integrating wind technologies, hub community energy producers tended to be more risk averse. Some hub communities have chosen to track progress of early adopters of wind-diesel technology to learn more about how technologies integrated with remote diesel systems before entering the market as a second or third stage technology adopter.

Interviewees 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 Hub Community

Consider a hypothetical rural hub community along the coast of western Alaska. The community is home to roughly 4,000 individuals, half of which are of working age. The residents of the community are predominantly Alaska Native and subsistence activities play an important role in the lives of many residents. The community plays a role as the supply, service, and transportation hub for its region, facilitating services to other, more remote communities. As a hub community, the local economy hosts retail stores, social service providers, air carriers, state and federal government offices, and local and regional tribal administrations, and a large bulk fuel storage farm. The community finished a new hospital in 2015 and now also plays an important role as a healthcare hub for the region.

Management of the local electric utility has been given guidance by the board of directors to investigate alternatives to offset diesel fuel consumption by 50 percent by 2030. Considering its options, the utility commissions an energy study, which considers the known energy alternatives and local renewable energy resources.

Economic and Housing Information

Roughly 100 residents hold commercial fishing permits. Other employment is predominantly in government, health and education, and trade, transportation, and utilities. Other jobs in the retail sector and other small businesses provide other year-round employment and income. Subsistence activities play an important role in the local economy.

The community is interested in expanding its tourism sector. In the region, several mines under development could provide jobs for locals.

Median household income is $81,000 annually, slightly higher than the statewide median of $76,000.[3] As a regional hub, employment opportunities are greater, and the workforce is more diverse than most of the small villages of rural Alaska.

In the region, access to affordable housing is an ongoing issue. Roughly 25 to 30 percent of housing units in the region are considered overcrowded or severely overcrowded, higher than the statewide and national averages.[4] While overcrowding is less of an issue in this hypothetical community, the cost of residential construction is still greater than the market value of housing units, causing rates of new housing construction to remain low.[5]

Region and Climate

Western Alaska is one of the most remote regions of the state. Bordering the Bering Sea, the region roughly stretches from the Aleutian Islands in the south to the Bering Strait in the north. The climate in the region ranges from transitional to sub-arctic, with tundra patchworked with boreal forest flowing across much of the landscape.

The hypothetical community discussed here is in the sub-arctic zone on the coast of the Bering Sea. The community is located in an area with permafrost. Historically, sea ice covers the coast in the winter, although ice thickness and coverage has been decreasing in recent years.[6] The community has been considering climate change impacts in long-term strategic planning.

Western Alaska is known for its wealth of renewable energy resources. Wind resources in the area local to this hypothetical community are plentiful. The community has also investigated a number of local wind and hydroelectric/hydrokinetic concepts.[7]

Energy System

Electric

The utility operates a wind-diesel hybrid system with six wind turbines of varying age and six diesel generators of varying capacity. The generation assets are operated with an integrated SCADA system which manages the diesel and wind assets and allows communication between the system and engineers in Anchorage and the rest of the U.S. who monitor system performance and provide remote maintenance.

Table 4 describes some of the community energy characteristics. The system has a maximum capacity of 18 MW which is overbuilt for the utility's peak demand. In 2019 the utility sold 35,000,000 kWh. Depending on wind speed, the turbines can offset up to 20 percent of the annual energy demand, the remaining demand is met through diesel generation. The utility has investigated other alternative energy sources but has not identified a cost-effective alternative to diesel systems. One MW of energy is captured in waste heat which is used to heat the community's water supply.

Hypothetical Hub Energy System Statistics	
System Capacity (MW)	18
Diesel Capacity (MW)	15
Wind Capacity (MW)	3
Annual Sales (kWh)	35,000,000
Percent Residential Sales	30%
Percent Community Facilities Sales	10%
Percent Commercial and Other Sales	60%

Table 4: Hypothetical Hub Community Energy Characteristics.
Source: AEA, 2019.

The system is run by nine plant operators, with three fiscal and administrative professionals supporting management activities. A stated challenge the utility grapples with is access to capital. The utility generates enough revenue to cover operations and maintenance costs, but is unable to fund large infrastructure projects. The most recent wind turbine was funded through a patchwork of grants and a small loan.

Administrative operations are a challenge. As a hub community there is access to a larger labor pool than much of rural Alaska; however, skill sets in finance are more difficult to access. In addition, individuals in management positions are nearing retirement age and it is unclear if there are individuals who will be able to fill those roles.

The system primarily serves residential customers (30 percent), community facilities (10 percent), and commercial customers (60 percent).[8] The community hosts a hospital and federal and state offices, all of which have large, well-defined loads. There are few 3-phase energy users and the daily energy demand to the system cycles daily and seasonally.[9]

Hypothetical Hub Community Energy Cost Statistics	
Total Power Cost ($/kWh)	$0.30
Non-fuel Cost ($/kWh)	$0.16
Fuel Cost ($/kWh)	$0.14
Rate for Service - Pre-PCE ($/kWh)	$0.20
Rate for Service - With PCE ($/kWh)	$0.11

Table 5: Hypothetical Hub Community Energy Cost Statistics.
Source: AEA and RCA, 2019.

Note, the rate for service is lower 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.

Power costs in the community are high compared to urban Alaska; however, they are lower than surrounding villages. The community participates in the PCE. In 2019, the rate for service for residents was $0.11/kWh. Commercial customers and businesses are not eligible to participate in the PCE program and pay a higher rate per kWh, roughly $0.20/kWh.[10] Table 5 describes the community's power costs.

Heat

For space heating, the community relies almost entirely on heating fuel which is sold by various entities in the community. Residential heating fuel costs between $4.50 and $5.50 per gallon and homes are heated with Toyo stoves. Larger users are able to purchase fuel in bulk and sometimes pay a lower price per gallon. There is no district heat system in the community, and permafrost makes the logistics and cost of constructing a district heat system difficult.

Energy Technology Market Drivers

The utility in this community operates under a cooperative model and is not regulated. However, the community does participate in the PCE program and makes filings to the State of Alaska to justify allowable costs for the program. The utility is also accountable to the board of directors and cooperative members.

Key energy concerns for the community include: cost, reliability, and decarbonization, all of which drive operational and technological decisions. In a region where costs of power are high and fuel costs are variable, costs are one of the clearest drivers of decision-making processes. Decisions about generation technology are made through considering the upfront capital costs and long-term operations and maintenance costs and fuel costs (if applicable) of the alternative technology compared to the current system.

Reliability: Reliability is a growing concern for this hypothetical community as it seeks to lower or stabilize costs through diversifying its energy resources. Reliability is critical; power must be there when people go to turn the lights on, especially in the middle of winter. As a result, the community operates with redundant capacity to ensure that if any single generation unit is shut down, enough capacity remains to meet peak demand.

Decarbonization: Decarbonization is a layered driver in this hub community. While there are motivations from the utility leadership to reduce reliance on fossil fuels as a result of environmental concerns and emissions reduction, an even stronger driver is reduction of risk of environmental contamination from fuel spills. Decarbonization is also synonymous with diversification to the extent that it includes integration of multiple resources. Decarbonization also reduces variability in costs.

Familiarity: Comfort with energy technologies is a forceful driver for technology adoption. The community has observed the experiences of other energy systems adoption of emerging energy technology and tried to learn through collaboration. Despite a moderate tolerance for risk, the utility remains wary of adopting unfamiliar technology. This is caused by several factors, including: relative isolation, access to resources, high capital costs, and workforce constraints.

Cost: While not as high as much of remote Alaska, power costs in this hypothetical community are high. High costs associated with diesel fuel and operations and maintenance have been a key driver in investigating technology alternatives which would lower energy costs.

Market Fit for Microreactors

Technical Capacity and System Fit

Hub communities operate advanced systems with sound technical capacity. A hub community without a seafood processor or large industrial users accommodate loads which cycle according to residential and seasonal demand characteristics, but without large spikes in demand. Hub communities with large industrial users, mostly seafood processors, experience greater seasonal loads. With, or without, a large industrial power user, nuclear systems would have to be designed to accommodate system cycling and function with integrated wind and solar resources. Alternatively, a nuclear system would have to be sized to accommodate the utility's base load with diesel integration to meet demand spikes.

There are several ownership models for integration which could provide varying levels of technical fit: utility operation and integration, leased 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.

One of the concerns expressed by rural hub communities in interviews was over operational liability. The regulatory and operational nuance of microreactors is as yet unknown. Any number of requirements placed by the U.S. Nuclear Regulatory Commission could present a hurdle for utility operators. A solution to this could be removing operational obligation from the utility, allowing another entity to either operate nuclear assets owned by the utility or sell nuclear power from a local entity which owns and operates nuclear assets. However, the challenge with either of those models is removing operational control of a community's energy source from the utility.

Many questions over operational characteristics remain unanswered in this hypothetical community. Energy operators and stakeholders have expressed concern over operational characteristics matching existing energy system needs, including workforce requirements, security requirements (both physical and environmental), and operating parameters. Given the existing physical, system, and energy characteristics of hub communities, as these questions are answered by the nuclear industry and regulatory agencies, technical compatibility will become more solid.

Microreactor developers are working toward testing operational characteristics which would suit remote operation conditions. These characteristics include: infrequent refueling, remote or autonomous operation, reduced security requirements, reduced maintenance requirements, and load-following capabilities.

Knowledge gaps around microreactor operations will need to be filled with concrete evidence on operational characteristics as they are established. Comfort levels with the operation of the technology will have to be built before the hypothetical community discussed here begins firm discussions about technology adoption.

Financial Fit

In our hypothetical community in western Alaska, the per kWh rate is $0.20/kWh for non-PCE customers and $0.11/kWh for PCE recipients. Energy rates are a composition of costs associated with depreciation and interest, administration, transmission, generation, and fuel. Only a portion of that includes variable cost which could be replaced through integrating a microreactor, specifically, generation and fuel costs.[11]

In the hypothetical community discussed here, generation and fuel costs make up approximately 60 percent of the cost of power. Given currently available cost data on nuclear systems, it is unclear how costs associated with microreactors would compare to existing diesel systems. NEI estimates that the first 50 microreactors deployed could produce energy at costs ranging from a high of $0.40 per kWh in remote communities to $0.10 per kWh in Alaska's Railbelt.[12] As microreactors move through the development stages, more concrete estimates on costs will likely become available.

One clear indication provided by energy planners and utility operators is that the financial fit could not be equal to or greater than current costs. Given the risk and technical hurdles associated with integrating the technology, many rural utilities would have to experience significant financial benefit.

With the function of the PCE program, these benefits may not be realized by residential customers; however, if the per kWh cost is low enough, some financial benefits could be experienced by commercial users and small businesses. In the hypothetical hub community discussed here, the majority of kWh produced are sold to non-PCE customers; therefore, any savings associated with integrating microreactors would have a real impact on the local economy.

Perception Fit

While energy leaders in the hypothetical community discussed here expressed that microreactors could offer a viable energy alternative to the community's diesel infrastructure, energy leaders agree public perception could be a hurdle. Specific information on attitudes surrounding nuclear energy in the community remain unknown, but energy leaders assume they are likely to match national attitudes.

Historical and current accounts of environmental contamination have impacted the community discussed here and the health of residents. Point source contamination from projects which were never remediated according to plan exist throughout the community. In addition, high levels of polychlorinated biphenyls (PCBs) and other chemical contamination have been found.[13]

In the hypothetical hub community discussed in this analysis, awareness of the impacts of environmental contamination and global warming are high and could act as a pull toward or push away from local nuclear energy depending on community perception levels. Local, widespread support of a microreactor could require broad and thorough education program facilitated by a trusted source. 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 and decommissioning of the plant.
- Understanding of system operation and maintenance requirements, safety measures, and differences from traditional nuclear technology.

There is a clear aversion toward being the first user of any new energy technology, including microreactor While interest from community energy stakeholders is high, as a potential 'first customer', the hub community discussed in this analysis is more likely to prefer to see the technology tested and deployed in urban Alaska or elsewhere to observe the functionality and success of the technology before making decisions on implementing it in a local setting.

In addition, attitudes toward the disposal of nuclear waste and environmental remediation following the life of a microreactor are likely to be strong. Clear, firm plans on waste disposal and site decommissioning will need to be expressed early in the planning process to reinforce comfort levels in the community discussed here.

Rural Hub Community Energy Value Propositions

Current Value:	**Barriers:**
• Heavy dependence on diesel fuels. • High cost of power. • Small consolidated system allowing for heat and power production. • Strong support of movement away from fossil fuels and energy diversification. • Medium-sized base load which could allow for integration of a single small system initially.	• Availability of workforce and technical skill sets. • Small energy system could force a heavy reliance on single technology. • General attitudes toward nuclear among the public and fear over risks. • Concerns over external environmental issues (i.e. earthquakes, erosion, and permafrost melting). • Undetermined regulatory hurdles and workforce 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.

Table 6: Hub Community Value Propositions.

Contributors

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Special Thanks

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