ENERGY
TRANSITIONS
INITIATIVE
U.S. Department of Energy

Renewable Energy Integration in Remote Alaska Communities

Rebecca Meadows (NREL), Elan Edgerly (Alaska Native Tribal Health Consortium),
Rob Jordan (Renewable Energy Alaska Project), and Laura Beshilas (NREL)

Table of Contents

List of Figures

List of Tables

Overview

There are approximately 200 remote Alaska villages that are not connected to a larger grid and that primarily rely on diesel generators for electricity. From 2019 to 2020, the annual electricity generation consumed in the rural communities that participate in Alaska's Power Cost Equalization (PCE) Program[1] was 475 gigawatt-hours, approximately 10% of the electricity consumed in the area from Fairbanks to Anchorage, known as the Railbelt. Renewably generated electricity accounted for approximately 10% of the total generation consumed in these rural communities and was primarily from wind and hydropower resources (Meadows et al. 2023).

PCE reimburses rural utilities for eligible expenses, reducing residential electrical rates in the communities they serve. In 2023, 188 communities participated in the PCE program (Alaska Energy Authority 2023). Because of the high cost of transporting diesel fuel to remote locations, residential electricity rates for remote communities can still be significantly more than the Railbelt, even with PCE (Allen et al. 2016). Communities often use more diesel fuel for heating than for electricity, with heating fuel bills consuming up to half of the total household income in some communities (Holdmann n.d.).

As of 2020, approximately 70 rural Alaska communities had deployed a renewable energy system to reduce greenhouse gas emissions and reliance on costly imported diesel fuel (Huang 2020). However, in many of these communities, renewable energy contribution levels have been limited (typically around 20%) by insufficient integration systems and maintenance obstacles (Jimenez 2018).

This case study report was developed through the U.S. Department of Energy's (DOE's) Energy Transitions Initiative Partnership Project (ETIPP) technical assistance (TA) projects for Nikolski and St. George. Both communities had wind turbine projects that failed due to integration and maintenance issues. Prompted by these failures, Nikolski and St. George sought help to investigate renewable energy alternatives and associated integration strategies, with a focus on technologies that could be easily maintained by the community.

As input to this case study report the ETIPP team conducted a literature review as well as interviews with energy practitioners in Alaska who have worked in remote communities (Table A-1). Interviews were conducted remotely during the fall of 2023 using video calls. Interview videos and transcripts were recorded for the ETIPP team's reference. All interviews generally followed a list of questions developed by the ETIPP team. Questions were informed by the literature review and the ETIPP team's experiences in remote Alaska communities. The goal of the interview process was to understand the nuances of renewable energy integration in remote areas of Alaska from the perspectives of those with first-hand experience.

The primary objective of this case study report is to document lessons learned to address potential renewable energy and storage integration issues in remote Alaska communities. This analysis can be used by rural Alaska communities who are considering renewable energy technologies (also referred to simply as "renewables") as a source of best practices and case studies to facilitate the successful implementation of renewable energy projects. The report is organized as follows:

- The "Existing Needs and Challenges" section summarizes the primary needs and challenges that rural communities face when working to successfully integrate renewables and includes case studies highlighting some of these challenges.
- The "Integration Strategies and Technologies" section provides information on renewable integration technologies and strategies that have proven to be successful in rural Alaska communities. It also includes case studies that highlight some of those successes.

Existing Needs and Challenges

Integrating community-scale renewable energy into remote diesel power plants can be challenging and, if not done correctly, can result in negative impacts to the power system. A topic of discussion in the interviews was the proportion of intermittent or variable renewable energy (such as wind or solar) in a diesel microgrid that warrants more sophisticated integration technologies. The resulting recommendations varied from 5% to 20% of the community's peak load, depending on the existing grid infrastructure and the type of renewable energy generation. Generally, the complexity of integration correlates to the amount of renewable penetration, with higher-penetration systems requiring more sophisticated technologies.

The amount of renewable energy that can be successfully integrated depends on many factors, including the minimum optimal loading on the diesel generators, the existing power system infrastructure (including spinning reserve requirements, defined below), the type of renewable resource being integrated, and the overall economic feasibility. Economically, as the renewable energy contribution exceeds an estimate of ~80%,[2] the cost of meeting the remaining electric load increases significantly due to the large storage requirements, resulting in diminishing rates of return. These factors and additional needs and challenges are detailed below.

---

[1] The PCE program lowers energy costs for rural residents who do not benefit from state-subsidized energy projects that reduce electrical rates for residents in road-connected and urban areas.

[2] Estimate from interview with Alan Mitchell, Analysis North, September 2023.

Power System Upgrade and Maintenance Requirements

One of the biggest challenges to successfully integrating a renewable energy project is that the existing power plant and distribution system are likely not optimized for such integration. A baseline power system assessment should include careful evaluation of the existing system to identify any required upgrades for the successful integration of the renewable energy system. Alaska Energy Authority's *Solar Power Best Practices Guide* (Alaska Energy Authority n.d.) lists key considerations, including the capacity for the existing controls and switchgear to accommodate renewables, when evaluating the configuration and operation of the power system. Specifically, renewable integration requires modern controls and switchgear that can automatically dispatch generation sources to maintain stable grid frequency and voltage, while accommodating the additional demands of a renewable energy system. These additional duties include managing additional spinning reserve requirements, responding to changes in renewable generation, managing battery charging and dispatch, and switching between diesels-on and diesels-off modes.

The integration of renewable energy may also require upgrades to electrical distribution. Conductors and transformers along the distribution branch, including those at the power plant, that contain the new renewables may need to be verified and upgraded.

Nikolski Case Study

The Village of Nikolski is located on Nikolski Bay on the southwest end of Umnak Island, one of the Fox Islands. It lies 116 air miles west of Unalaska, and 900 air miles from Anchorage. The population is less than 20 people. Residents are known as Unangan, and Aleut is spoken in most homes (Aleutian Pribilof Islands Association n.d.[a]).

Umnak Power Company provides electricity for the community and is wholly owned by the Native Village of Nikolski. It operates a diesel power plant with three John Deere generators. Fuel is expensive in Nikolski: The cost of diesel has ranged from approximately $6 to $8 per gallon in recent years (Alaska Energy Authority 2021, 2022, 2023; Figure 1). In addition to the burden of high fuel costs, the extremely remote location and small population can complicate fuel deliveries. In 2007, the fuel barge operator canceled deliveries, and weather almost prevented a winter fuel delivery by air. This would have resulted in a loss of electricity and presented a real threat to the life and safety of community members.

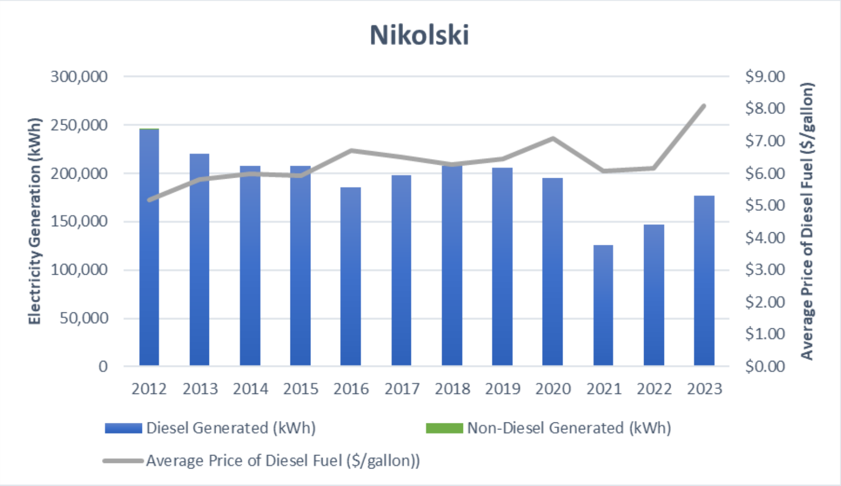

Figure 1. Nikolski's electricity is 100% diesel generation. While energy usage has declined in recent years, the price of diesel fuel has increased significantly.

A 65-kW wind turbine was installed in 2007 and commissioned in 2010 (Figure 2) but has never operated well due to controls and integration issues. The average load in Nikolski at the time of the wind turbine design was approximately 22 kW; however, the wind turbine was rated at 65 kW. Because of the turbine's fixed-pitch blades and control deficiencies, it produced energy that far exceeded what the power plant controls could effectively integrate, which required frequent curtailment.

To address the issue, Nikolski received funding from the Alaska Energy Authority in 2012 to integrate the turbine into the power system and develop a heat recovery system, as well as install electric boilers in the lodge and school to use excess

Nikolski Case Study *(continued)*

wind. Neither electric boiler is in service at the time of writing. Due to the expense of sending a trained technician to the site, the wind turbine has not been serviced since 2016.

Through the ETIPP program, Nikolski developed a Community Energy Plan in 2023–2024 with the goal to “reduce the amount of imported diesel required to heat and power the village and investigate alternatives to wind with a focus on technologies that can be easily maintained within the community.”[3]

Figure 2. Nikolski installed a 65-kW remanufactured Vestas V-15 in 2007.
Photo from Rich Stromberg, University of Alaska Fairbanks

Increased Maintenance Complexity

In addition to needed power system upgrades, community capacity to operate and maintain renewable microgrids is also an important consideration when evaluating and selecting the appropriate renewable technology for a remote community. As community microgrids become more complex, they also become more challenging to maintain. This complexity brings an increasing dependence on outside experts to solve operations and maintenance issues. Maintenance service calls to remote communities can cost thousands of dollars and can be delayed by inclement weather, which can result in excessive downtime and decrease the overall cost-effectiveness of the renewable energy technology.

The Kodiak Electric Association, the cooperative electric utility in Kodiak, Alaska, sends employees to the General Electric Renewable Energy Learning Center in New York to enhance the capabilities of their local workforce. Darron Scott, the Kodiak Electric Association president and CEO, emphasizes that communities should not pursue a renewable energy project if they do not have a solid operations and maintenance plan with the trained local support that is needed for the successful operation of renewables in remote communities.

> “A needs assessment could be completed to identify the commonality across communities in terms of the skills and knowledge and monitoring tools that are needed to troubleshoot a broad range of renewables, inverters, and storage technologies—and to better understand the experiences from these different communities as to what has worked well and what has been a challenge from an operator perspective. Consider travel training resources throughout the state because it is culturally and socially challenging to pull people so far away from their communities and their responsibilities to family and their subsistence way of life.”
>
> *—Rich Stromberg, University of Alaska Fairbanks*

Degradation of Diesel-Fired Generators

A minimum optimal loading ratio (which is the actual load as a percentage of the diesel generator’s rated capacity) of 20%–30% is usually recommended by the manufacturer to minimize wear and tear on the equipment (Mueller-Stoffels 2014). When adding renewables to a diesel microgrid, the power plant must manage a wider variation of loads. Additionally, the average demand for diesel generation is reduced and less predictable, but the peak load remains the same. This can result in running diesel generators at lower capacity factors and below the recommended minimum load ratio to ensure there is adequate spinning reserve to meet load fluctuations as well as potential interruptions in renewable generation. If the diesel generators are run excessively at load levels below the recommended ratio, in addition to lower fuel efficiency levels, a condition called wet stacking can occur from incomplete fuel combustion, resulting in a loss of lubrication that can eventually result in catastrophic failures (Mueller-Stoffels 2014).

> “Wet stacking the diesels is one of the concerns, but wear and tear from additional starting and stopping of the diesels and overcooling of the diesels in the shoulder seasons in communities where we have solar projects are also concerns.”
>
> *—Amy Survant, Alaska Village Electrical Cooperative (AVEC)*

---

[3] Developed through ETIPP biweekly calls with Nikolski community.

Diesel microgrids with a higher penetration of renewables ideally employ a variety of engine sizes to efficiently meet the net system load. Additionally, even though it becomes possible to turn the diesel generators off with higher penetrations of renewable energy, frequent stops and starts can result in excessive wear.

Loss of Power Plant Heat and Heat Recovery

Like the engine in a car, diesel engines in power plants require cooling. This is accomplished by circulating a glycol-water mixture through the engine cooling jacket, then to a remote radiator, where the heat is dissipated to the outside air (Figure 3). The load on the generator directly correlates to the amount of heat the engine generates. Before reaching the radiator, the coolant is generally diverted through a heat exchanger where it warms up the power plant's hydronic heating loop. If enough heat is available, the generator coolant can also warm an exterior heat recovery loop, which can supplement the heating loads at nearby buildings. As renewables are brought online, the generators carry less load, and at times they can even turn off, resulting in reduced available heat for the power plant and adjacent facilities. The following potential issues can result:

- Reduced temperature in the generator coolant loops: The heat recovered from the generator coolant is generally the only source of space heat in rural Alaska power plants. Without it, the plant can get cold and even freeze. Further, if coolant temperatures are low enough, it can cause seals to contract and leak. Cold coolant can also prevent the timely dispatch of diesel generators because they need time to warm up, especially from a cold start.
- Reduced output for heat recovery: For many buildings, particularly water treatment plants, recovered heat from the power plant is a critical byproduct of electrical generation. Not only does it reduce heating oil fuel consumption by supplementing a building's primary heating system, but it also provides a critical redundancy that can prevent a catastrophic freeze if the primary heating system fails.

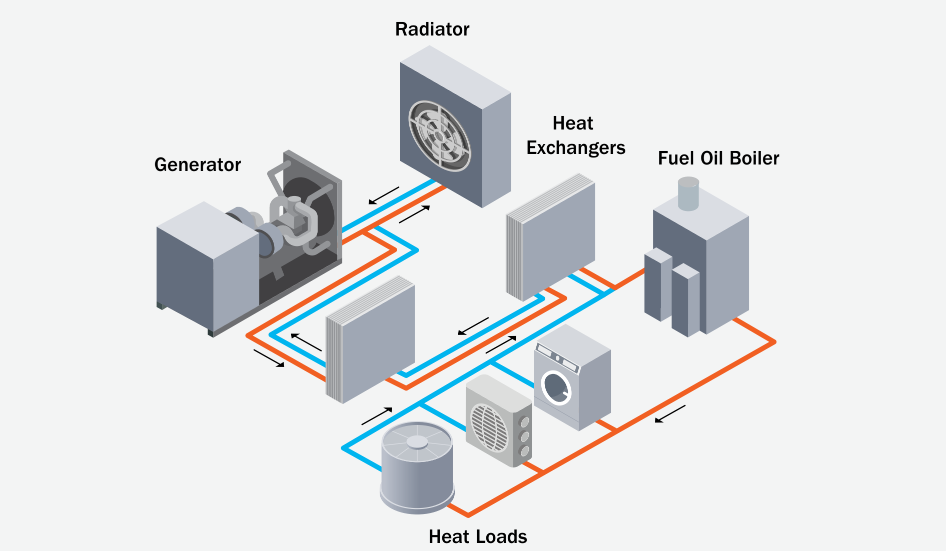

Figure 3. Schematic of a heat recovery system

Increased Spinning Reserve Requirements

Spinning reserve refers to the surplus generating capacity kept online and primed to respond to a sudden increase in electric load. This surplus in diesel-only microgrids is achieved by running diesel generators at less than full capacity, ensuring an excess that can be accessed to avoid power outages and meet unmanaged loads. The ability of diesel generators to quickly adjust output makes them ideal for providing spinning reserves, stabilizing the grid, and ensuring consistent power quality amidst fluctuations in demand or supply.

When intermittent renewables are included in the power system, additional spinning reserve is required to account for sudden decreases in renewable power. A lack of readily deployable generation assets to accommodate load fluctuations can result in lower power quality, damage to electrical equipment, and power outages.

To illustrate this point, imagine a power plant has 300- and 600-kilowatt (kW) diesel generators, an instantaneous load of 300 kW, and a 20% spinning reserve requirement to accommodate any load fluctuations. This would require having at least 360 kW of capacity online and running the 600-kW generator at approximately 50% load (300 kW). If the plant receives 100 kW of wind power, it needs to meet the remaining load (200 kW) plus 20% spinning reserve, as well as keep enough additional capacity online to cover the wind generation if it goes offline. If the plant switches to the 300-kW generator, it could meet the instantaneous load but would not be able to cover the 100 kW of wind power if it goes offline. In this case, the plant needs to continue to run the 600-kW generator, albeit at a lower load, which results in lower fuel efficiency. The peak load does not change, but the average output is now lower—and also less predictable and more variable

Post-Commissioning Optimization Needs

Ongoing troubleshooting and optimization of a power system after commissioning a renewable energy project is an often underestimated or overlooked step but is necessary to ensure the sustained viability and value of renewable energy systems. Time should be invested in post-commissioning to determine the most effective strategies for system optimization, such as scheduling diesel usage, adjusting inverter and secondary load settings, and promptly addressing system faults. This process can require ongoing manufacturer support, especially for more proprietary controllers or inverters. Neglecting post-commissioning optimization can result in suboptimal performance when faced with unforeseen system faults or changes in operating conditions.

When designing the project, a comprehensive approach must be taken to integrate renewable power effectively with existing power plants, distribution systems, and community heat loads. This broader perspective is crucial for ensuring seamless integration and optimal performance of renewable energy systems within the larger energy infrastructure. Post-commissioning, AVEC and Cordova both recommend running new, large renewables at a constant output and in manual mode for a period of time to troubleshoot before moving to full automation.

> “Our operators will run [the system] in manual for several months and record every nuance and glitch. Then we will program and tune the automation and eventually we’ll hand it over to automated operation. Manually operating it for a while and then moving to true automated operation—you’re in good shape.”
>
> —*Clay Koplin, Cordova*

St. George Case Study

The City of St. George is located on the northeast shore of St. George Island in the Pribilof Islands. It is 750 air miles west of Anchorage. The population is less than 100 people, who are predominantly of Aleut descent (Aleutian Pribilof Islands Association n.d.[b]). The city owns and operates the electric utility. Electricity is generated from four diesel generators, which generate approximately 550 megawatt-hours of power per year. Monthly average loads at the plant range between 50 and 95 kW. In December 2021, the local fuel company ran out of diesel because bad weather prevented a fuel barge from getting into the harbor. The city had to fly in fuel by the barrel, increasing the cost of fuel by approximately $2 per gallon. Diesel fuel has recently risen to almost $9 per gallon (Figure 4).

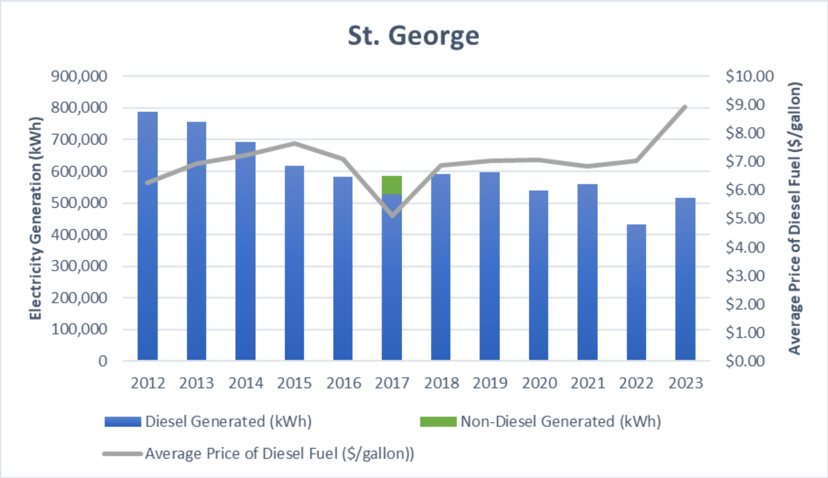

Figure 4. St. George meets its electricity demand through diesel generation. The price of diesel fuel has increased significantly in recent years.

A 95-kW refurbished Windmatic 17S wind turbine was installed in 2014, with blade extensions to increase the rotor diameter from 17 to 19 meters, which increased the wind turbine rated capacity from 95 kW to 120 kW. The wind turbine output at rated power was too high for the controller to effectively integrate, and the mechanical brake on the turbine engaged to provide a resistive load. This action burned out the controller in the wind turbine and caused a fire in the hub, resulting in a catastrophic failure just a few weeks after commissioning (wind turbine failure assessment from interview with Rich Stromberg, 2023). In 2023, the City initiated a Community Energy Planning process through the ETIPP program and established the following vision statement: “Harnessing the Bering Sea’s affordable and renewable energy, St. George has a diverse energy supply that can not only power the community, but its residents, through job creation and training.”[4]

---

[4] Developed through ETIPP biweekly calls with St. George community.

Data Limitations

Easy access to data is critical to properly design and operate integrated renewable energy systems. The absence of detailed energy data not only limits the ability to monitor and manage energy consumption effectively but also hampers the design and operation of integrated renewable energy solutions.

The community of Cordova, Alaska, is an example of successful data collection. Cordova installed a supervisory control and data acquisition (SCADA) system that archives data for the successful operation of their renewable microgrid. The community automated their power system more than 20 years ago and archives operating data at 1-second resolution for the entire power grid. The data have proved very valuable for the community on multiple occasions. For instance, the data were used to size and locate the battery energy storage system to ensure optimal sizing and placement. The data have also been used to quickly and accurately troubleshoot operational issues.

> “I’m a big fan of Alaska Housing’s building and building monitoring system, BMON.[5] It is one of the lowest-cost, homerun things we can do. You can’t manage what you don’t measure. Monitoring and anything that keeps us from potentially sending somebody in a plane to go check an asset out hundreds of miles away is so, so valuable and dovetails with the anticipated broadband investment coming to the state.”
>
> *—Griffin Hagle-Forster, Association of Alaska Housing Authorities*

Another critical need is having sufficient bandwidth for smart metering and remote monitoring systems. Without adequate bandwidth, accessing real-time data becomes difficult, hindering the implementation of effective energy management strategies, including remote troubleshooting support. AVEC is currently in the process of revamping their SCADA systems to take advantage of the communications improvements currently happening in rural Alaska, such as Starlink (Erickson 2023). Upgrades like this are needed in most communities before they can have effective remote monitoring.

Social Considerations

It is important to understand not just the technical aspects but also the social and cultural aspects of integrating renewable energy into remote diesel microgrids in Alaska. It can be difficult for contractors and consultants from outside Alaska to fully understand the unique challenges faced by Alaska’s island and remote communities.

In most remote communities, the renewable energy systems have been built at varying stages, and while the technical characteristics are very important, it is also important to understand the community perspectives that accompany past projects. In cases like Nikolski, the nonperformance of a wind energy system led to a clear decision not to move forward with wind, but the nonperforming structure remains and impacts the community’s perspectives on future renewable energy projects.

> “To provide effective technical support (from outside Alaska), it is important to have at least one or two people travel to that remote community in the first week of the project. You can spend a month or two having once-a-week calls for an hour trying to understand the dynamics of what that remote, isolated community is and still not grasp how remote or how islanded it is and what the dynamics are of getting something done. Two days on site are worth 6 months. It’s cost-effective in that it will move projects ahead rapidly as opposed to spending the first 4 to 6 months trying to do it in one-hour meetings on the web.”
>
> *—Kord Christianson, City of Sitka Electric Department*

Children in Sitka, Alaska, learn about renewable energy through storytelling and activities at the Sitka Sound Science Center. The event was part of the community’s work with ETIPP. *Photo by Brittany Falch, NREL 85287*

---

[5] BMON is Alaska Housing’s Building Monitoring System (Alaska Housing Finance Corporation n.d.).

Integration Strategies and Technologies

In remote communities with small power generation capacities, typical fluctuations in demand or renewable supply can result in large impacts to power quality and reliability and require innovative strategies and technologies to effectively integrate high-penetration renewable energy projects. As a baseline, effective integration requires modern power plant controls and switchgear. Beyond that, the go-to integration strategy in Alaska since 2019 has been dispatchable thermal loads, followed by energy storage (Holdmann, Wies, and Vandermeer 2019). These and other renewable energy integration strategies are described below.

Microgrid Controllers

The control system in a rural power plant refers to the combination of off-the-shelf controllers and custom programmable logic controllers that dispatch generation assets to maintain a consistent power supply for the community. The controls system has several responsibilities, which can include:

- Maintaining a constant frequency and voltage of the power grid by ramping generation up and down
- Selecting the proper asset or combination of assets to dispatch to meet the community load and spinning reserve requirements
- Controlling breakers and switches to match the asset or combination of assets that is supplying power to the community
- Maintaining a sufficient load on diesel generation assets to avoid low-load maintenance issues
- Switching to larger assets or paralleling assets when electrical load increases beyond the maximum load of a particular generator
- Detecting any faults, including ground faults, and disconnecting power to avoid risks to life and safety of community members
- Managing dispatchable loads for frequency control and thermal management
- Managing the charging and dispatch of a battery energy storage system (BESS) to maintain stable frequency and voltage delivery, provide synthetic spinning reserve, and prevent unnecessary BESS cycling
- Bridging between diesels-on and diesels-off operation.

In communities with no renewable energy generation, the control architecture is relatively simple and generally consists of individual controls to regulate speeds for each diesel generator and a supervisory controller for overall control and dispatch. These are often off-the-shelf products. When renewables are added to the system, the controls complexity increases. The degree to which it increases is often correlated to the renewable technology. For example, the controls for a wind system with dispatchable electric heat are generally more complex than controls for a solar energy system.

In the case of a diesel power plant coupled with a solar array and BESS, as in Noatak or Shungnak, an additional off-the-shelf controller is required to manage the microgrid. The new microgrid controller is at the same hierarchal level as the supervisory controller for the diesel gensets. It communicates output from the solar array and BESS to the supervisory genset controller, which will dispatch the appropriate diesel genset to meet the remaining load. When there is sufficient renewable generation to meet the community's load, the diesel generators can be shut off. This requires the microgrid controller, working in tandem with the solar and BESS inverters, to form the grid and control outputs to maintain a constant voltage and frequency of the power supplied to the community.

The controls tend to be more complex for a system that includes wind energy because wind power often requires the addition of dispatchable heat or secondary load control for frequency regulation. AVEC has found that off-the-shelf controllers have not historically been able to meet these additional control responsibilities and instead have relied on custom programmable logic controllers to manage their wind-diesel microgrids.

The power plant controls tie all the disparate parts of a project together and ensure that they communicate well and function as a holistic system. A well-designed and thoroughly commissioned control system is critical to the success of a renewable energy project.

> "In 2020, Hughes installed a 120-kW ground-mounted solar PV system and 240-kW, 337-kilowatt-hour BESS with an Ageto controller installed post-commissioning with the goal of operating the microgrid more efficiently. It is one of the first projects that was installed entirely by Alaska Native contractors. The controller strategy has increased the diesel generator off time from 3 to 7 hours to now almost 13 hours on really sunny days."
>
> *—Edward Dellamary, Tanana Chiefs Conference*

Dispatchable Thermal Loads

In grids with higher renewable energy contribution, dispatchable thermal electric loads can provide many benefits, including regulating grid frequency, reducing renewable curtailment, addressing heat loss at the power plant, and reducing heating fuel use at community buildings. However, successful implementation of this integration strategy requires fast (every power cycle) communication for frequency control and custom controls logic.

For example, AVEC uses high-speed, modulated electric boilers in their power plants to adjust the electrical load in response to fluctuations in wind production. This high-speed control helps them maintain a stable frequency despite wind power's unpredictability. Frequency stabilization is especially critical for smaller wind turbines that do not have pitch-controlled blades. The electric boilers also provide an additional load that uses excess renewable energy, prevents low loading of diesel generators, and reduces the amount of additional diesel fuel needed to heat the power plant.

The coupling of renewables with energy storage is becoming a larger part of remote communities' cost savings and diesel reduction strategies. As a result, there has been a shift from trying to get rid of heat at the power plant to trying to replace or contain it. Less runtime for diesel generators means lower coolant loop temperatures, but dispatchable electric boilers can replace the lost heat. The electric boilers inject heat into the power plant's generator coolant loop or heat recovery loop, which can help address low coolant temperatures and loss of power plant heat that results from turning the diesel generators off during periods of high renewable production. For example, the electrical utility in Cordova historically used diesel boilers to supplement their generator coolant loop temperatures. However, they recently moved to an electric boiler powered by their hydroelectric system to serve this purpose instead.

Further, when renewable production exceeds the demand from the community and power plant heat loads, dispatchable electric boilers or heaters can be used to supplement the heating systems in other buildings. Such a strategy has been successfully implemented in Kotzebue, which has an electric boiler in the hospital, and in Kongiganak, which uses residential Steffes stoves to heat homes. In Kongiganak, where the cost of heating fuel consumes half of the total household income (Holdmann n.d.), this heating strategy provides critical relief to residents. Additionally, communities are beginning to consider dispatchable heat pumps, which can be up to 4 times more efficient than electric boilers.

Kongiganak Case Study

The village of Kongiganak, located on the west shore of Kuskokwim Bay, lies 70 miles southwest of Bethel and 451 miles west of Anchorage. The population of around 400 people of primarily Yup'ik Eskimo descent receives electricity from the Puvurnaq Power Company, which is owned and operated by the Kongiganak Traditional Council. Puvurnaq Power Company runs a diesel power plant with four generators. The community's peak load is approximately 230 kW, and annual electricity generation in 2023 was approximately 1,500,000 kilowatt-hours (kWh) (Alaska Energy Authority 2023; Figure 5). High fuel costs and the challenges of barge fuel delivery once or twice a year leads to high energy costs.

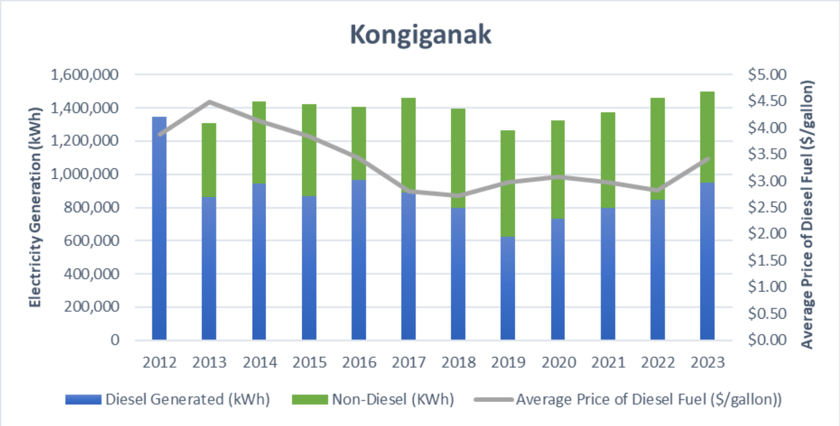

Figure 5. Over a decade-long dedication to renewable energy generation and integration has resulted in substantial reduction in diesel fuel consumption in Kongiganak. In 2023, approximately 37% of the annual generation came from non-diesel sources (Alaska Energy Authority 2023).

Kongiganak is part of Chaninik Wind Group, which was formed in 2005 with neighboring villages to collaboratively pursue wind energy projects, reduce energy costs, and decrease dependency on diesel fuel (Figure 6). To achieve these objectives, Chaninik Wind Group implemented Wind Heat Smart Grids to provide a lower-cost source of home heat to residential customers through wind-diesel systems with high wind capacities, approximately 200% of the peak load (Chaninik Wind Group 2013).

In 2009, five Windmatic wind turbines with a combined capacity of 475 kW were installed, although two are currently nonoperational. These installations, managed by a nonprofit independent power producer, have significantly reduced diesel consumption and stabilized electricity prices.

Kongiganak Case Study *(continued)*

Fifty electric thermal stoves, each with a 6-kW peak charge, 31 kWh of storage, and a smart metering system, were installed in 2011 to use excess wind energy for supplemental heating, significantly reducing heating fuel usage and costs for some residents. The following year, an electric boiler was installed to buffer wind variability and provide heat to the local washeteria. In 2018 a 250-kW/300-kWh lithium-ion battery was added to provide voltage and frequency regulation and to further reduce wind energy curtailment.

Kongiganak is well on their way to meeting their goal of reducing diesel use by 50% by 2030 and was recently funded in 2022 to add 200 kW of solar photovoltaic (PV) generation to their power system (Office of Indian Energy Policy and Programs n.d.).

Figure 6. Kongiganak's community wind project. *Photo from Amanda Byrd, Alaska Center for Energy and Power*

Energy Storage and Grid-Forming Inverters

Battery energy storage systems with reliable grid-forming inverters for the small load sizes in rural communities have only become available in the past few years. In addition to storing excess renewable energy that would otherwise be curtailed, this technology allows for the diesel generators to be turned off and the battery and inverter to grid form and supply spinning reserve. The need for spinning reserve capacity is thus decoupled from the diesel generator load, and smaller diesel generators can be employed to meet the real-time energy requirements.

In 2020, the Alaska Center for Energy and Power and Sandia National Laboratories evaluated the ability of energy storage coupled with a grid-forming inverter or grid bridging system to mitigate wind variability and displace spinning reserve from diesel generators in St. Mary's, Alaska. With a sudden loss in wind power and drop in frequency in the system, the grid bridging system was able to provide spinning reserve and system stability, which allowed the diesel generators to be turned off and provided more time for them to respond when needed (Flicker et al. 2020).

> "It is critical for rural communities in Alaska to have customer support and technical assistance for new battery and inverter technologies. Since there are few people in Alaska that can work on batteries, there should be a recommended three or so models used statewide, which would allow for more consistency and an increased knowledge base. There is so much value in installing equipment that someone else has knowledge about."
>
> —*Rob Bensin, Alaska Center for Energy and Power*

Kotzebue Case Study

Kotzebue, located 33 miles north of the Arctic Circle at the tip of the Baldwin Peninsula in northwest Alaska, is home to approximately 3,200 residents, predominantly of Iñupiat descent. The community experiences an arctic climate with long, cold winters and short, mild summers, where winter temperatures range from –50°F to 35°F and summer temperatures range from 40°F to 80°F (Northwest Arctic Borough n.d.[a]). Annual total electricity generation is approximately 19,500,000 kWh (Alaska Energy Authority 2023; Figure 7), with a peak load of 3.4 megawatts (MW) (Northwest Arctic Borough n.d.[b]). Electricity is provided by Kotzebue Electric Association (KEA), the locally owned utility.

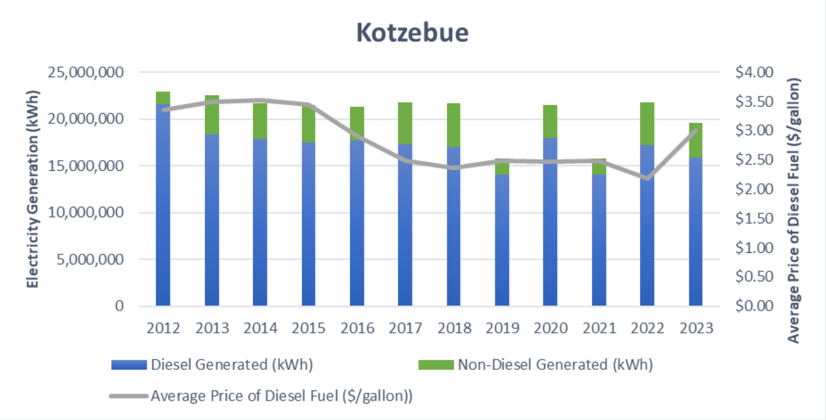

Figure 7. Kotzebue has been an early adopter of renewable energy, installing the first utility-scale wind project in the Arctic as well as the largest PV array at the time in rural Alaska (Northwest Arctic Borough n.d.[b]). As of 2023, Kotzebue has reduced annual electricity generation from diesel fuel by approximately 20% (Alaska Energy Authority 2023).

The local economy is primarily based on subsistence activities, government jobs, healthcare, education, and some tourism. Accessible mainly by air, Kotzebue lacks a road connection to the rest of Alaska. The community has essential infrastructure, including a hospital, schools, a community college, and various local businesses, all deeply rooted in Iñupiat culture and traditional practices (Northwest Arctic Borough n.d.[a]).

Historically, Kotzebue has relied on diesel generators for electricity, and diesel fuel is expensive due to transportation costs. However, the community has been a pioneer in adopting renewable energy, starting efforts in 1995 to transition from diesel. Between 1995 and 2008, Kotzebue installed 925 kW of wind capacity and upgraded switchgear and SCADA systems at their power plant. From 2008 to 2023, an additional 2.92 MW of renewable generation capacity was installed, including 576-kW and 540-kW solar PV arrays (Figure 8). To stabilize the energy supply, BESS with grid-forming inverters have been integrated, allowing excess power from wind and solar to be stored. A heat recovery system captures waste heat from diesel generators for heating buildings, improving energy efficiency (Northwest Arctic Borough n.d.[b]).

Key renewable energy integration projects include the installation of a 450-kW electric boiler at the hospital in 2014 and additional electric boilers for four other customers that use excess wind energy and help regulate grid frequency. A 1,225-kW/950-kWh lithium-ion battery installed in 2015 provides spinning reserve and frequency support. Smart meters and remote monitoring systems enhance energy management, and advanced control software optimizes renewable integration (Northwest Arctic Borough n.d.[b]). As of 2023, approximately 20% of electricity generation came from renewable energy (Alaska Energy Authority 2023).

Future plans to meet their goal of producing 50% of electricity from renewable sources by 2025 involve expanding solar PV capacity, installing more wind turbines, significantly expanding battery storage, and developing thermal energy storage systems to further reduce reliance on diesel.

Figure 8. Kotzebue's wind and solar projects. *Photo from Amanda Byrd, Alaska Center for Energy and Power*

Igiugig Case Study

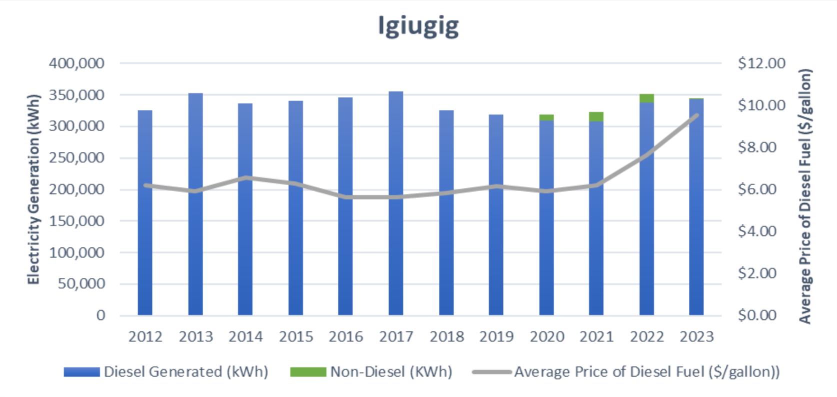

Figure 9. Igiugig's journey towards sustainable began in the early 2000s with their first comprehensive community plan that established alternative energy as a priority. Their 2022 CEP has a goal to reduce electricity generation from diesel by 50% by 2030.

Igiugig Village is located in southwestern Alaska on the banks of the Kvichak River, which they rely on for drinking water and subsistence fishing. The small community of 68 people are primarily of Yup'ik Eskimos, Aleuts, and Athabascan Indian descent. The village is only accessible by air and primarily relies on diesel fuel for electricity, which is provided by the Igiugig Village Council (IVC). The annual electricity demand is approximately 350,000 kWh (Figure 9) which equates to roughly 25,000 gallons of diesel fuel used for electricity generation. Approximately 27,000 gallons of diesel fuel is used annually for space heating. In 2023, diesel fuel prices rose to $9.61 per gallon for electricity and $10 per gallon for heating fuel.[6]

The community has a long history of sustainability initiatives, which started in 2000 with the entire community working together to develop their first comprehensive community vision and plan. Since 2008, IVC has navigated from a hydrokinetic power test site to a commercial microgrid. In 2015, the Ocean Renewable Power Company (ORPC) deployed the first RivGen® 2.0 device and power system, which generates electricity from river currents.

In 2022, in collaboration with NREL, Igiugig developed and adopted a Comprehensive Energy Plan (CEP), which established a goal to achieve "50% reduction in diesel fuel for electricity by 2030" from the 2019 electricity usage baseline. Also in 2022, the RivGen 2.1 (40 kW) and 125-kW/253-kWh BESS and Microgrid Controller were installed (Figure 10).

Although installed in 2022, the BESS was not successfully commissioned until 2 years later. Post-commissioning, the community was able to reflect and share the following recommendations for other communities considering adding energy storage to their power system:

- Detail all interoperability requirements beforehand, such as needed ethernet runs and internet requirements.
- Define contingencies for overrun of the commissioning period with agreement on ongoing technical support and expenses for any malfunctions during the project planning phases.
- Perform third-party independent assessment/modeling to verify proof of concept.
- Ensure there are consistent and dedicated representatives from the microgrid controller and BESS module manufacturers who are committed to supporting the project during ongoing troubleshooting and commissioning efforts.

A 200-kW solar array is planned for installation in the summer of 2025. The community is receiving technical assistance through ETIPP to evaluate renewable heating scenarios that will use excess solar energy to reduce heat demand and to perform interoperability studies for BESS and the future solar project. Once installed and in conjunction with the BESS, the 200-kW solar array is expected to reduce diesel fuel used for electricity generation by approximately 36%.[7] With successful operation of the RivGen or future additions of wind energy, the community plans to exceed their diesel reduction goals and further reduce diesel fuel consumption for both electricity and heating.

Figure 10. Igiugig's (left) diesel power plant and (right) BESS system.
Photos from Jon Salmon, Igiugig Village Council

---

[6] Diesel fuel consumption and price data from ETIPP biweekly calls with Igiugig community.

[7] Unpublished data from ETIPP project modeling.

Energy Efficiency

The Alaska Affordable Energy Strategy (Alaska Energy Authority 2016) addressed the barriers to building and maintaining energy infrastructure in rural Alaska communities and evaluated the cost-effectiveness of various potential energy infrastructure improvements. While the cost-effectiveness of electricity generation, transmission, and distribution improvements varied by location, demand-side energy efficiency measures were found to be beneficial for all communities studied. Additionally, depending on the community, the most significant opportunity for cost savings in electricity generation and distribution is in reducing distribution line losses (Alaska Energy Authority 2016). Energy efficiency reduces costs to consumers, and by reducing the overall energy need of the community, it also reduces the overall costs of the renewable energy project by reducing the optimal size of the components needed.

> "I think with robust energy monitoring resulting in investment-grade data, energy efficiency can turn into the 'fuel' of choice—it should really be the first thing in the toolbox so that the majority of kilowatt-hours or BTUs are avoided before topping off with renewables. Energy efficiency is your vegetables and renewables are your dessert."
>
> *—Griffin Hagle-Forster, Association of Alaska Housing Authorities*

Additional Considerations

In 2022, the Alaska Center for Energy and Power and the University of Saskatchewan published an article that summarized a qualitative comparative analysis of 24 remote communities in Alaska to identify key variables that lead to community renewable energy deployment. Results show the presence of favorable subsidies, community capacity to manage projects, and community ability to work collaboratively to pool regional resources are key variables in successful renewable energy transitions (Holdmann et al. 2022).

Further, it is important to consider how Alaska's PCE program will affect the project economics. Historically, the development of utility-owned renewable energy projects has not dramatically reduced costs for households in rural communities because of unintentional disincentives for renewables resulting from Alaska's PCE program. The PCE program provides cost reduction for rural residents who do not benefit from subsidized energy projects that reduce residential electricity rates in more urban areas. The cost-reduction payments are paid out of a PCE endowment fund and are calculated based on a rural utility's cost of generation: a higher cost of generation results in a higher PCE payment. While this program is critical for rural residents, one unintended consequence is that there is less financial incentive for utility-owned renewables, because much of the savings of generation costs stay with the PCE endowment fund rather than being passed on to residents. While it is possible to realize savings and reduce electrical rates for entities not eligible for PCE, it is much harder to reduce residential rates that receive PCE support.

However, a model that is gaining acceptance in Alaska is community ownership, rather than utility ownership. If the community owns the renewable asset and sells power to the local utility at a price close to the avoided cost of fuel, the PCE payment is preserved, and the revenue from power sales stays in the community. The community in this case acts as an independent power producer (IPP). This structure maintains the electric utility's costs—and thus its PCE payment—at close to current levels and ensures that most of the economic benefits of the renewable energy system are realized by the community.

> "A lot of the focus should be at the local ratepayers in the system because with the Power Cost Equalization program in Alaska, the only place that most people are going to see a reduction in their energy costs is through energy efficiency, unless you do the IPP approach that has been demonstrated up in the Northwest Arctic Borough."
>
> *—Rich Stromberg, University of Alaska Fairbanks*

A group of high school students from communities in the Yukon-Kuskokwim Delta prepare to give their final Home Energy Basics presentations at the Kusilvak Career Academy in Anchorage, Alaska, as part of a program sponsored by Renewable Energy Alaska Project (REAP). *Photo from REAP.*

Shungnak Case Study

Shungnak is an Iñupiat community located in northwestern Alaska on the Kobuk River. There is no road access; the community's 272 residents (per the 2020 U.S. Census) rely on airplanes or river barges for delivery of goods and materials. Further, barge service is inconsistent, which often requires that fuel and other goods be flown in. As a result, fuel is extremely expensive, ranging from $9.11/gallon (Alaska Energy Authority 2023; Figure 11) for fuel purchased by the utility to up to $16.14/gallon (data from unpublished presentation by Northwest Arctic Borough) for residential heating fuel. Electricity for Shungnak and the nearby community of Kobuk is primarily generated at the AVEC-owned and operated power plant, which houses three diesel generators. In addition to electricity, the power plant supplies recovered heat from generator coolant to the nearby water treatment plant and city office, with an expansion to other nearby buildings scheduled for 2025.

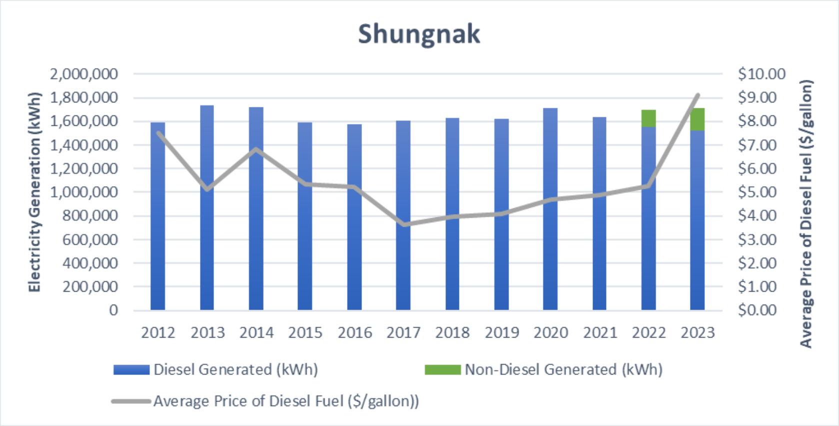

Figure 11. Shungnak's solar and storage project reduced diesel fuel consumption for electricity by 11% in 2023.

In 2021, a collaborative effort between the Northwest Arctic Borough and several other local entities culminated in the installation of a 223-kW solar array and 250-kW/384-kWh BESS in the community (Figure 12). The new solar array is jointly owned by the Native Village of Shungnak and the Native Village of Kobuk, who act as an IPP and sell power to the local electrical utility, AVEC. This keeps money in the community that would otherwise be used to purchase fuel from outside entities. In its first year of operation, the project saved approximately $120,000, with a net revenue to the IPP of $89,000 after expenses. The project uses bifacial solar panels and SolarEdge inverters and optimizers to maximize production. The battery is manufactured by Blue Planet and uses an EPC grid-forming inverter sized to meet the community's electrical loads without the diesel generators running. The new solar array and battery are integrated into the existing power plant using an Ageto microgrid controller. This project highlights the advantages of regionalizing resources, the IPP model of ownership, and the importance of compatible controls and detailed commissioning for successful integration.

The Shungnak solar and BESS project also identified challenges that need to be addressed by future renewable installations. For example, the generator coolant is the primary heat source for the power plant; when the solar and BESS are able to cover the community load the diesel generators do not run, the temperature of the generator coolant loop is decreased. If the generators are off frequently enough, it can reduce the efficacy of the power plant heating system and the availability of recovered heat for adjacent buildings (in this case, the water treatment plant and city office). There is ongoing work to mitigate this effect.

Figure 12. Shungnak's solar PV project, water treatment plant, and water tank. *Photo from Alaska Native Tribal Health Consortium*

Summary

In rural Alaska communities, electricity is typically supplied by diesel-fired generators housed in a local powerhouse. Because rural communities are generally not connected to a larger grid, diesel generators serve as the primary source of electricity, with supplemental power provided by renewables in some cases. In many of these communities, renewable energy contribution levels have been limited by renewable energy integration and maintenance challenges.

Primary challenges to higher amounts of renewable energy integration include ensuring that the diesel generators are not operated at too low of a load, the spinning reserve and heating requirements of the power system are met, and the existing power plant and distribution system are optimized for such integration. Community capacity to operate and maintain renewable microgrids is also a critical consideration.

Remote communities are employing innovative strategies and technologies to effectively integrate high-penetration renewable energy projects, such as advanced central controllers, dispatchable heat loads for frequency controls, and BESS with grid-forming inverters for storage and grid stability. Prior to installing renewable energy projects, reducing line losses and end-user consumption can be the most cost-effective first steps. A best practice for post-commissioning of large renewable systems is to run the renewable generation manually and at a capped capacity for several months to troubleshoot and optimize before moving to full automation.

The case studies included in this report illustrate the importance of considering the power system holistically and ensuring that power plant controls, combined with dispatchable loads or energy storage are able to work as an integrated system to provide consistent and reliable power. By implementing these measures and technologies in a careful and holistic way, success stories of reducing fuel use—and energy costs—in rural Alaska will proliferate.

References

Alaska Energy Authority. 2016. *Alaska Affordable Energy Strategy: A Framework for Consumer Energy Sustainability Outside of the Railbelt*. Anchorage, AK: Alaska Energy Authority. https://www.denali.gov/wp-content/uploads/2018/10/Alaska-Affordable-Energy-Strategy.pdf.

Alaska Energy Authority. 2021. *Power Cost Equalization Program Statistical Report FY2021*. Anchorage, AK: Alaska Energy Authority. https://www.akenergyauthority.org/Portals/0/Power%20Cost%20Equalization/2022.02.28%20FY21%20PCE%20Statistical%20Report%20-%20Community%20Version.pdf?ver=2022-02-28-112622-127.

Alaska Energy Authority. 2022. *Power Cost Equalization Program Statistical Report FY2022*. Anchorage, AK: Alaska Energy Authority. https://www.akenergyauthority.org/Portals/0/Power%20Cost%20Equalization/FY22%20PCE%20Community%20Report.pdf.

Alaska Energy Authority. 2023. *Power Cost Equalization Program Statistical Report FY2023*. Anchorage, AK: Alaska Energy Authority. https://www.akenergyauthority.org/Portals/0/Power%20Cost%20Equalization/2024.02.26%20FY23%20PCE%20Statistical%20Report%20by%20Community%20(Final%20Optimzed).pdf?ver=om4p4ZK_A-xwHiFPOHfvDQ%3d%3d.

Alaska Energy Authority. No date. *Solar Power Best Practices Guide: Renewable Energy Fund Application*. Anchorage, AK: Alaska Energy Authority. https://www.akenergyauthority.org/Portals/0/09%202020_07_17%20Solar%20Power%20Best%20Practices%20Guide.pdf.

Alaska Housing Finance Corporation. No date. “Building Monitoring System (BMON).” Accessed July 23, 2024. https://www.ahfc.us/efficiency/non-residential-buildings/building-monitoring-system.

Aleutian Pribilof Islands Association. No date (a). “Nikolski.” Accessed July 23, 2024. https://www.apiai.org/tribes/niko-lski/.

Aleutian Pribilof Islands Association. No date (b). “St. George.” Accessed July 23, 2024. https://www.apiai.org/tribes/st-george/.

Allen, Riley, Donna Brutkoski, David Farnsworth, and Peter Larsen. 2016. *Sustainable Energy Solutions for Rural Alaska*. Berkeley, CA: Lawrence Berkeley National Laboratory. LBNL-1005097. https://www.energy.gov/sites/default/files/2016/04/f30/sustainable-energy-solutions-AK.PDF.

Chaninik Wind Group. 2013. *Chaninik Wind Group Multi-Village Wind Heat Smart Grids Final Report*. https://www.energy.gov/sites/prod/files/2015/12/f27/chaninik_final_report_ee00002497_july_2013.pdf.

References *(continued)*

Erickson, Evan. 2023. “Starlink Connections Among Latest Round of Tribal Broadband Funding for Alaska.” Alaska Public Media. Accessed July 23, 2024. https://alaskapublic.org/2023/09/22/starlink-connections-among-latest-round-of-tribal-broadband-funding-for-alaska/.

Flicker, Jack, Javier Hernandez-Alvidrez, Mariko Shirazi, Jeremy Vandermeer, and William Thomson. 2020. “Grid Forming Inverters for Spinning Reserve in Hybrid Diesel Microgrids.” Presented at *2020 IEEE Power & Energy Society General Meeting (PESGM)*, Montreal, QC, Canada, August 2–6, 2020. https://doi.org/10.1109/PESGM41954.2020.9281497.

Holdmann, Gwen P., Richard W. Wies, and Jeremy B. Vandermeer. 2019. “Renewable Energy Integration in Alaska’s Remote Islanded Microgrids: Economic Drivers, Technical Strategies, Technological Niche Development, and Policy Implications.” *Proceedings of the IEEE* 107(9): 1820–1837. https://doi.org/10.1109/JPROC.2019.2932755.

Holdmann, Gwen, Dominique Pride, Greg Poelzer, Bram Noble, and Chad Walker. 2022. “Critical Pathways to Renewable Energy Transitions in Remote Alaska Communities: A Comparative Analysis.” *Energy Research & Social Science* 91: 102712. https://doi.org/10.1016/j.erss.2022.102712.

Holdmann, Gwen. No date. YouTube Video: “Kongiganak Alaka Field Trip.” https://www.youtube.com/watch?app=desktop&v=9gRSelBDv1M.

Huang, Daisy. 2020. YouTube Video: “Professional Development Seminar: Renewable Energy Implementation in Alaskan Islanded Microgrids.” UAA College of Engineering. https://www.youtube.com/watch?v=2IYzOzRjkt0&t=826s.

Jimenez, Antonio. 2018. *Chefornak Energy Configuration Options: Energy Infrastructure Optimization to Reduce Fuel Cost and Dependence in Chefornak, Alaska*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-70579. https://www.nrel.gov/docs/fy18osti/70579.pdf.

Meadows, R., A. Cooperman, M. Koleva, C. Draxl, L. Kilcher, E. Baca, K. Strout Grantham, E. DeGeorge, W. Musial, N. Wiltse, and O.J. Guerra Fernandez. 2023. *Feasibility Study for Renewable Energy Technologies in Alaska Offshore Waters*. Anchorage, AK: U.S. Department of the Interior, Bureau of Ocean Energy Management, AlaskaOCS Region. 131 p. Report No.: OCS Study BOEM 2023-076. Contract No.: M21PG00029.

Mueller-Stoffels, Marc. 2014. YouTube Video: “Renewable Energy Integration Into Diesel Microgrids - Theory and Practice Seminar.” Alaska Center for Energy and Power UAF. https://www.youtube.com/watch?v=ICTHvKMfjEM.

Northwest Arctic Borough. No date (a). “Kotzebue *Qikiqtagruk*.” https://www.nwabor.org/village/kotzebue/.

Northwest Arctic Borough. No date (b). “Kotzebue *Qikiqtagruk* Community Profile.” https://www.nwabor.org/wp-content/uploads/H.-Community-Profile-Kotzebue.pdf.

Office of Indian Energy Policy and Programs. No date. “Puvurnaq Power Company – 2022 Project.” U.S. Department of Energy. Accessed July 23, 2024. https://www.energy.gov/indianenergy/puvurnaq-power-company-2022-project.

Appendix A: Alaska Energy Expert Interviews

Interview Participants

Table A-1. Interview Participants

Name	Organization	Community
Rob Bensin	Alaska Center for Energy and Power	Kokhanok
Matt Bergan	Kotzebue Electric Association	Kotzebue
Kord Christianson	City of Sitka Electric Department	Sitka
Edward Dellamary	Tanana Chiefs Conference	Hughes
Griffin Hagle-Forster	Association of Alaska Housing Authorities	Utqiagvik
Clay Koplin	Cordova Electric Cooperative	Cordova
Ingemar Mathiasson	Northwest Arctic Borough	Shungnak and Kobuk
Neil McMahon	Alaska Energy Authority	
Alan Mitchell	Analysis North	
Dave Pelunis-Messier	Tanana Chiefs Conference	Tanacross
Jon Salmon	Igiugig Village Council	Igiugig
Darron Scott	Kodiak Electric Association	Kodiak
Rich Stromberg	University of Alaska Fairbanks	
Aimie Survant	Alaska Village Electric Cooperative	
Jeanette Dushkin		Nikolski
Bill Thompson	Alaska Village Electric Cooperative	

ENERGY
TRANSITIONS
INITIATIVE

U.S. Department of Energy

NREL/TP-5700-90685 • January 2025