RivGen® Power System Celebration in July 2019. *Photo from Austin McDaniel, Office of Alaska Governor Mike Dunleavy*

Igiugig's Journey Toward Sustainability

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About the Community

Igiugig is a remote southwestern Alaskan community of 70 people who belong to the place where Lake Iliamna is swallowed by the Kvichak River. The Kvichak River is vital to the Igyararmiut (people of Igiugig) for drinking water and for salmon, which the community has relied on as a primary staple to their subsistence lifestyle for generations.

For more than 8,000 years, the Igyararmiut have lived sustainably on their land. Igiugig's traditional food preservation techniques required no electricity. However, some preservation methods now use machinery and require electricity, which is expensive and depends on diesel fuel—a resource the community has been trying to shift away from for the past 20 years.

Igiugig Village is located in southwestern Alaska, on the south bank of where the Kvichak River meets Lake Iliamna. *Photo from Igiugig Village Council (2020)*

Accomplishments Toward a More Sustainable Future

Igiugig is a consensus-based community with strong leadership. This means that the community supports their leaders, and these leaders are committed to seeing that the entire community is included in the plans they collectively pursue. Their journey toward sustainability started in 2000 when the village completed its first comprehensive community vision and plan. Alternative energy was identified as a top priority.

In 2014, after completing renewable energy feasibility studies with the help of the Alaska Energy Authority and the National Renewable Energy Laboratory (NREL; refer to Figure 1 for a timeline of events), the community decided to move forward with permitting a test bed for hydrokinetic devices. Two devices were tested, and the community chose to enter into a sole partnership with Ocean Renewable Power Company (ORPC) to pursue a hydrokinetic project that could deliver baseload renewable energy without harming the salmon, the central component of Igiugig's subsistence lifestyle.

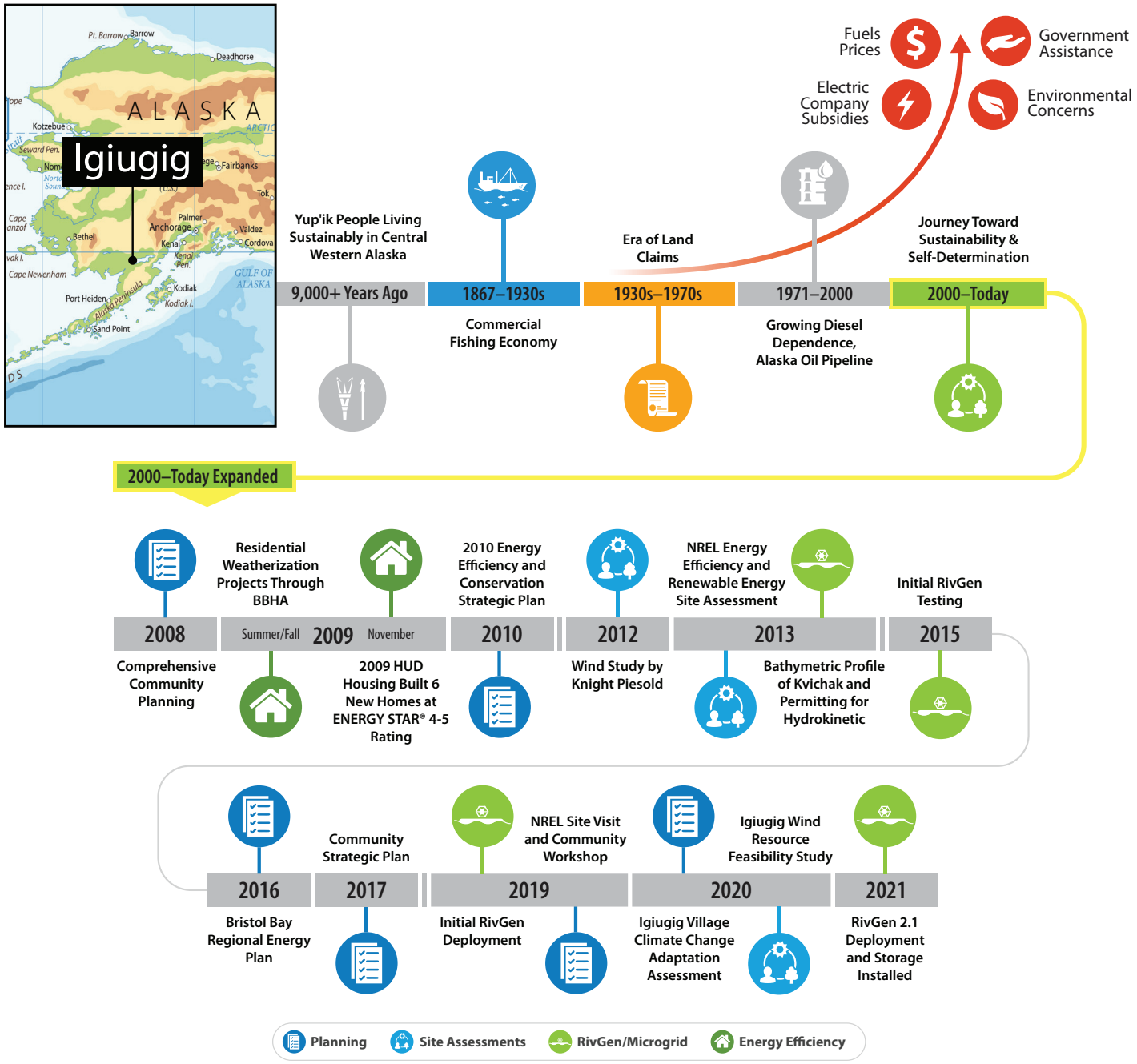

Figure 1. Igiugig's accomplishments toward a more sustainable future

Since 2014, Igiugig Village Council has navigated from a hydrokinetic power test site to a commercial microgrid, which has included multiple deployments of ORPC's RivGen® device and power system, incorporating lessons learned through each deployment. In 2021, the RivGen 2.1 and battery energy storage system were installed; a second RivGen installation and potentially additional renewable energy resources are planned within the next few years.

Additionally, as people of the land, the community have long been aware of their carbon footprint. Although they have contributed the least to climate change, they bear the brunt of the impacts: their access to subsistence foods is in danger, which threatens the long-term sustainability of their way of life.

2022 Comprehensive Energy Plan

The U.S. Department of Energy's Water Power Technologies Office funded NREL to support Igiugig in updating their Comprehensive Energy Plan (Figure 2). The plan was developed through a series of community meetings followed by data collection and analysis throughout 2021. The plan was adopted by the community in January 2022.

Baseline Assessment and Key Findings

The team, which was led by Igiugig and included NREL and Deerstone Consulting, gathered baseline data and reviewed all existing plans and studies to identify and evaluate strategies and prioritize actions to address the Comprehensive Energy Plan's (CEP) five focus areas. Key findings by focus area from the baseline assessment are discussed in the following subsections.

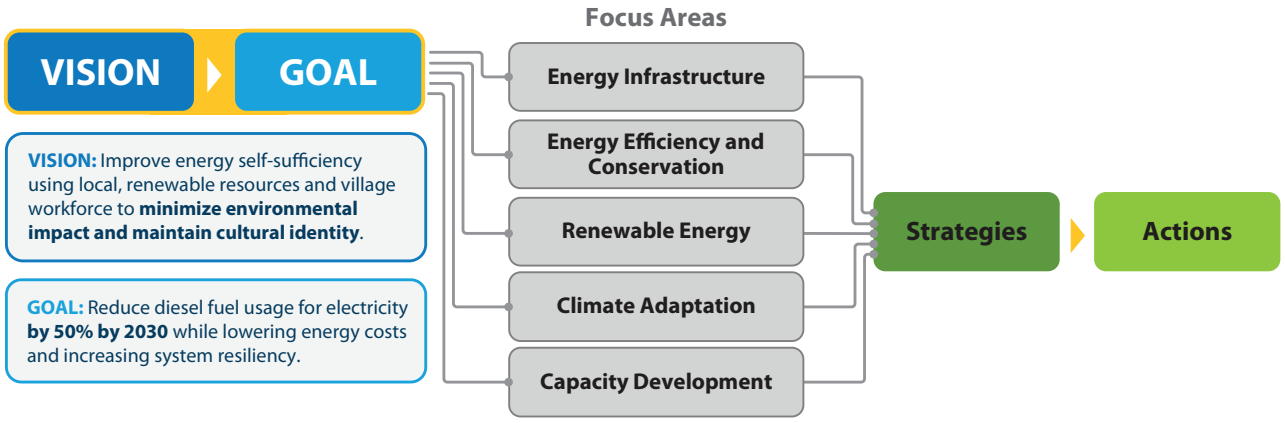

Figure 2. Comprehensive Energy Plan structure

Key Findings for Energy Infrastructure

The major components of Igiugig's electric power plant and thermal infrastructure are summarized in Table 1. Figure 3 shows that in 2019, more diesel fuel was used for space heating than electricity.

Table 1. Electric Power Plant and Thermal Infrastructure Description

Asset	Description
Diesel Generators	Three 65-kW John Deere 4045 diesel generators were installed in 2013. When the village load exceeds 55 kW, a second generator is brought online, but for most of the year, only one diesel generator is needed. Diesel control upgrades were installed in the summer of 2021.
Solar Photovoltaics (PV)	1.2-kW residential solar PV
Wind Turbines – Horizontal Axis	Six 2.5-kW turbines by Skystream. Two are operational at the greenhouse. The others were repaired in 2020 but are currently not working.
Wind Turbines – Vertical Axis	Two 2-kW turbines by Wing Power Energy located near the mouth of the river at fish camp that have required manual supervision to operate. The greenhouse unit is old and not functional.
RivGen Unit	40-kW RivGen currently derated by 40% due to turbine retrofit in 2019. Lessons learned were applied to RivGen 2.1, installed in the summer of 2021.
Battery Energy Storage System/ Controller	253-kWh/125-kW system installed in the summer of 2021 with microgrid controller.
Heat Recovery System	Buildings served: water treatment plant, post office, store, and offices. Planning heat recovery replacement systems (pump house heat exchanger).
Space Heating	Most homes use heating oil for Toyo or baseboard heat, with many homes having wood stoves for backup heat and to reduce diesel costs. Most businesses use diesel boilers.
Domestic Hot Water Heating	Diesel hot water heaters are used for residential and businesses. The airport hangar uses an electric hot water heater.

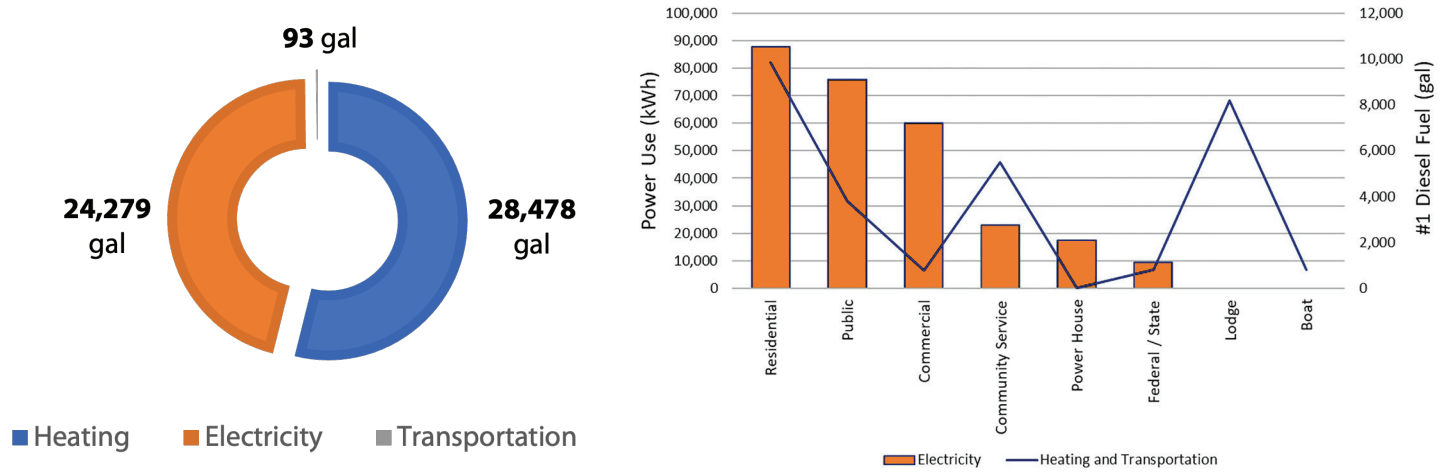

Figure 3. 2019 diesel fuel usage for electricity and heat, in total and by premise type

In 2019, 319,544 kWh were generated from diesel fuel, and lines losses were 14.8% (Alaska Energy Authority 2020), presenting a significant fuel savings opportunity. There are also ongoing power quality issues in the electrical infrastructure—such as frequency fluctuations, phase imbalances, and outages—that threaten the community's critical infrastructure (residential freezers, clinic medical systems, heating systems, airport runway lights, etc.).

Key Findings for Energy Efficiency and Conservation

Igiugig has completed significant energy efficiency work to date, primarily focused on residential premises, with more than 71% of the homes receiving an energy audit and retrofit (Sorensen et al. 2015). Opportunities for efficiency are in the commercial/community loads and in improving the efficiency of space heating throughout the community. However, revenue loss disincentivizes the Igiugig Village Council to work with the largest consumers—who are nonresident or non-village—to save diesel fuel. High-priority energy efficiency measures include completing an audit for the pumphouse as well as implementing energy efficiency retrofits at the clinic, both of which benefit the village.

Key Findings for Renewable Energy

The need for additional renewables is dependent on the performance of the RivGen devices. Evaluation of this need was completed as part of the strategic energy planning process using the Hybrid Optimization Model for Electric Renewables (HOMER®) microgrid simulation and optimization software. The following scenarios were evaluated:

- Baseline: Diesels Only
- Scenario 1: Medium RivGen Performance[1]
- Scenario 2: Medium RivGen Performance and Additional Renewables (Solar and Wind)
- Scenario 3: No RivGen and Additional Renewables (Solar and Wind).

The analysis showed that about 30–70 kW of solar PV would be cost-effective, along with 100 kW of wind, depending on the RivGen's availability and performance. While Igiugig has a good wind resource, it is difficult to find a reliable wind turbine option in the 25–100-kW range with adequate maintenance support for their remote location.

Given the uncertainty around the RivGen's performance due to the maturity of the technology as well as the lack of reliable small wind turbine options, the addition of solar PV as a low-maintenance and proven renewable technology would help cover summer loads and provide resiliency to the microgrid for unplanned maintenance and downtime associated with the RivGen devices. However, none of the evaluated scenarios would significantly reduce the larger diesel usage attributed to space heating. Therefore, moving forward, the community would like to evaluate a larger wind turbine in combination with the RivGen devices for electrifying thermal use.

[1] The HOMER Pro software was used for this analysis, and average performance estimates for the RivGen were modeled, assuming one RivGen 2.1 with 83% availability (down for a month in the winter for icing and a month in the summer for maintenance).

Key Findings for Climate Adaptation

In 2020, the Igiugig Village Climate Change Adaptation Assessment was completed through a series of eight community planning meetings. The main hazard identified was wildfire threat to subsistence resources, infrastructure, and community health. Other primary hazards included the shifting seasonal harvest calendar, water quality issues due to increased water temperatures, melting permafrost, and erosion (Igiugig Village Council 2020).

Key Findings for Capacity Development

As the community's microgrid has become more complex, it has become more challenging to maintain. This complexity brings an increasing dependence on outside experts to solve operations and maintenance (O&M) issues, which reduces autonomy and increases system downtime. These outcomes are in opposition to Igiugig's Energy Vision of improving energy self-sufficiency using local, renewable resources and village workforce (Figure 2).

At present, ORPC and the community are working together to better understand and define the O&M requirements and associated costs for the RivGen. Community involvement, including local vessels and marine operations expertise, will continue to be critical to the project's success. To date, the O&M requirements of the device itself have primarily been handled by ORPC. As O&M procedures are established, training within the community is key for ongoing deployment success.

Strategies and Next Steps

While the ownership structures and performance of the new RivGen device and battery energy storage system are evaluated, the community is focusing on other initiatives. One priority is energy efficiency of community buildings, and a second involves solving power quality and line loss issues before they consider adding more renewables to the system and incorporating renewable heating strategies. Table 3 summarizes high- and medium-priority strategies by focus area.

Table 2. Key Findings From the Baseline Assessment by Focus Area

Focus Area	Key Findings
Energy Infrastructure	• More diesel fuel is used for space heating than electricity. • Power system line losses are high and present a savings opportunity. • There are ongoing power quality issues with frequency dips.
Energy Efficiency and Conservation	• Energy efficiency on residential housing stock is good . • Opportunities for efficiency are in the commercial/community loads and improving the efficiency of space heating. • There is a disincentive for Igiugig Village Council to work with the largest consumers who are customers to save diesel fuel usage due to revenue loss.
Renewable Energy	• Ownership scenarios and future maintenance costs for the RivGen units are not clear. • Additional PV and wind could be cost-effective, depending on the performance of the RivGen. • While Igiugig has a good wind resource, it is difficult to find a reliable wind turbine option in the 25–100-kW range with adequate maintenance support for their remote location.
Climate Adaptation	• Initial assessment was developed in 2020 with University of Alaska Fairbanks through a series of eight community planning meetings. • The main hazard identified was "wildfire threat to subsistence resources, community, and health."
Capacity Development	• As the technology and microgrid have become more complicated, there has been a loss of independence and predictable budgeting. • Training on renewable energy O&M is key to future renewable energy deployment success.

Table 3. Igiugig's Comprehensive Energy Plan Strategies by Technical Priority

Focus Area	Immediate: 2021–2023	Midterm: 2024–2025
Energy Infrastructure	• Implement upgrades to power plant and resolve line loss issues • Optimize heat recovery system • Explore RivGen ownership opportunities	• Implement strategic renewable heating
Energy Efficiency and Conservation	• Complete high-priority energy conservation measures • Complete high-priority energy efficiency measures	• Complete medium-priority energy conservation measures • Complete medium-priority energy efficiency measures
Renewable Energy	• Evaluate the need for additional renewables • Evaluate renewable heating options	• Install additional renewables as needed
Climate Adaptation	• Complete climate adaptation plan	• Implement climate adaptation plan and fire mitigation work
Capacity Development	• Explore Bristol Bay regional partnerships	

Power Cost Equalization and Ownership Considerations

A critical next step for the community is finalizing the ownership structure of the RivGen devices. Primary options currently under consideration include the village owning the units versus purchasing the power produced from an independent power producer. Key factors in which ownership option the community selects include future performance and maintenance costs of the RivGen units and the State of Alaska's Power Cost Equalization (PCE) Program.

The PCE reimbursement to utilities is based on a formula that includes the cost and usage of diesel fuel. When a community utility owns and installs a renewable energy system, their usage of diesel is reduced, resulting in a reduction in the PCE reimbursement to the utility. Therefore, utility rates to PCE residential and community consumers are negligibly impacted by renewable energy projects because the majority of the fuel savings cost benefits go to the State of Alaska in reduced PCE payments. However, commercial rate payers within the community are not eligible for PCE, so they will see a reduction in rates due to renewable energy projects that result in fuel savings.

When an independent power producer (IPP) produces renewable energy and sells the power to the community utility, the cost of power from the IPP is considered a fuel cost and is treated the same as purchased diesel fuel in the PCE formula that determines reimbursement to the utility. The "lost" PCE reimbursements from utility-owned renewable energy projects are recouped by the IPP. If the IPP is a community-based entity and the IPP revenue is used for the benefit of the utility and community, this can result in additional benefit flows equivalent to reduced rates to the residential and community-based electric customers. However, if the IPP is an outside entity trying to make a profit or recoup project development costs, the IPP does not typically benefit the community financially. Instead, the "recouped" PCE payments flow out of the community to the IPP.

In addition to PCE reimbursement considerations, equipment operation is also a key factor when considering ownership options. The IPP model can help improve the economics of rural Alaskan renewable energy projects by maintaining PCE funding. However, because the operations and maintenance costs of the RivGen are currently unknown and ownership negotiations are ongoing, it is critical that final decisions reduce the risk to the community of proving the reliability of a newer technology.

Future Pathways

Igiugig acknowledges the long journey and strong partnerships, including stable tribal governance, that helped the community come this far and that will be required to reach their 2030 diesel fuel reduction goal. They continue to look for strong partners, like ORPC, that prioritize the village's concerns. While it has taken millions in private, state, and federal investments to achieve their accomplishments to date, their way of life and relationship to the land is priceless. Climate change and dependence on diesel fuel are significant threats that impact the community's existence.

Keeping tribal sovereignty and local ownership of the microgrid are critical components of Igiugig Village Council's transition to renewable energy. The Council would also like to focus on working with other rural Alaskan communities to create efficiencies in the energy transition process and help improve policies to move forward together as a state toward a more sustainable future.

References

Alaska Energy Authority. 2020. Power Cost Equalization Program Statistical Report. Anchorage, AK: Alaska Energy Authority.
https://www.akenergyauthority.org/LinkClick.aspx?fileticket=iCwGWYtX_Dl%3d&portalid=0.

Igiugig Village Council. 2020. Igiugig Village Climate Change Adaptation Assessment.
https://uaf-snap.org/wp-content/uploads/2020/08/Igiugig-Adaptation-Assessment.pdf.

Sorensen, Lawrence, Doug Griffin, Laura Vaught, Jamie Hansen, Jana Peirce, and Richard Raines. 2015. Bristol Bay Regional Energy Plan: Phase II - Stakeholder Engagement.
https://bbna.com/wp-content/uploads/2019/10/b36f8-bb-regional-energy-plan-phase-ii-9.21.15.pdf.

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NREL/BR-5700-83816 • December 2022