# Microgrid Market Analysis: Alaskan Expertise, Global Demand

A study for the Alaska Center for Microgrid Technology Commercialization

Prepared by the University of Alaska Center for Economic Development

# Contents

## Introduction

Today, Alaska is a world leader in microgrid systems innovation, with over 200 remote microgrids, and the tailored research capabilities of the Alaska Center for Energy and Power (ACEP).[1] Approximately 70 of the microgrids are integrated electrical systems (with hybrid wind-diesel being the most common) in remote areas without access to road systems.[2] In addition to operating in geographic isolation, these systems have been tested in the harshest of weather conditions and environments.[3] This is significant for the state's rural areas because microgrid systems are designed to provide power in the absence of a central grid, which is unavailable throughout most of the Alaska's landmass. While microgrids were first constructed in the state simply to solve the challenge of powering remote communities, global demand for microgrid technologies is growing. This report examines some of the key innovations in microgrid systems that have been developed in Alaska, especially wind-hybrid systems, geothermal, and solar energy systems, as well as energy storage. Each resource will also include a case study of a community that had a unique technical problem, the solution developed, and the innovation that can be applied to the outside world. The purpose is to demonstrate ways in which Alaska is a testbed for innovation in renewable energy generation, storage, and microgrid management technology, and to link these competencies to global trends.

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[1] Erica Martinsen, "Alaska's Rural Energy Microgrids Offer a Prototype for Powering the World," Alaska Dispatch News, February 15, 2016, Accessed July 22, 2016, http://www.adn.com/energy/article/alaskas-microgrids-offer-prototypye-powering-world/2016/02/15/

[2] Ibid.

[3] Heather A Resz. "Renewable Energy in Alaska." *Alaska Business Monthly*, April 2016, 58-61.

# Market Trends

In order to understand how Alaska fits into the microgrid market, one must understand the trends that have made microgrids more prevalent in the global market. The shift to microgrids for some applications is a response to the unreliability of some centralized grids. This is especially prevalent in the United States, where the annual average electrical outage time is 120 minutes, and increasing; as opposed to Europe's annual average electrical outage time of 10 minutes, and decreasing.[4] The need for reliable energy resources and transmission is appealing to institutions such as hospitals, military bases, and even small communities that are dependent on fossil fuels to generate electricity. Using information from Navigant Research, this section provides a general overview of the global demand for microgrids, including the major segments and world players. It will also examine which segments are most relevant to Alaskan expertise, and thus the most viable service export targets.

## Major Microgrid Segments

Five of the major microgrid segments are listed below, included is their total Megawatt and percentage share as of 2013:

1. Campus/Institutional microgrids (1,031 MW, 25% global share)
2. Community/Utility microgrids (957 MW, 23% global share)
3. Remote microgrids (949 MW, 23% global share)[5]
4. Military microgrids (661 MW, 16% of the global share)[6][7]
5. Commercial/Industrial (C/I) microgrids (549 MW, 13% global share)[8]

## Global demand of microgrids

In the 2013 microgrid report, Navigant Research stated that it is difficult to quantify the Value of Electrical Energy Security (VEES) because microgrids are customized to solve problems and accommodate the region they are located in. However, the report also states that "given the diversity of resources, scale, and development patterns, it is clear that microgrids are poised to proliferate across the world over the next 7 years setting the stage for an even higher market penetration rate thereafter" (this statement was written in 2013).[9] Although Navigant declared that it was too difficult to quantify energy security, they sought to measure the impacts of microgrids by breaking down the top global players by region and segment. The authors measured the total capacity of projects in the region, country/state, and around the world, as well as the Compound Annual Growth Rate (CAGR), vendor revenue, and available

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[4] Asmus, Peter, and Mackinnon Lawrence, *Microgrids*, Report. Boulder, Colorado: Navigant Consulting, 2013.
[5] Asmus and Lawrence, *Microgrids*.
[6] Ibid
[7] Note: the US DOD is "the largest consumer of energy in the federal government...to power its permanent military installations around the world."
Source: "Energy Management in DOD Facilities." U.S. Government Accountability Office. Accessed April 1, 2016. http://www.gao.gov/key_issues/energy_management_dod_facilities/issue_summary#t=0.
[8] Asmus, Peter, and Mackinnon Lawrence, *Microgrids*.
[9] Ibid, p. 90.

infrastructure. They also projected the base scenario for the aforementioned categories will be in 2020.

North America is the leader in microgrids with 49% of the total global capacity. The United States is the regional leader with a base scenario CAGR of 29.9%, and an annual vendor revenue of their top 5 states (California, Alaska, Hawaii, Connecticut, and New York) at approximately $1.8 billion by the year 2020. The most lucrative enterprises are remote microgrids because of the increased demand for “robust grid infrastructure to bolster service in light of an unreliable utility grid.”[10]

Behind North America is the Asia Pacific Region, which includes: Australia, China, India, Japan, and South Korea. The Asia Pacific Region is expected to exceed North America, due in large part to carbon tax policies such as those found in China and Australia, as well influential advocates that promote the implementation of renewable energy resources and energy storage. According to the base scenario, it is projected that the region will have a CAGR of 24.5% by 2020 and a vendor revenue increase from $1.5 billion in 2013 to $6.9 billion by 2020.[11]

Europe’s microgrid movement is driven by Denmark, Germany, Spain, and the United Kingdom (UK). Germany is the leader in grid-tied systems due to the high penetrations of Renewable Distributed Energy Grids (RDEGs), as well as the increased demand for remote microgrids. Denmark’s movement is motivated by their plans to generate 100% of their electricity from renewable energy sources by the year 2050. Their success in implementing microgrids is driven by offshore wind generation, which accounts for as much as140% of the country’s power demand.[12] In addition, they also have strong intertie connections with Sweden and Norway and can transfer excess wind energy to those nations.[13]As a result, Denmark has achieved a 43% renewable energy capacity.[14] Overall, Europe is expected to have a CAGR of 11.2% and vendor revenue of $1.9 billion by 2020.[15]

Latin America lags in microgrid growth because it lacks a communication infrastructure which is vital to smart grid systems. About 75 million people in Latin America are without access to electricity, and 31 million people are not connected to the primary grid. As a result, most

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[10] Asmus and Lawrence, *Microgrids*, p. 81.
[11] Ibid, p. 79-81.
[12] Arthur Nelsen, "Wind Power Generates 140% of Denmark's Electricity Demand," The Guardian, July 10, 2015, Accessed September 13, 2016. https://www.theguardian.com/environment/2015/jul/10/denmark-wind-windfarm-power-exceed-electricity-demand.
[13] Justin Gillis, "A Tricky Transition from Fossil Fuel," The New York Times. November 10, 2014, Accessed September 13, 2016, http://www.nytimes.com/2014/11/11/science/earth/denmark-aims-for-100-percent-renewable-energy.html?_r=0.
[14] Helle Jeppesen, "Denmark Leads the Charge in Renewable Energy," DW.COM, May 5, 2014, Accessed September 13, 2016, http://www.dw.com/en/denmark-leads-the-charge-in-renewable-energy/a-17603695.
[15] Asmus and Lawrence, *Microgrids*.

communities rely on diesel generators. Although there is hydroelectric capacity, recent droughts in countries such as Chile have shifted focus towards generating electricity from other energy resources.[16] However, it is still projected that by the year 2020, Latin America will have a CAGR of 43.8% due to remote microgrids serving nations such as Haiti and Puerto Rico, as well as Chile's remote mining operations. Latin America is also expected to reach $900.4 million in vendor revenue by 2020.[17]

In the Middle East and Africa, growth in microgrids is driven by DC telecom towers that modernize utility management by incorporating automatic systems, and also by the Solar PV and security of energy systems. In addition, the growth of diesel hybrid systems in Sub-Saharan Africa is expected to become the largest share of electricity generation by the year 2040.[18] According to the base scenario, the region is expected to have a CAGR of 35.1% and vendor revenues are expected to reach $1.5 billion by 2020.[19]

Remote microgrids are the most prevalent microgrid segment in the global market because they act either as an auxiliary source when the central grid is down or function independently from the central grid. The advantage is the ability to operate 24 hours a day, seven days a week without fear of disruption in areas without reliable primary grid infrastructure. They can also be integrated with other renewables resources such as Solar PV, wind, remote diesel generators (such as in Alaska), and hydroelectricity. In addition, policies that promote individual remote microgrids can have long-term benefits. India is a promising example because they deregulated all microgrids that produce less than 1 MW and have a successful pay-as-you-go approach on Solar PV systems, making it easier to use solar panels for microgrids. As a result, under the base scenario, India is expected to grow from 7 MW to 54 MW capacity by 2020, with a CAGR of 33.9%.[20]

## Where does Alaska fit into the picture? Which segments are relevant?

Alaska is one of the top 5 US states in microgrid capacity development. The state boasts over 200 remote microgrids with diesel generators acting as a primary source of electricity generation in most of these communities.[21] Unlike other US states, Alaska's power demand outside of the Railbelt is served entirely by remote grids. This is because the state lacks an extensive road system due to its landscape and geographic dispersion. As a result, rural communities' fuel has to be transported via barge during the summer months, or costly air freight.  However, the constant fluctuation in fuel prices has been taxing on the financial stability of communities and their residents.

[16] Elisa Wood, "The Vital Role of Reciprocating Engines in Remote Communities," Microgrid Knowledge. September 12, 2016, Accessed September 13, 2016. http://microgridknowledge.com/reciprocating-engines-in-remote-communities/.
[17] Asmus and Lawrence, *Microgrids*, p. 85.
[18] Elisa Wood, "The Vital Role of Reciprocating Engines in Remote Communities."
[19] Asmus and Lawrence, *Microgrids*, p. 86.
[20] Ibid, p. 82-83.
[21] Erica Martinsen, "Alaska's Rural Energy Microgrids Offer a Prototype for Powering the World," Alaska Dispatch News, February 15, 2016, Accessed July 22, 2016. http://www.adn.com/energy/article/alaskas-microgrids-offer-prototypye-powering-world/2016/02/15/.

### Remote/Wind-Diesel Microgrids

There are approximately 70 microgrids integrated with diesel generators, the majority of them being wind-diesel systems.[22] Although there are constraints, some communities such as Kotzebue and Kodiak, have made the effort to transition to renewable energy sources such as wind and hydroelectric to generate power in conjunction with their diesel engines. Kotzebue and Kodiak recognized the need to switch to renewable energy and reduce their dependence on fossil fuels. As a result, these communities saw a decrease in both their electricity rates and their dependency on fossil fuels. These are but a few examples on how rural Alaskan villages are innovating their electrical grid through microgrid technologies.

### Military Microgrid

Alaska's military bases, such as the Joint Base Elmendorf-Richardson (JBER) must be able to maintain military operations when the central grid fails. In partnership with Doyon Utilities and the Municipality of Anchorage, they constructed a landfill gas production plant in 2011, which began producing electricity in 2012. Since 2013, the project has produced 26.2% of the electricity required for JBER, which exceeds the federal mandate that all federal government facilities must consume 7.5% of their electricity from renewable/alternative energy.[23] This was achieved with the help of 2,050 cubic feet of methane per minute that the Anchorage landfill produces, where the plant uses only 1,800 cubic feet to produce 5.6 megawatts an hour.[24] Fiscally, it saves approximately $30 million to $50 million for JBER over a 20-year period.[25] Although a small amount of electricity is produced compared to Chugach's South Central Power Plant (with a production capacity of 183 Megawatts per hour), the gas power plant has proven beneficial for JBER to meeting both their operational and federal mandate requirements, while offsetting greenhouse emissions.

## Microgrid Resources with Examples in Alaska

This report examines the innovations in microgrid systems that have been developed in Alaska, especially wind-hybrid systems, geothermal, and solar energy systems. Each resource is highlighted in a section, which includes case studies that show what specific communities have done to resolve their electricity production issues using that particular resource. It will highlight the specific problems utilities had to resolve, how they solved them, and the innovations they advanced by integrating renewable energy into their electrical grids. Each section will illustrate how Alaska is a testbed for innovation in renewable energy generation, storage, and microgrid technology, and how that innovation that can be applied to the outside world.

### Wind

Before a community can utilize wind resources, they must determine the potential output, and how to best utilize it. A community's wind potential is dependent on the strength of wind sources. This is

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[22] Heather A. Resz, "Renewable Energy in Alaska," *Alaska Business Monthly*, April 2016, 58-61.
[23] Doyon Utilities and Municipality of Anchorage. *Anchorage Landfill Gas to Energy Project*. Anchorage, Alaska.
[24] Suzanna Caldwell, "New Power Plant Expanding Thanks to Extra Gas from Anchorage Landfill." Alaska Dispatch News, May 6, 2013, Accessed April 1, 2016.
[25] Ibid.

measured by the Wind Class Scale, which quantifies and ranks wind strength in specific areas in Alaska.[26] The scale rates localities from Class 1, the lowest, to Class 7, the highest.[27] An area with a rank between 4 and 7 has the best potential to produce electricity from wind.[28][29] In addition, the size of the community can determine whether they need small, medium, or large turbines. For example, Kodiak falls within the above requirements to produce electricity from wind energy because they have Class 7 winds.[30] As a result, they installed six 1.5 MW turbines on the island from 2009 to 2012.[31] Today, approximately 30% of electricity produced in Kodiak comes from wind energy. When combined with hydroelectricity, renewables produce 99% of their electricity needs.[32] [33]

*Table 1: List of communities with wind turbines installed capacity and the number of wind turbines.*

| Community Name | Installed Capacity (kW) | Number of Turbines |
|---|---|---|
| Saint Paul Island | 675 | 3 |
| Saint George | 95 | 1 |
| Nikolski | 65 | 1 |
| Sand Point | 1,000 | 2 |
| Perryville | 24 | 10 |
| Kodiak | 9,000 | 6 |
| Kokhanok | 180 | 2 |
| Fire Island | 17,600 | 11 |
| Eva Creek | 24,600 | 12 |
| Delta Wind | 1,917 | 3 |
| Quinhagak | 300 | 3 |
| Kongiganak | 355 | 5 |
| Kwigillingok | 450 | 5 |
| Tuntutuliak | 450 | 5 |
| Bethel | 100 | 1 |
| Kasigluk | 300 | 3 |
| Toksook Bay | 400 | 3 |
| Mekoryuk | 200 | 2 |

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[26] Jill Maynard et al., Community Wind Toolkit: A Guide to Developing Wind Energy Projects in Alaska. Renewable Energy Alaska Project (REAP), 2011. Accessed March 24, 2016.http://alaskarenewableenergy.org/wp-content/uploads/2009/04/WindToolkit_For-web_FINALMarch24_20111.pdf.
[27] Ibid, p.2.
[28] Alaska Energy Authority, *Renewable Energy Atlas of Alaska.* Anchorage, Alaska, 2013.
[29] Martinsen, "Alaska's Rural Energy Microgrids Offer a Prototype for Powering the World."
[30] Vaught, Douglas. Kodiak, Alaska Site 1 Wind Resource Report. Report. Alaska Energy Authority (AEA). Eagles River, Alaska, 2006. Accessed August 22, 2016. http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/WindResourceAssessment/Kodiak Site 1 Wind Report Nov 06 by V3.pdf.
[31] Alaska Energy Authority, *Renewable Energy Atlas of Alaska.*
[32] Stephanie Nowers, "100% Renewably-Powered: Alaska's Kodiak Island Goes All in with Wind and Hydro," Islanded Grid Resource Center, Accessed April 4, 2016, http://islandedgrid.org/100-renewably-powered-alaskas-kodiak-island-goes-all-in-with-wind-and-hydro.
[33] "KEA Generation," Kodiak Electric Association, Accessed April 19, 2016, http://www.kodiakelectric.com/generation.html.

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|---|---|---|
| Chevak | 400 | 4 |
| Hooper Bay | 300 | 3 |
| Emmonak | 400 | 4 |
| Gambel | 300 | 3 |
| Savoonga | 200 | 2 |
| Unalakleet | 600 | 6 |
| Shaktoolik | 200 | 2 |
| Nome | 2,775 | 18 |
| Wales | 355 | 2 |
| Buckland | 200 | 2 |
| Deering | 100 | 2 |
| Selawik | 260 | 4 |
| Kotzebue | 2,965 | 19 |
| **Total Capacity** | **66,766** | **149** |

Source: http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/WindMaps/Statewide%20-%20Installed%20Wind%20Fall%202015.jpg
http://alaskarenewableenergy.org/why-rewenable-energy-is-important/alaskas-renewable-energy-projects/
http://www.tdxpower.com/sand-point
http://www.iesconnect.net/projects/tuntutuliak-wind-heat-system/

As early as the 1990s, wind turbines began to appear in rural Alaskan villages' electricity portfolio. As of fall 2015, there are 31 rural communities in the state that utilize wind energy. In total, there are approximately 149 wind turbines that produce over 66,766 kW (66.766 MW) of electricity. The majority of these wind turbines are integrated with pre-existing diesel engines to create wind-diesel hybrid microgrid systems. In tandem with hydroelectricity, wind power systems contributed 25% to Alaska's electricity generation in 2016.[34] This is a significant increase in power generation compared to production from other electricity sources in 2016: gas (48.1%), oil (3.4%), coal (9.4%), and renewables (29%).[35] Communities such as Kotzebue, Kodiak, and the villages of the Chaninik Wind Group utilize these integrated systems because wind is intermittent, and the need for additional methods of electricity production are essential to maintain the electrical grid. The reason for the transition to renewable resources are the economic benefits such as, cutting the use of diesel fuel, which saves money in buying the resources that could be used for other purposes, such as economic development or the continued integration of renewable energy resources.

## Kotzebue

***Problem***

[34] Resz, "Renewable Energy in Alaska."
[35] U.S. Energy Information Administration, "Alaska State Energy Profile." U.S. Energy Information Administration, August 18, 2016, Accessed August 29, 2016. http://www.eia.gov/state/print.cfm?sid=ak.

Prior to the installation of their wind turbines, the community of Kotzebue relied heavily on the use of fossil fuels, like many of Alaska's remote places. Accessible only by air or water (summer only), Kotzebue is located 30 miles north of the Arctic Circle on the Baldwin Peninsula and serves as the regional hub for 11 rural communities.[36] It relied on 6 diesel generators with a combined 11.2 MW capacity, and fuel that had to be transported during the ice-free summer via barge.[37] As a result, the area was vulnerable to diesel price shocks, which could make power prohibitively expensive for businesses and households. At the same time, Kotzebue needed to replace its fuel storage tanks, as they were reaching the end of their useful lifespan.[38]

***Solution***

Price shocks in fossil fuels motivate rural communities like Kotzebue to consider other energy options, especially where wind is abundant. In 1997, after diesel subsidies from the state decreased,[39] the Kotzebue Electric Association (KEA)[40] created the first utility wind farm, in the state, to help power its community. According to the KEA, three major characteristics must be present to make wind energy an attractive choice to create electricity. First, Kotzebue has Class 4-5 wind resources.[41] It has average wind speeds of more than 13 miles an hour and often stronger during winter. Second, Kotzebue is situated on the coast, where the air is denser and produces more force to move the turbines. Third, there are few natural barriers such as trees and mountains to create a turbulent, and inconsistent wind flow. As a result, the turbines rotate near their fullest capacity.[42] At its minimum, the wind farm produces electricity from 11 mile an hour winds. At its highest, it produces 80 kW from 24-26 mile per hour winds.[43] These conditions proved promising for the community because of the aforementioned savings that are incurred from generating wind power.

The current wind farm consists of 19 wind turbines that produce 2,965 kW of electricity (see Table 2). This undertaking displaced over 90,000 gallons of diesel in 2012.[44] In 2013, Kotzebue saved "$839,000

[36] Rana Zucchi, Global Energy Concepts, and Kotzebue Electric Association Brad Reeve, DOE Project Officer - Doug Hooker. 2007. "Final Technical Report - Kotzebue Wind Power Project - Volume I", United States, doi: 10.2172/918467, http://www.osti.gov/scitech/servlets/purl/918467.

[37] Ibid.

[38] Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), *Wind Turbine Provides Electricity for Arctic Town*, February 2001, Technical Brochure No. 143, United Kingdom. http://www.akenergyauthority.org/Content/Programs/AEEE/Reports and Presentations/Wind-Turbine-Provides_Electricity-for-Arctic-Town_CADDET-Kotzebue-Article.pdf.

[39] James Haselip, and David Pointing, eds, *The Cool 100 Book*. Roskilde, Denmark: UNEP Risø Centre on Energy, Climate and Sustainable Development Risø DTU National Laboratory for Sustainable Energy, PDF. doi:http://www.iser.uaa.alaska.edu/Publications/TheCool100Book.pdf., p.102

[40] Not to be confused with the Kodiak Electric Association (KEA).

[41] Geographic Information Network of Alaska, University of Alaska Fairbanks, "Alaska Wind Power Potential (AEDI, 2011)," ArcGIS, February 10, 2012, Accessed August 19, 2016, http://www.arcgis.com/home/item.html?id=6aaef4ce5821459cad757bf9adda3079.

[42] "Winds in Kotzebue," Kotzebue Electric Association, 2013, Accessed April 09, 2016, http://www.kea.coop/articles/winds-in-kotzebue/.

[43] "Wind Energy Production," Kotzebue Electric Association, 2013, Accessed April 09, 2016, http://www.kea.coop/articles/wind-energy-production/.

[44] Hannah Heimbuch, "Massive Wind Turbines Newest Features of Kotzebue Skyline," Alaska Dispatch News, May 2, 2012, Accessed May 12, 2016, http://www.adn.com/rural-alaska/article/massive-wind-turbines-newest-features-kotzebue-skyline/2012/05/03/.

(in diesel fuel)...dropping to 1.28 million gallons from 1.55 million."[45] By 2014, the wind farm provided 20% of the community's annual average load of 2.5 MW.[46] It also displaced over 250,000 gallons of diesel, an equivalent of $900,000 for the community of Kotzebue.[47] The project has been innovative and successful. It has received "national attention-and awards-for its design and high percentage of power to the community."[48]

***Innovation Applied***

As the first utility-owned wind farm in Alaska, KEA has been "learning all the little tricks over the years on how to handle higher penetrations of the wind."[49] When constructing the wind farm, KEA had to consider how to install wind turbines in cold weather conditions. First, KEA built an ice road to allow for the transportation of supplies and equipment. Then, contractors drilled deep holes to house the turbine pilings, secured and reinforced them with a slurry of gravel and water and 8-inch thick foam around the base.[50] This knowledge set would prove useful for the Kodiak Electric Association in the mid-2000s when they sought out Kotzebue's insight on how to build a utility-owned wind farm.[51] Kotzebue's expertise in building utility-owned wind farms in extreme environments is not only beneficial for Alaskan villages, but also for other Arctic communities in Canada and Russia.

Kotzebue is the first notable example of how to construct utility-owned windmills in the tundra.[52] In the 1980s, Alaska invested in over 140 wind projects funded by the state and federal government to help alleviate energy issues. Renewable energy sources like wind turbines were at their infancy stage, and taking advantage of an opportunity to utilize renewable energy was attractive to many diesel-dependent communities. The turbines were successful in states such as California, because they were made to last in less extreme climates. However, they were not initially successful in Alaska due to a lack of: utility involvement, supporting infrastructure, and cold weather designs. The turbines were decommissioned and the project was abandoned within a year because the turbines were unable to withstand the harsh conditions of the tundra.[53] It was not until the 1990s when Kotzebue decided to invest in the updated wind turbines that could withstand colder climates that wind power began to reemerge.[54] The switch to wind energy resulted in better community energy practices because the turbines operated year round, resulting in year-long fuel savings.

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[45] Julie Stricker, "Kotzebue Microgrid Local Alternatives Paying off," Alaska Business Monthly, October 2, 2014, Accessed April 19, 2016, http://www.akbizmag.com/Alaska-Business-Monthly/October-2014/Kotzebue-Microgrid/.
[46] Margaret Kriz Hobson. "ELECTRICITY: A Renewable Energy Success Story above the Arctic Circle." E&E Publishing. October 20, 2015. Accessed May 05, 2016. http://www.eenews.net/stories/1060026559.
[47] http://www.eenews.net/stories/1060026559
[48] Haselip, James, and David Pointing, eds. The Cool 100 Book. Roskilde, Denmark: UNEP Risø Centre on Energy, Climate and Sustainable Development Risø DTU National Laboratory for Sustainable Energy. PDF. doi:http://www.iser.uaa.alaska.edu/Publications/TheCool100Book.pdf., p.102
[49] Stricker, "Kotzebue Microgrid Local Alternatives Paying off."
[50] Heimbuch, "Massive Wind Turbines Newest Features of Kotzebue Skyline."
[51] Michelle Theriault Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska," Alaska Dispatch News, September 26, 2015, Accessed May 12, 2016, http://www.adn.com/energy/article/kodiak-builds-renewably-powered-island-lessons-rural-alaska/2015/09/27/.
[52] Ibid.
[53] Brad Reeve, "Kotzebue Electric Association Wind Projects," Lecture, Wind Diesel Conference, Anchorage, http://acep.uaf.edu/media/62312/KEA-Wind-Projects-Presentation.pdf.
[54] Ibid.

## Chaninik Wind Group

***Problem***

The Chaninik Wind Group (CWG) is a group of four tribal governments from the villages of Kongiganak, Kwigillingok, Tuntutuliak, and Kipnuk, Alaska,[55] which share services and administrative functions in operating wind systems.[56] They came together as a group because of a common problem, their dependency on fossil fuels to power and heat their communities. The combined population of these villages is 1,900, with 29% of residents living below the poverty line, and a 48% unemployment rate. Residents often spend 60% of their income on heating and electricity. In 2013, CWG communities paid $0.65/kWh for electricity and $9.00/gallon for stove and heating oil.[57] Between the formation of the CWG in 2005, and 2011, energy costs for the group, and all of remote Alaska, quadrupled, leading to an increasing percentage of income being spent on heating homes.[58] In response, the CWG established a goal to reduce their fossil fuel dependency by 40%.[59]

***Solution***

CWG's solution to reducing their dependency on fossil fuels was to integrate their diesel generators with wind turbines. Specifically, planners wanted to utilize a wind heat smart grid system. This system is built to incorporate excess wind capacity by transferring the energy to electric thermal storage (ETS) units that store heat in ceramic bricks to be used to control and heat homes.[60]

Each of the four CWG village's wind system consist of the following:[61]

1. (5) 95 kW wind turbines
2. (2) diesel generators rated at 250 kW
3. (21) residential electric thermal storage (ETS) units (Note: this is a select few homes within the four communities)
4. Smart metering system that control, communicate, and manage the ETS devices
5. Improvements to the diesel power plant to better facilitate all the systems linked to the smart grid

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[55] "Chaninik Wind Group - 2010 Project." Department of Energy. Accessed April 13, 2016. http://energy.gov/indianenergy/chaninik-wind-group-2010-project.
[56] Ibid.
[57] Dennis Meiners, "Chaninik Wind Group Wind Heat Smart Grids Final Report", 2013, United States. doi:10.2172/1086573. http://www.osti.gov/scitech/servlets/purl/1086573
[58] James Haselip, and David Pointing, eds. *The Cool 100 Book*. Roskilde, Denmark: UNEP Risø Centre on Energy, Climate and Sustainable Development Risø DTU National Laboratory for Sustainable Energy. PDF. doi:http://www.iser.uaa.alaska.edu/Publications/TheCool100Book.pdf., p. 84
[59] "Chaninik Wind Group - 2010 Project." Department of Energy. Accessed April 13, 2016. http://energy.gov/indianenergy/chaninik-wind-group-2010-project.
[60] Meiners, "Chaninik Wind Group Wind Heat Smart Grids Final Report"
[61] Ibid.

The CWG communities are located in the Kuskokwim Bay area and have wind classes between 6 and 7 (outstanding).[62] The highest amounts of wind occurs during the winter months "when temperatures drop as low as minus thirty degrees Celsius."[63]

Although the region is wind abundant, it has periods of slow production. Peak wind production occurs during the winter months when temperatures are below zero, and usually decreases in the spring and summer. Luckily, the CWG has a small population and does not require a high electric capacity to sustain their livelihoods. CWG communities average 150-200 kW and each wind project consists of 5 wind turbines that generate a total of 495 kW of wind power.[64] However, their microgrid system is designed to produce energy at minimal speeds. When wind speeds are low, the wind turbines produce electricity for the CWG communities without storing it. When winds produce excess energy, it gets diverted to the ETS units to store electrical heat for residences in the area. As a result, the CWG communities decreased their dependence on fossil fuels by 30% at the diesel power plant, as well as heating fuel at native residential areasand 50% on the communities' home heating fuel costs.[65]

***Innovation Applied***

The technical innovation with relevance to other areas in the world is the smart grid system that diverts excess wind energy to heating. The advantage is not just the use of wind turbines, but the ability to store excess output as thermal energy. At modest-to-high winds, the electronic thermal storage units heat homes and reduce dependency on fuel. In addition, their smart grid system helps automate when wind or diesel energy should be utilized. Although this is a complicated piece of the system and requires skilled workers, the CWG shares a common control system for managing multiple grids in several communities at once.

## St. Paul Island (hybrid wind-diesel)

***Problem***

St. Paul Island several hundreds of miles west of Anchorage,[66] is surrounded by the Bering Sea, and is only accessible by air or sea.[67] It has a population of approximately 700 residents, which consist mostly of Aleut Natives.[68] Historically, the island has depended on the sea for its livelihood. Seal fur hunting and trading were prevalent from the 1700's well into the 20$^{th}$ Century. Then the fishing industry dominated the economy until recent declines brought economic hardship.[69]

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[62] James Jensen, *Yukon-Kuskokwim Region Wind Resource Summary*, Presentation http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/Yukon-Kuskokwim-Wind-Resource_Jenson.pdf
[63] Haselip Pointing, eds. *The Cool 100 Book*, p. 80
[64] Meiners. *Chaninik Wind Group Multi-Village Wind Heat Smart Grids Final Report*.
[65] Ibid.
[66] Alaska Center for Energy and Power (ACEP), "Project Snapshot: Alternative Transportation Options on St. Paul Island, Alaska," Accessed April 8, 2016, http://acep.uaf.edu/media/144754/Alternative-Transportation-St-Paul-final.pdf.
[67] Jill Erin Maynard. *Factors Influencing the Development of Wind Power in Rural Alaska Communities*. Master's thesis, University of Alaska Fairbanks, 2010. Fairbanks, Alaska: University of Alaska Fairbanks, 2010.
[68] Martino Dabo, "TDX High Penetration Wind-Diesel Hydrogen and Electric Vehicle Project St. Paul," Lecture, Accessed April 13, 2016, http://alaskarenewableenergy.org/wp-content/uploads/2009/10/KatKeithStPaul.pdf.
[69] Maynard, *Factors Influencing the Development of Wind Power in Rural Alaska Communities*.

Limited employment options are further exacerbated by the community's dependence on expensive fossil fuel resources. As is the case elsewhere in Alaska, fossil fuel prices are high and volatile, and the residents pay exorbitant rates for basic energy needs. St. Paul's energy situation is worse than many other rural areas however, as its remoteness, turbulent weather, and intermittent winter sea ice make it a difficult place to supply with fuel and other necessities.

***Solution***

However, the violent weather in the Bering Sea can be an asset. St. Paul Island has an arctic maritime climate and is regularly hit by wind gusts of up to 100 mph,[70]which ranks it as Class 7, perfect for wind generation.[71] This presented an opportunity for the local village corporation, Tanadgusix Corporation (TDX) to install a wind-diesel combined heat and power system. As an Alaska Native Corporation representing the island, TDX owns 22 business entities operating around the world, including TDX Power, which operates the system and other utilities in Alaska.[72]

In 1999, TDX Power, funded and constructed a new wind-diesel plant.[73] The idea for a wind-diesel plant was inspired by a business trip the CEO took to California, where he learned about wind energy and how it could be used in a combined heat and power system (CHP) with diesel engines.[74] With an abundant wind source and the ability to integrate diesel, TDX installed CHPs at TDX facilities and the St. Paul Airport.[75] Unable to find government grants to fund the project, TDX decided to fund it themselves. The total project cost was $1.2 million and consisted of:[76]

- (3) 225 kW Vestas V-27 wind turbines
- (2) 150 kW Volvo diesel generators
- Smart switch systems and condensers

In addition, the system uses its excess wind energy and converts it to thermal energy. Specifically, the excess energy is diverted to the water heater for the industrial complex.[77] The basic principle is similar to the CWG villages using excess power to heat homes, although the specific technology is a different type. By identifying the most abundant renewable resource it had on the island, TDX embraced the opportunity to reduce the heat and power costs of residents. The community's innovation in providing cheap wind energy inspired other communities.

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[70] TDX Power "History and Culture." TDX Power. Accessed May 03, 2016. http://www.tdxpower.com/history-culture.
[71] Maynard, *Factors Influencing the Development of Wind Power in Rural Alaska Communities*.
[72] TDX Power "History and Culture."
[73] ACEP, "Project Snapshot: Alternative Transportation Options on St. Paul Island, Alaska."
[74] Maynard, *Factors Influencing the Development of Wind Power in Rural Alaska Communities*.
[75] "Alaska's Renewable Energy Projects," Alaska's Renewable Energy Project, Accessed March 14, 2016, http://alaskarenewableenergy.org/why-renewable-energy-is-important/alaskas-renewable-energy-projects/.
[76] Engerati, "St. Paul Island Project To Demonstrate Flywheel Energy Storage In Remote Alaska," Engerati. September 01, 2014, Accessed April 05, 2016, http://www.engerati.com/article/st-paul-island-project-demonstrate-flywheel-energy-storage-remote-alaska.
[77] ibid

***Innovation Applied***

Two elements stand out in the St. Paul Island case: privately funding and the use of high penetration systems to produce electricity. The $1.2 million dollar project was able to reduce energy costs for TDX facilities and the airport complex from $0.37/kWh to $0.12/kWh. In turn, TDX Power was formed in 1999 as a subsidiary company to manage the project on St. Paul Island and turn the newfound expertise into a profitable business. As of 2008, the company had $10 million in excess assets and $7 million in sales of electricity across several communities.[78] This illustrates how private funding of projects can bring a positive return on investment and government grants are not the only way to finance renewable systems in Alaska.

The private investment that TDX supplied to the CHP system saw significant results. The TDX connected facilities have an average electrical load of 70 kW per year. The project saved $200,000 a year in utility payments and $50,000 a year in diesel purchases.[79] TDX has been so effective they sought to buyout St. Paul Municipal Utilities. TDX wanted to acquire the community's diesel plant and integrate it with their wind-diesel hybrid project so that all of St. Paul could benefit from the $0.12/kWh rate. However, this has not yet occurred.

More recently, TDX and Beacon Power are currently testing a flywheel system, which stores electricity (such as excess from wind power) for future use.[80] The goal is to optimize wind power by diverting it to flywheels and achieving fuel savings as much as 30%.[81] Results on that initiative have not been published yet but it may be promising for other communities considering energy storage methods. Finally, TDX is exploring the use of wind power for transportation by using wind energy to produce electricity and hydrogen for vehicles.[82]

St. Paul Island has many opportunities to reduce its dependence on diesel generators. Although wind energy has proven to be a cost-effective alternative to TDX Power-owned facilities, the community of St. Paul needs to highly consider how to partner with the organization to better optimize their cost savings. With effective collaboration, the possibility of using wind energy savings to power a more sustainable transportation system on the island could be achieved.

## Chena Hot Springs (Renewable/Mix)

***Problem***

As the preceding examples illustrate, many of Alaska's rural areas struggle with the high cost to producing power with diesel. Although located on a road system, and not a rural community, Chena Hot Springs has the same struggle. In 2006, the resort, which is not connected to the Railbelt grid, paid $0.30 kWh for the production of electricity, mainly by a 400 kW diesel generator that averaged 230 kW (essentially, the generator was not working at full capacity). The cost to produce energy at the resort

[78] Maynard, *Factors Influencing the Development of Wind Power in Rural Alaska Communities*.
[79] ACEP, "Project Snapshot: Alternative Transportation Options on St. Paul Island, Alaska."
[80] Alaska Center for Energy and Power (ACEP). *Power Systems Integration*.
[81] Engerati, "St. Paul Island Project to Demonstrate Flywheel Energy Storage In Remote Alaska."
[82] ACEP. "Project Snapshot: Alternative Transportation Options on St. Paul Island, Alaska."

totaled $604,000, of which $362,400 was from purchasing fuel.[83] This meant that the resort was susceptible to the price shocks of fossil fuels and would see spikes in the costs of generating electricity. These costs placed severe limits on the resort's profitability and financial performance.

***Solution***

The key to Chena Hot Springs's success has been the use of geothermal energy. Alaska has four major geothermal regions: the Interior, the Wrangell Mountains, the "Ring of Fire" in the Aleutians, and Southeast Alaska. These resources have seldom been developed for power generation.[84] Chena Hot Springs has moderate geothermal activity, attractive to visitors for its warm pools, but insufficient for power generation. However, one company, United Technologies Incorporated (UTC), requested that Chena Hot Springs experiment with their technology. UTC had been awarded a grant by the Department of Energy to test the viability of electrical production at 165 degrees Fahrenheit, roughly the temperature in Chena Hot Springs's geothermal pools.[85]

The geothermal energy at the resort is harnessed by the Organic Rankine Cycle (ORC) system. The ORC is a "thermodynamic process where heat is transferred to a fluid at a constant pressure. The fluid is vaporized and then expanded in a vapor turbine that drives a generator, producing electricity. The spent vapor is condensed to liquid and recycled back through the cycle."[86] Unlike conventional steam engines, ORCs do not require the use of water to generate heat resources. Other kinds of working fluids, such as refrigerants, are utilized to generate vapor.[87]

***Innovation Applied***

In Alaska, specifically in the Interior and Southeast regions, geothermal activity is classified as low to moderate temperatures, not hot enough just for water to produce energy.[88] Chena Hot Springs falls into that category because their typical water temperature is at 165 degrees Fahrenheit.[89] Using the ORC is innovative because it can be used to power areas with low to medium geothermal resources.[90] Their specific method is using a refrigerant called R-134a, which has a lesser boiling point than water.[91] Utilized with the ORC system, the hot spring water can generate heat energy. Since the installation of the ORC systems in 2006, Chena Hot Springs has decreased its energy rate down to $0.05/kWh and UTC was able to release its PureCycle product to the public in 2007.[92] Chena Hot Springs serves as an example on how medium temperature geothermal areas can utilize their geothermal resources. With

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[83] Gwen Holdmann, *The Chena Hot Springs 400 kW Geothermal Power Plant: Experience Gained During the First Year of Operation*, Alaska: Fairbanks, 2007, Accessed April 18, 2016. http://static1.1.sqspcdn.com/static/f/386714/3483652/1246465202447/Experience.
[84] Alaska Energy Authority, *Renewable Energy Atlas of Alaska.*
[85] Holdmann, *The Chena Hot Springs 400 kW Geothermal Power Plant: Experience Gained During the First Year of Operation.*
[86] Ormat, "Organic Rankine Cycle," Ormat, Accessed March 9, 2016, http://www.ormat.com/organic-rankine-cycle.
[87] "ORC Technology." Organic Rankine Cycle, Geothermal, Waste Heat Recovery. Accessed March 21, 2016. http://www.exergy-orc.com/technology/orc.
[88] Alaska Energy Authority, *Renewable Energy Atlas of Alaska.*
[89] FACT SHEET ON: THE CHENA GEOTHERMAL POWER PLANT. Fact sheet found online, Chena Hot Springs, Fairbanks, AK.http://static1.1.sqspcdn.com/static/f/386714/3483656/1246465202543/Powerfactsheet.pdf?token=Rx0QkNahJDk09goiE6Gyap5aiTA=
[90] Ibid.
[91] "GEOTHERMAL POWER." CHENA POWER. Accessed March 21, 2016. http://www.chenapower.com/geothermal-power/.
[92] Holdmann, *The Chena Hot Springs 400 KW Geothermal Power Plant: Experience Gained During the First Year of Operation*.

careful examination, planning, as well as collaboration, these regions can power their properties with geothermal energy to reduce their dependency on fossil fuels. As well as integrate other renewables such as wind and solar into their systems.

## Kodiak

***Problem***

Kodiak Island is the second largest island in the United States with over 15,000 residents. As with most rural Alaskan communities, they relied heavily on diesel generators and could only access supplies and resources such as fossil fuels either by air or sea. This put an economic strain on the community of Kodiak, especially during the 1970s, as the price of commodities such as diesel increased.[93]

High-energy costs were seen as unsustainable by the Kodiak Electric Association (KodEA). As a result, KodEA became highly motivated to resolve the issue by any means, including integrating renewable energy resources.[94] So, they commissioned Terror Lake Dam in 1984, which produced over 80% of the communities' electricity.[95] Although a significant source of power it was not enough, and they still relied on diesel generators to make up for the rest of the electrical load. In 2005, KodEA resolved to produce 95% of their energy from renewables by the year 2020.[96]

***Solution***

Kodiak benefitted financially from producing renewable energy when KodEA commissioned the Terror Lake Hydroelectric Dam. It was conceived in the 1970s as oil prices skyrocketed. After obtaining the essential construction permits, the dam began operations in 1984 and consisted of 2 hydroelectric turbines with a 20 MW capacity[97] with additional room for another turbine.[98] In 2011, Kodiak surpassed its electric capacity by reaching 26 MW. In response, KodEA installed an additional 10 MW turbine to compensate for the overcapacity.[99] Today, the hydroelectricity that comes from the Terror Lake provides 80.4% of Kodiak's electricity.[100]

Like many of Alaska's coastal areas, Kodiak also has abundant wind resources. The KodEA consulted with the Kotzebue Electric Association, known as the pioneer of utility-run wind energy to determine its potential in the mid-2000s.[101] In their findings, KodEA found that Pillar Mountain had the highest potential to produce wind energy in the area. Pillar Mountain is classified as having Class 5 (excellent) wind resources.[102]

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[93] Savage, Harlin, *The Terror Lake Case*.
http://www.snre.umich.edu/ecomgt/cases/pubs/acus/Terror_Lake.pdf
[94] Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska."
[95] Kodiak Electric Association (KEA), "KEA Generation." Kodiak Electric Association. Accessed March 9, 2016.
http://www.kodiakelectric.com/generation.html.
[96] Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska."
[97] EcoWatch, "Second Largest Island in U.S. Goes 100% Renewable," EcoWatch, March 20, 2015, Accessed April 22, 2016,
http://www.ecowatch.com/second-largest-island-in-u-s-goes-100-renewable-1882043985.html.
[98] Savage, Harlin, *The Terror Lake Case*.
[99] EcoWatch, "Second Largest Island in U.S. Goes 100% Renewable."
[100] Kodiak Electric Association (KEA), "KEA Generation."
[101] Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska."
[102] Renewable Energy Atlas of Alaska.

To meet their goal of producing 95% of their electricity through renewables by 2020, KodEA installed 3 General Electric wind turbines at 1.5 MW each (4.5 MW in wind turbine capacity) on Pillar Mountain in 2009. In 2012, KodEA installed an additional 4.5 MW worth of wind turbines, as well as a 3 MW energy storage system to store additional energy to Kodiak's grid system.[103] It was a worthwhile investment because as of March 2016, the wind turbines produce over 18% of the community's electrical resources.[104] Combined with hydroelectricity, Kodiak produces 99% of their energy needs through renewable sources.

***Innovation Applied***

Kodiak is unique because it is the first "islanded" grid, to use megawatt capacity wind turbines and to produce renewable energy on the Megawatt scale. These resources produce over 99% of the 28 MW capacity required to serve the electrical needs of 15,000 residents. KodEA harnessed the power of wind and hydroelectricity, and integrated them to power all of its energy needs, without having to rely on diesel generators.[105] In conjunction with Terror Lake Hydroelectric Plant, which produces most of the island's power resources, Kodiak's dependence on diesel engines decreased[106] (they currently only account for 0.3% of electricity generated in Kodiak).[107]

In addition, it saved the city $22 million in diesel fuel costs and those savings were passed on to the community.[108] Currently Kodiak residents pay $102.73 for 600 kWh of energy, which is less than historical averages, and less than Railbelt communities such as Homer, Fairbanks, and Mat-Su.[109] Kodiak pays approximately $0.178/kWh for both hydroelectric and wind energy as opposed to paying $0.289/kWh for diesel generation.[110] As a result, not only does Kodiak save money and reduce its dependency on diesel fuel, it also presents new opportunities to reduce its dependence on fossil fuel, such as flywheels and battery storage.

## Eagle (Solar)

***Brief overview of solar in Alaska***

It is often assumed to be impossible to generate viable solar energy in Alaska due to the climate and weather, with most solar penetration occurring during the 3-4 short summer months. Despite the long dark winters when electricity demand is the most essential, parts of Alaska have comparable amounts of sunlight penetration to Germany, the world leader in solar electricity generation with 38,500 MW of solar installed.[111] Alaska has a broad geographic range, meaning that different regions can have

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[103] Kodiak Electric Association (KEA), "KEA Generation."
[104] Ibid.
[105] Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska."
[106] Alaska Energy Authority, *Renewable Energy Atlas of Alaska*.
[107] Kodiak Electric Association (KEA), "KEA Generation."
[108] "100% Renewably-Powered: Alaska's Kodiak Island Goes all in with wind and hydro," Islanded Grid Resource Center, Accessed March 21, 2016, http://islandedgrid.org/100-renewably-powered-alaskas-kodiak-island-goes-all-in-with-wind-and-hydro/.
[109] Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska."
[110] Kodiak Electric Association (KEA), "KEA Generation."
[111] Paul Schwabe, *Solar Energy Prospecting in Remote Alaska*, Report, Washington, DC: U.S. Department of Energy, 2016, http://energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf.

abundant solar resources at different times of the year. For example, the Arctic and Interior regions of Alaska have high solar production potential percentages that average approximately 14.67% and 13.17% respectively between the months of March and August. The Southwest and Southeast regions, on the other hand, have a gradual transition of solar production throughout the year.[112] This presents an opportunity for rural Interior Alaska communities to tap into this resource and reduce their fossil fuel dependence by using solar energy.

Despite the potential for solar energy in Alaska, it remains an underutilized resource. However, the price of solar arrays has decreased since 1977 from $76.67/W to $0.76/W in 2013 due to advances in manufacturing,[113] as well as recent federal tax credits that make it easier to purchase the required technology.[114] The small variable amounts of sunlight during the winter also give solar panels an advantage in Alaska because "low ambient temperatures (help) improve the efficiency of solar modules and the reflectivity of sunlight off the snow cover from the ground (more sunlight to the modules)."[115] This can help, not impede, the effectiveness of harnessing solar power for rural communities in Alaska, especially where solar is abundant for at least half the year.

Other than for electricity production, additional solar techniques, such as passive solar and solar thermal, are utilized in Alaska. The former uses windows, additional insulation, and thermal mass techniques to capture and retain sunlight by orienting windows to the south side of homes.[116] The latter, also known as active solar, utilize pumps and fans to heat water heaters by transferring heat from water to a heat-transfer fluid.[117] Although these techniques have examples that prove their effectiveness in Alaskan communities, this section will focus on how solar PVs produce electricity for a rural community in Alaska.

***Problem***

The community of Eagle, Alaska consists of less than 100 residents and consumes 777,000 kWh/year. The primary energy source comes from three diesel generators located at their diesel generation plant.[118] As a result, the community is prone to price shocks of diesel fuels. Although there is a road to the community, it is only open on a seasonal basis.[119] The prospect of producing renewable energy was an attractive solution to the people of Eagle because it presented a cheap and reliable source of energy to the community. However, unlike other rural communities in Alaska, Eagle does not have abundant

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[112] Schwabe, *Solar Energy Prospecting in Remote Alaska*.
[113] "Alaska's Renewable Energy Projects." Alaska's Renewable Energy Project (REAP). Accessed April 13, 2016. http://alaskarenewableenergy.org/why-renewable-energy-is-important/alaskas-renewable-energy-projects/.
[114] Alaska Center for Energy and Power (ACEP), *Solar Thermal Energy for Alaska*, Fairbanks, Alaska, http://acep.uaf.edu/media/50765/ACEP_ResourceOverview_SolarEnergy.pdf.
[115] Schwabe, *Solar Energy Prospecting in Remote Alaska*, p.3.
[116] Alaska Energy Authority, *Renewable Energy Atlas of Alaska*.
[117] "Solar," Renewable Energy Alaska Project (REAP), Accessed April 13, 2016, http://alaskarenewableenergy.org/why-renewable-energy-is-important/alaskas-resources/solar/.
[118] Benjamin Beste, "Solar Energy in Rural Alaska: AP&T's Solar PV Project in Eagle," Lecture, Alaska Rural Energy Conference, Fairbanks, Alaska, September 2014, http://www.akruralenergy.org/2014/AP&T's_Solar_PV_Project_in_Eagle-Ben_Beste.pdf.
[119] Benjamin Beste, In-person with Michael Lockwood, Alaska Rural Energy Conference, April 28, 2016.

wind resources.[120] Even if there was wind potential, the seasonality of the community's main road would prevent the expedient transport of materials and construction operations would have been costly. In addition, the community had a hydrokinetic project along the Yukon River, but it was not effective due to factors such as winter freezes and debris build-up.[121]

***Solution***

Although renewable resources such as wind are unavailable, the community of Eagle and Alaska Power and Telephone utilized solar energy because it is the most abundant resource available in its region. The community has a 6.0-6.5 kWh per square meter per day solar penetration in the month of June. During the first day of the month, especially between March and October, the sun is out between a low of approximately 10 hours and a high of over 21 hours.[122] The project only encompasses a small electrical grid, with a peak of 125 kW during the year; meaning construction of a small-scale project was appropriate for the community.

The decision to utilize solar was not just influenced by its abundance or the reasonably priced products, but also because of their simplicity to transport along the road available. The project was completed in 2015 and produces 24 kW of electricity on 96 pv panels with 250 W capacity on each panel. These panels are grouped together on a 4x3 foot top of pole mounting system, and are connected to a combiner, inverter, and a web-connected energy meter/data collector system.[123] This project is interconnected to the current diesel generation plant system and has the potential to offset 2,600 gallons of fuel, saving the Eagle community $10,000.[124] However, since December 2015, the Eagle solar project produced an average 80 kW load, saving $7.5k in diesel fuel.[125] Although the fuel savings are lower than expected, the ability to produce more electricity than what was expected has shown promise since the project's installation in 2015.

***Innovation Applied***

Other than the integration with the diesel plant, there is no unique innovation that could be replicated. However, Benjamin Beste, the mechanical engineer for Alaska Power and Telephone responsible for the creation of the solar array, highlighted some unique aspects of the project. First, the solar array is located on the north end of the diesel plant because the south end was found to be unsuitable during the land survey phase. As mentioned earlier, sunlight is best collected if solar panels (as well as windows) are oriented towards the south. The north side of the facility was the only suitable alternative landmass to effectively collect solar energy. Although there was a tradeoff, the solar arrays are still in a position to collect abundant sunlight, as demonstrated by the 80 kW production load. Second, the solar

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[120] Glen D. Martin, *Renewable Energy Fund Round 6 Grant Application*, September 21, 2012, Grant Application for Eagle Solar Project, Anchorage, Alaska, ftp://aidea.org/RENEWABLE ENERGY FUND/Round 6 09242012/915_Eagle Solar Array Project/092112_AEA-Eagle Solar Array Project.pdf.

[121] Ibid, p.10

[122] Ibid.

[123] Benjamin Beste, "Solar Energy in Rural Alaska: AP&T's Solar PV Project in Eagle."

[124] Ibid.

[125] David Lockard, "Solar Energy in Alaska," Lecture, BIA Providers Conference, Anchorage, Alaska, December 2, 2015, http://energy.gov/sites/prod/files/2015/12/f27/Session4-Lockard-Solar.pdf

panels are positioned on poles and can tilt between 15 and 65 degrees to maximize solar penetration. There was the possibility of placing the poles on a rotator to follow the sun's direction, but the technology was deemed unsuitable in the Alaskan weather.[126]

Little information is available about the project's effectiveness due to the fact that it was completed in 2015. Its impact and effectiveness are still being measured. At initial glance, the Eagle project was able to produce more energy than what was originally expected. During the summer months, however, there was haze due to the forest fires in the area which impacted the project's effectiveness to collect solar power.[127] Additional projects to store excess energy or divert it into another system are not currently being developed in Eagle. The reason, as Benjamin Beste stated, is that if it the array was doubled in size, then the possibility of establishing a storage system would have been considered.[128]

## Technology/Storage

For areas with high energy loads, a storage system is essential to maintain balance within the grid and provide extra energy for the community. This section will examine two specific methods of energy storage used in Alaska: the typical battery system, and the flywheel system.

### Batteries

Battery storage systems act as reserves for interruptible power supply systems (UPS) such as microgrids. Typical battery storage systems include flywheels, flooded cell batteries, and valve regulated lead-acid batteries (VRLA). Other commonly used batteries, especially in Alaska, include Lithium-ion (Li-ion) and Lead Acid batteries. Lead Acid is the more popular choice because of its low cost and convenience. However, they have a short lifespan and huge space requirements.[129] Li-ion batteries, on the other hand, are more reliable, last longer, and provide not only power but also energy services. Also, the price for Li-ion batteries are slowly, but steadily decreasing.[130]

### Kotzebue

In 2011, the Kotzebue Electric Association (KEA)[131] sought to use zinc bromine flow batteries to store excess energy when there were slow periods in production and high demand.[132] They wanted to increase their capacity to provide more energy to the community. However, according to the Alaska

[126] Benjamin Beste, 2016 Alaska Rural Energy Conference, April 28, 2016.
[127] Ibid.
[128] Ibid.
[129] Ami Joseph, and Mohammad Shahidehpour, *Battery Storage Systems in Electric Power Systems*, 2006, Accessed August 28, 2016, http://www.iitmicrogrid.net/microgrid/pdf/papers/battery/battery.pdf.
[130] Peter Asmus and Mackinnon Lawrence, *Microgrids*.
[131] Not to be confused with the Kodiak Electric Association.
[132] Heimbuch, "Massive wind turbines newest features of Kotzebue skyline."

Center for Energy and Power (ACEP), the battery project was put on hold due to complications with the product and supplier.[133] It is also cited that the battery could not handle the harsh winter conditions.[134]

Most recently, however, Kotzebue may have found a viable solution to their battery storage system. In 2015, Saft, a French-based battery technology firm, delivered their Intensium Max+20M containerized Battery Energy Storage System (BESS) to Kotzebue. The system "provides 950kWh and has the ability to operate in environments reaching ambient temperatures of -58°F, the delivered BESS also includes a 1.2MW EssPro Power Conversion System and (connected to a grid) transformer, supplied by ABB."[135] This solves the problem of storing wind energy in cold climate conditions by preventing fluctuations when the energy source is either not abundant or when the main grid system goes down. Regardless, as stated by Brad Reeve, CEO of the Kotzebue Electric Association, battery storage is an "additional tool we need to increase our cooperative's efficiency and reduce our diesel dependence."[136]

## Flywheels

A flywheel energy storage system (FESS) uses "electric energy input which is stored in the form of kinetic energy."[137] It acts as a buffer in electrical disruptions and transitions into another energy resource when needed. It acts as an effective way-spinning reserve that provides about 2 to 10 minutes of Spinning Reserve Capacity (SRC), enough time to turn on additional power engines.[138] For example, when a community with wind-diesel hybrid system does not have enough wind to maintain grid stability, the flywheel spins for long-enough that the utility plant can turn on, or increase the electrical capacity of their secondary resource, such as diesel generators. Flywheels ensure grid stability and a smooth transition of energy generation when the need arises.

### Kodiak

Flywheels also have been integrated to serve other purposes such as powering electric cranes. In 2015, Kodiak installed an all-electric gantry crane that runs solely on the energy produced by a flywheel. Originally purposed for Anchorage, the crane was diverted to Kodiak to replace an old crane for shipping

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[133] "Flow Battery Energy Storage Systems-An Emerging Energy Technology Grant Project," Alaska Center for Energy and Power. Accessed February 25, 2016, http://acep.uaf.edu/projects/kotzebue-electric-association-flow-battery-energy-storage-systems.aspx.

[134] Stricker, "Kotzebue Microgrid Local Alternatives Paying Off."

[135] "Cold Weather Energy Storage System Delivered in Arctic Alaska," Transmission and Distribution World, November 11, 2015. Accessed February 25, 2016, http://tdworld.com/renewables/cold-weather-energy-storage-system-delivered-arctic-alaska.

[136] Peter Maloney, "Remote Alaskan town turns to cold-weather battery microgrid as diesel alternative," Utility DIVE, November 17, 2015. Accessed February 25, 2016, http://www.utilitydive.com/news/remote-alaskan-town-turns-to-cold-weather-battery-microgrid-as-diesel-alter/409286/.

[137] "Flywheels." Energy Storage Association. Accessed April 19, 2016. http://energystorage.org/energy-storage/technologies/flywheels.

[138] Schade, Hendrik, Maximilian Schneider, Jeremy Vandermeer, Marc Mueller-Stoffels, and Stephan Rinderknecht. *Development of Kinetic Energy Storage Systems for Island Grids*.
This was sent by Alaska Center for Energy and Power for research purposes.

and receiving.[139] The flywheel is powered by energy that is diverted from the Terror Lake hydroelectric dam, as well as solar panels on the island.[140]

The community of Kodiak originally said no to the project because it potentially added a 2 megawatt strain on the system, which would have created unstable conditions for the grid. However, KodEA changed their mind when they found that they could add a flywheel system to compensate for any disruptions in the electrical system.[141] Kodiak's 99% renewable power generation rate meant they could afford to divert some renewable energy into a crane that did not require fossil fuels to operate it. Using the flywheels to power the crane helped reduce the cost of fuel.

### St. Paul Island

As mentioned earlier in the St. Paul section, a test in 2014 of the flywheel system by TDX was being conducted to determine the feasibility of using flywheels. The flywheel system acts as a buffer to stabilize excess wind power and curtail diesel use by generating electricity up to 15% of the time.[142] Potential savings from curtailing diesel use could be up to as high as 30% by integrating the system into the current wind-diesel CHP system. However, little is known about its true capacity and whether or not it can be applied to the community.

## Control System

The objective of the control system is to manage and modulate the supply and loads of electrical grid systems. They are connected through a communication network (via broadband) to better facilitate electricity management. In microgrids, the major system component of the control system is the Microgrid Central Controller (MGCC), which processes energy supply and demand data for the system to balance and distribute energy resources effectively and efficiently. It performs two-way communications between the distribution network operator (DNO) and the market operator (MO) and monitors operations conditions, as well as respond to disturbances in the grid. It also sends back control signals and scheduling references for the grid to follow.[143] Control systems are essential for microgrids because it allows the grid to maintain proper generation levels if there are disruptions in the central grid. The ability to switch to island mode via the control system preserves the operations of communities, as well as facilities such as hospitals. Just like the microgrid itself, the functionality of a control system is dependent on the specific needs of the organization.[144]

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[139] Colin Young, and Will Galton, "2 MW Flywheel System Integration," Lecture, Alaska Rural Energy Conference, Fairbanks, Alaska, April 27, 2016, http://www.akruralenergy.org/2016/2016_REC_Integrating_an_Electric_Crane_with_a_Flywheel_in_Kodiak-Colin_Young.pdf

[140] Sean Doogan, "Kodiak Gets New, 65-ton Crane That Runs on Renewable Energy," Alaska Dispatch News, August 13, 2015, Accessed April 20, 2016, http://www.adn.com/article/20150813/kodiak-gets-new-65-ton-crane-runs-renewable-energy.

[141] Boots, "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska."

[142] Kent Harrington, "High-Tech Flywheels Help Bring Stability to Grid," AIChE ChEnected, March 20, 2015, accessed April 29, 2016, http://www.aiche.org/chenected/2015/03/high-tech-flywheels-help-bring-stability-grid.

[143] Wenchong Su and Jianhui Wang, "Energy Management Systems in Microgrid Operations." *The Electricity Journal* 25, no. 8 (October 2012): 45-60. Accessed September 8, 2016. http://www.sciencedirect.com/science/article/pii/S104061901200214X.

[144] Peter Asmus and Mackinnon Lawrence, *Microgrids*, Report. Boulder, Colorado: Navigant Consulting, 2013.

There are two major control philosophies of microgrid energy management systems (EMS).[145] First, there are centralized control systems where one controller regulates and distributes energy resources. The central control system monitors and manages energy supplies and loads to maintain balance within the grid and coordinates energy resource generation. These require high bandwidth as they have to communicate commands and functions to a bigger grid.[146] Second, there are decentralized control systems. These are characterized by having one or more local controllers: “Every local control monitors and communicates with the other local controllers through the communication network.”[147] This means that each controller maintains autonomy of their own systems while communicating with each other. The CWG is an example of a decentralized microgrid because each community controls its own wind-diesel system but maintains a communication network with each other.

There are a variety of control systems for different purposes. Researchers Wencong Su and Jianhui Wang list eleven major companies that have energy management systems (EMS), each one serving different purposes. For example, ABB’s MicroSCADA Pro manages both utility and industrial network distributions in the same system. Tridium, Inc.’s Vykon, on the other hand, manages building system functions that include not only energy, but also security and HVAC.[148] Basically, no one specific control system is preferred because each community and/or organization require different hardware/software approaches to fulfill different goals and needs. There is no one size fits all system because they are tailored to meet specific needs.[149]

## Chaninik Wind Group

CWG is an example of a decentralized grid because each of the four communities control their own wind-diesel systems. According to consultant Dennis Meiners, each of the four communities are connected to a larger communication network that allows for open communication between each other. In addition, it also allows for each community to have independent control of their individual wind-diesel systems. Each community has software modules and parallel controls that shut off diesel engines as well as manage other energy generation devices without disrupting the others generation operations.[150] With a decentralized grid, the CWG communities maintain their operations without one disrupting the others.

The combined wind-diesel systems are controlled under a System Master Controller (SMC) that automates the system through remote control operation. It also records the data on energy use, storage, and metering excess wind energy. Although the SMC controls the system, there is room for independence between the energy generation systems. For example, the diesel generators are controlled separately from the SMC. This is beneficial because if the SMC is not performing at a high capacity or shuts down, the diesel generators remain operational and make up for the loss of

[145] Su and Wang, "Energy Management Systems in Microgrid Operations."
[146] Asmus and Lawrence, *Microgrids*.
[147] Su and Wang, "Energy Management Systems in Microgrid Operations."
[148] Ibid.
[149] Asmus and Lawrence, *Microgrids*.
[150] Dennis Meiners, Interview by Michael Lockwood, Phone Interview. Anchorage, AK, August 31, 2016.

generation, and vice versa.[151] This is the benefit of having a decentralized system because it allows the communities to maintain their operations without interruption if one system goes down, as opposed to a centralized system where if one part of the system fails, the rest of the system fails.

Each community manages its own wind-diesel operations. When there is excess wind, the electricity gets transferred to the ETS units and the control system tells the diesel generators to reduce their output and establish a minimum load and frequency. As the ETS units become fully charged, the control system reduces its wind generation. Conversely, when there is minimal wind generation, the diesel generators increase their frequency and make up for the potential energy that would have been produced by wind and ETS.[152] This coordination provides each community with a source of uninterruptible electricity as well as controls the amount of diesel that is used when other resources such as wind can be used.

## Challenges

One of the issues of maintaining microgrids in Alaska is the need for capital to conduct repairs and maintenance.[153] In fact, a large share of energy generation is funded by subsidies such as Alaska's PCE program, and grants from AEA for new generators.[154] One hypothesis is that rural villages intentionally neglect their equipment on the belief that a grant will be found to purchase new equipment in the event of a failure. As a result, "they forego maintenance and replacement activities that could improve their efficiency, extend equipment life and lower the cost to the state, who in the end, bears most of the cost of replacing worn out equipment" according to one source.[155] In 2015, over 80 organizations were approved for PCE to reduce the cost to produce energy from diesel. Even though Kotzebue has a utility-owned wind farm, they still rely on PCE because the wind farm produces only 20% of their electricity.[156] The rest is dependent on diesel and PCE.

Part of the reason for the lack of maintenance may be due to the fact that they are often installed by people from outside of the community and no residents have been trained in proper maintenance. One such example is from Kwigillingok, Alaska. William Igkurak, the Chaninik Wind Group's president, made it a priority to build human capacity by teaching local people how to maintain the wind turbines within the CWG. Prior to that, "when something broke, (you) had to call someone in - perhaps from the Lower

[151] Dennis Meiners. 2013, "Chaninik Wind Group Wind Heat Smart Grids Final Report", United States. doi:10.2172/1086573. http://www.osti.gov/scitech/servlets/purl/1086573
[152] Ibid.
[153] Andrew Crow, "Rural Village Electric Utility Management Plan Using Common Performance Indicators," The University of Alaska Center for Economic Development (2015).
[154] The Power Cost Equalization Program is the Alaska Energy Authority's "cost relieve for electric power to residents and community facilities. The program reduced power costs at an average of 55 percent for residential customers using up to 500 kilowatt hours per month and for eligible community commercial facilities." From the AEA's Report to Alaskans 2014.
[155] Andrew Crow, "Rural Village Electric Utility Management Plan Using Common Performance Indicators," The University of Alaska Center for Economic Development (2015). P. 3.
[156] Julie Stricker, "Kotzebue Microgrid Local alternatives paying off," Alaska Business Monthly, October 2, 2014. Accessed February 23, 2016, http://www.akbizmag.com/Alaska-Business-Monthly/October-2014/Kotzebue-Microgrid/

48."[157] The aforementioned quote encouraged the CWG to empower its people to build the structures and then learn how to maintain them throughout the year. By doing this, the local communities are invested in the project and can share their successes with a broader audience.

## Appendix: Firms Operating in the Microgrid Space

Table 1 provides a list of companies that are involved in microgrid development and implementation. There are over 96 entities involved in microgrid development with nearly 60 entities in Alaska. These firms range from utility companies to engineering and energy firms.

*Table 2: Firms Operating in the Microgrid Space*

| Company | Relevant Expertise in Microgrids | Alaska-Based | Works outside of Alaska |
|---|---|---|---|
| Con Edison | Poles and Wires | No | Yes |
| DONG Energy | Electric vehicles, wind and CHP | No | Yes |
| San Diego Gas and Electric | UDM microgrids into commercial operations; Solar PV | No | Yes |
| American Electric Power | Grid-Powered Energy storage | No | Yes |
| BC Hydro | Feeder line islanding, remote villages | No | Yes |
| Duke Energy | VPP testing, energy storage, HEM | No | Yes |
| Eskom | Remote villages, mines | No | Yes |
| Sacramento Municipal Energy District | Solar PV, control room power security | No | Yes |
| Alstrom Grid | Eco-cities by 2030 | | Yes |
| Schneider Electric | 30 microgrids in the USA; USCG microgrid; full-scale microgrid technology and service | | Yes |
| Siemens AG | Smart Grid | Yes | Yes |
| ABB | Active in transmission and distribution | Yes | Yes |
| Eatom | Smart Islanding Inverter | | Yes |
| GE Digital Energy | Microgrid controllers and generator products | | Yes |
| Samsung C&T | South Korea | | Yes |
| Toshiba | Systems integrator-controllers, inverters, storage | | Yes |
| Chevron Energy Solutions | Efficiency and solar PV for public sector | | Yes |
| Leidos | Design, build, finance microgrids | | Yes |
| Optimal Power Solutions | Hundreds of microgrids up and running today, from 1 kW to 5 MW | | Yes |

[157] Rachel Waldholz, "In rural Alaska, building wind power means building people power," Alaska Public Media, February 26, 2016, Accessed February 26, 2016, http://www.alaskapublic.org/2016/02/26/in-rural-alaska-building-wind-power-means-building-people-power/.

| | | | |
|---|---|---|---|
| S&C Electric | Create hybrid storage platforms that allow batteries to perform more than a single grid service | | Yes |
| Honeywell | Green building systems integrator of microgrids | | Yes |
| Johnson Controls, Inc. | Integrated demand-side management technology | | Yes |
| Blue Pillar | Consolidation of monitoring and control of DER assets | | Yes |
| Power Analytics | Software compares how microgrid system is performing with how it should perform | | Yes |
| Viridity Energy | Ancillary services to grid operators | | Yes |
| ABS Alaskan, Inc. | Selling and Distributing remote power products, battery systems and installation services for renewable energy products. | Yes | Yes |
| Alaska Power and Telephone | Broadband internet, electrical power, communications services | Yes/No | Yes |
| Black and Veatech Corporation | Consulting and engineering-energy, water, telecomm, federal management | No | Yes |
| Chena Power, LLC | Boilers, solar water heaters, piling machine; biomass and geothermal power plant | Yes | No |
| Cook Inlet Region, Inc. | Traditional and Alternative Energy and resource development | Yes | Yes |
| Electric Power Systems, Inc. | Construction, generation, SCADA, substations, testing and transmission | Yes | Yes |
| Hatch | Flywheels for energy storage | No | Yes |
| Intelligent Energy Systems | Self-regulating grid for Tuntutuliak, wind-diesel battery hybrid for Kwigilinok | No | Yes |
| Lime Solar | Energy efficiency, feasibility of renewable power generation | Yes | |
| Marsh Creek, LLC | Wind energy and high efficiency diesel electric generator set | Yes | Yes |
| Nortech Inc. | Energy, Environmental, Health and Safety | Yes | |
| Ocean Renewable Power Company (ORPC) | Tidal and river technology developer | Yes | Yes |
| Ormat Technologies | Geothermal and recovered energy generation and remote power | No | Yes |
| STG Incorporated | Installation of renewable energy systems in rural Alaska, construction of diesel power plants, installation of communication towers, construction of bulk fuel systems | Yes | No |
| TDX Power | Power generation, operations and maintenance, feasibility studies and consulting, design, installation, commissioning, planning and scheduling, smart grid tech with alternative energies and energy conservation. | Yes | No |
| TerraSond, Ltd. | Consulting and survey services | Yes | |
| Tetra Tech | Consulting, engineering, technical services | No | Yes |
| V3 Energy | Wind Energy consulting | Yes | No |

| | | | |
|---|---|---|---|
| WHPacific | 100% Native-owned Architecture and Engineering corporation; Wide range including energy efficiency and renewables | Yes | Yes |
| YourCleanEnergy, LLC | Energy Audits, renewable energy resource assessments, financial evaluations, renewable energy system design, design of sea water heat pump systems | Yes | No |
| Tanana Power Co | | Yes | No |
| Alaska Village Electric Cooperative | Largest retail cooperative in the world; multiple project across the state | Yes | No |
| Gwitchyaa Zhee Utility Co | To preserve our Traditional way of life through the Protection of our lands and Creation of Opportunity to enhance our future | Yes | No |
| Alaska Electric Light and Power | Lake Dorothy project produces 14.3 MW of electricity and increases output by 20% | Yes | No |
| Kwig Power Company | Flywheel energy storage to stabilize village power grid | Yes | No |
| Kodiak Electric Association | Produce wind energy in Megawatts, combined with hydroelectricity; 99% renewable energy production and less than 1% diesel generator | Yes | No |
| Chitina Electric | Hydroelectric and diesel integration; looking for supplemental financial support to fund the project | Yes | No |
| Hasz Consulting LLC | Developing innovative methods to produce renewable electrical power | Yes | No |
| Kipnuk | | Yes | No |
| Levelocok Electric Co-op | | Yes | No |
| TCSA Electrical Services | | Yes | No |
| Iqnatchiaq Electric Company | | Yes | No |
| Copper Valley Electric Association | Hydro-electric diesel | Yes | No |
| Elfin Cove Utility | Run-of-river hydroelectric project; expected to produce approximately 90% of electricity demand | Yes | No |
| Golden Valley Electric Association | Eva Creek wind project | Yes | No |
| Nushagak Coop | | Yes | No |
| McGrath Light and Power | Diesel CHP | Yes | No |
| Naknek Electric Association | | Yes | No |
| Puvurnaq Power Company | | Yes | No |
| Kwethluk Incorporated | Kwethluk Wind-Diesel | Yes | No |
| Kokhanok Village Council | | Yes | No |

| | | | |
|---|---|---|---|
| Inside Passage Electric Cooperative | Thayer Creek hydro project; solar arrays | Yes | No |
| Beaver Joint Utilities | | Yes | No |
| Tuluksak Traditional Power Utility | | Yes | No |
| Nuvista Light and Electric Co-op | Help Y-K communities implement solutions that reduce the long-term cost of power, heating, and transportation; determine if communities can share public services and/or infrastructure to support community sustainability | Yes | No |
| Akiak Power Utilities | | Yes | No |
| Ruby Electric | | Yes | No |
| Metlakatla Power and Light | Metlakatla Hydro-diesel-battery | Yes | No |
| Igiugig Electric Company | AEA diesel generator updates and waste heat lines | Yes | No |
| MKEC | | Yes | No |
| Naterkaq Light Plant | | Yes | No |
| INN Electric Cooperative | Upgrades for hydroelectricity and increase capacity to 1.4 Megawatts | Yes | No |
| Rampart Village Council | | Yes | No |
| Pedro Bay Village Council | Pedro Bay Knutson Creek Hydro-Diesel | Yes | No |
| Kotzebue Electric Association | Utility-owned wind power | Yes | No |
| Chaninik Wind Group | 4-village wind project | Yes | No |
| Saft | Microgrid Battery Storage-Kotzebue | No | Yes |
| SAIC | Smart Grid Service for Chaninik Wind Group | No | Yes |
| Sitnasuak Corporation | Wind-geothermal-diesel | Yes | No |
| Sandia National Lab | Lime Village solar-Diesel; Metlakatla hydro-diesel-battery | No | Yes |
| Sustainable Power Systems | Leverage technical abilities by working with regional project developers and service organizations to support renewable hybrid power systems; Wind-Diesel Kokhanok | No | Yes |
| Alaska Center for Energy and Power (ACEP) | Provides leadership in developing energy systems for islanded, non-integrated electric grids and their associated oil-based heating systems. | Yes | |
| United Technologies Corporation (UTC) | Geothermal generator for Chena Hot Springs | No | Yes |
| Yakutat Power | Diesel Engine Power-ongoing | Yes | No |
| YourCleanEnergy, LLC | Alaska SeaLife Center Heat Pump Project | Yes | No |
| Nelson Lagoon | Nelson Lagoon Wind-Diesel | Yes | No |

| | | | |
|---|---|---|---|
| Northern Power Systems | Technology, wind, ownership, power conversion, microgrids; Kotzebue Wind-Diesel-Heat | No | Yes |
| Nunam Iqua Electrical Company | | Yes | No |
| New Koliganek | Wind-Diesel, CHP | Yes | No |
| USDOD | SPIDERS Program | No | Yes |
| USDOE | All-Around Energy Projects | No | Yes |

# Bibliography

"100% Renewably-Powered: Alaska's Kodiak Island Goes all in with wind and hydro," Islanded Grid Resource Center. Accessed March 21, 2016, http://islandedgrid.org/100-renewably-powered-alaskas-kodiak-island-goes-all-in-with-wind-and-hydro/.

Alaska Center for Energy and Power (ACEP). *Power Systems Integration*. June 26, 2015. Alaska Center for Energy and Power (ACEP), Fairbanks, Alaska. http://acep.uaf.edu/media/158033/Power-Systems-Integration-6-26-15.pdf

Alaska Center for Energy and Power (ACEP). "Project Snapshot: Alternative Transportation Options on St. Paul Island, Alaska." Alaska Center for Energy and Power, Fairbanks, Alaska. http://acep.uaf.edu/media/144754/Alternative-Transportation-St-Paul-final.pdf

Alaska Center for Energy and Power (ACEP). *Solar Thermal Energy for Alaska*. Fairbanks, Alaska. http://acep.uaf.edu/media/50765/ACEP_ResourceOverview_SolarEnergy.pdf

Alaska Energy Authority, *Renewable Energy Atlas of Alaska.* Anchorage, Alaska, 2013.

"Alaska's Renewable Energy Projects." Alaska's Renewable Energy Project. Accessed March 14, 2016. http://alaskarenewableenergy.org/why-renewable-energy-is-important/alaskas-renewable-energy-projects/.

Crow, Andrew. "Rural Village Electric Utility Management Plan Using Common Performance Indicators." *The University of Alaska Center for Economic Development* (2015).

Asmus, Peter, and Mackinnon Lawrence. *Microgrids*. Report. Boulder, Colorado: Navigant Consulting, 2013.

Beste, Benjamin. Interview by Michael Lockwood. In-Person Interview. Fairbanks, AK, April 28, 2016.

Beste, Benjamin. "Solar Energy in Rural Alaska: AP&T's Solar PV Project in Eagle." Lecture, Alaska Rural Energy Conference, Fairbanks, Alaska, September 2014. http://www.akruralenergy.org/2014/AP&T's_Solar_PV_Project_in_Eagle-Ben_Beste.pdf

Boots, Michelle Theriault. "Kodiak Reaps Benefits of Renewable Energy, with Lessons for Rural Alaska." Alaska Dispatch News. September 26, 2015. Accessed May 12, 2016. http://www.adn.com/energy/article/kodiak-builds-renewably-powered-island-lessons-rural-alaska/2015/09/27/.

Caldwell, Suzanna. "New Power Plant Expanding Thanks to Extra Gas from Anchorage Landfill." Alaska Dispatch News. May 6, 2013. Accessed April 1, 2016. http://www.adn.com/article/20130506/new-power-plant-expanding-thanks-extra-gas-anchorage-landfill.

"Chaninik Wind Group - 2010 Project." Department of Energy. Accessed April 13, 2016. http://energy.gov/indianenergy/chaninik-wind-group-2010-project.

Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). *Wind Turbine Provides Electricity for Arctic Town*. February 2001. Technical Brochure No. 143, United Kingdom.
http://www.akenergyauthority.org/Content/Programs/AEEE/Reports and Presentations/Wind-Turbine-Provides_Electricity-for-Arctic-Town_CADDET-Kotzebue-Article.pdf

“Cold Weather Energy Storage System Delivered in Arctic Alaska,” Transmission and Distribution World, November 11, 2015. Accessed February 25, 2016, http://tdworld.com/renewables/cold-weather-energy-storage-system-delivered-arctic-alaska.

Dabo, Martino. "TDX High Penetration Wind-Diesel Hydrogen and Electric Vehicle Project St. Paul." Lecture. Accessed April 13, 2016. http://alaskarenewableenergy.org/wp-content/uploads/2009/10/KatKeithStPaul.pdf.

Doyon Utilities, and Municipality of Anchorage. *Anchorage Landfill Gas to Energy Project*. Anchorage, Alaska.
https://swana.org/Portals/0/Awards/2013/Landfill_Gas_Utilization_Silver.pdf

EcoWatch. "Second Largest Island in U.S. Goes 100% Renewable." EcoWatch. March 20, 2015. Accessed April 22, 2016. http://www.ecowatch.com/second-largest-island-in-u-s-goes-100-renewable-1882043985.html.

Engerati. "St. Paul Island Project To Demonstrate Flywheel Energy Storage In Remote Alaska." Engerati. September 01, 2014. Accessed April 05, 2016. http://www.engerati.com/article/st-paul-island-project-demonstrate-flywheel-energy-storage-remote-alaska.

"Energy Management in DOD Facilities." U.S. Government Accountability Office. Accessed April 1, 2016. http://www.gao.gov/key_issues/energy_management_dod_facilities/issue_summary#t=0.

FACT SHEET ON: THE CHENA GEOTHERMAL POWER PLANT. Fact sheet found online, Chena Hot Springs, Fairbanks, AK.http://static1.1.sqspcdn.com/static/f/386714/3483656/1246465202543/Powerfactsheet.pdf?token=Rx0QkNahJDk09goiE6Gyap5aiTA=

Geographic Information Network of Alaska, University of Alaska Fairbanks. "Alaska Wind Power Potential (AEDI, 2011)." ArcGIS. February 10, 2012. Accessed August 19, 2016. http://www.arcgis.com/home/item.html?id=6aaef4ce5821459cad757bf9adda3079.

"GEOTHERMAL POWER." CHENA POWER. Accessed March 21, 2016. http://www.chenapower.com/geothermal-power/.

Gillis, Justin. "A Tricky Transition From Fossil Fuel." The New York Times. November 10, 2014. Accessed September 13, 2016. http://www.nytimes.com/2014/11/11/science/earth/denmark-aims-for-100-percent-renewable-energy.html?_r=0.

Harrington, Kent. "High-Tech Flywheels Help Bring Stability to Grid." AIChE ChEnected. March 20, 2015. Accessed April 29, 2016. http://www.aiche.org/chenected/2015/03/high-tech-flywheels-help-bring-stability-grid.

Haselip, James, and David Pointing, eds. *The Cool 100 Book*. Roskilde, Denmark: UNEP Risø Centre on Energy, Climate and Sustainable Development Risø DTU National Laboratory for Sustainable Energy. PDF. doi:http://www.iser.uaa.alaska.edu/Publications/TheCool100Book.pdf.

Heimbuch, Hannah. "Massive Wind Turbines Newest Features of Kotzebue Skyline." Alaska Dispatch News. May 2, 2012. Accessed May 12, 2016. http://www.adn.com/rural-alaska/article/massive-wind-turbines-newest-features-kotzebue-skyline/2012/05/03/.

Hobson, Margaret Kriz. "ELECTRICITY: A Renewable Energy Success Story above the Arctic Circle." E&E Publishing. October 20, 2015. Accessed May 05, 2016. http://www.eenews.net/stories/1060026559.

Holdmann, Gwen. *The Chena Hot Springs 400 KW Geothermal Power Plant: Experience Gained During the First Year of Operation*. Chena Hot Springs/Chena Power. Accessed March 21, 2016. http://static1.1.sqspcdn.com/static/f/386714/3483652/1246465202447/Experience.

"KEA Generation." Kodiak Electric Association. Accessed April 19, 2016. http://www.kodiakelectric.com/generation.html.

Jensen, James. *Yukon-Kuskokwim Region Wind Resource Summary*. Presentation http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/Yukon-Kuskokwim-Wind-Resource_Jenson.pdf

Jeppesen, Helle. "Denmark Leads the Charge in Renewable Energy." DW.COM. May 5, 2014. Accessed September 13, 2016. http://www.dw.com/en/denmark-leads-the-charge-in-renewable-energy/a-17603695.

Jill Maynard et al., Community Wind Toolkit: A Guide to Developing Wind Energy Projects in Alaska. Renewable Energy Alaska Project (REAP), 2011. Accessed March 24, 2016.http://alaskarenewableenergy.org/wp-content/uploads/2009/04/WindToolkit_For-web_FINALMarch24_20111.pdf.

Joseph, Ami, and Mohammad Shahidehpour. *Battery Storage Systems in Electric Power Systems*. 2006. Accessed August 28, 2016. http://www.iitmicrogrid.net/microgrid/pdf/papers/battery/battery.pdf.

Lockard, David. "Solar Energy in Alaska." Lecture, BIA Providers Conference, Anchorage, Alaska, December 2, 2015.
http://energy.gov/sites/prod/files/2015/12/f27/Session4-Lockard-Solar.pdf

Martin, Glen D. *Renewable Energy Fund Round 6 Grant Application*. September 21, 2012. Grant Application for Eagle Solar Project, Anchorage, Alaska.
ftp://aidea.org/RENEWABLE ENERGY FUND/Round 6 09242012/915_Eagle Solar Array Project/092112_AEA-Eagle Solar Array Project.pdf

Martinsen, Erica. "Alaska's Rural Energy Microgrids Offer a Prototype for Powering the World." Alaska Dispatch News. February 15, 2016. Accessed July 22, 2016. http://www.adn.com/energy/article/alaskas-microgrids-offer-prototypye-powering-world/2016/02/15/.

Meiners, Dennis. “Chaninik Wind Group Wind Heat Smart Grids Final Report.” 2013, United States. doi:10.2172/1086573. http://www.osti.gov/scitech/servlets/purl/1086573.

Meiners, Dennis. Interview by Michael Lockwood. Phone Interview. Anchorage, AK, August 31, 2016.

Neslen, Arthur. "Wind Power Generates 140% of Denmark's Electricity Demand." The Guardian. July 10, 2015. Accessed September 13, 2016.
https://www.theguardian.com/environment/2015/jul/10/denmark-wind-windfarm-power-exceed-electricity-demand.

Nowers, Stephanie. "100% Renewably-Powered: Alaska’s Kodiak Island Goes All in with Wind and Hydro." Islanded Grid Resource Center. Accessed April 4, 2016. http://islandedgrid.org/100-renewably-powered-alaskas-kodiak-island-goes-all-in-with-wind-and-hydro.

"ORC Technology." Organic Rankine Cycle, Geothermal, Waste Heat Recovery. Accessed March 21, 2016. http://www.exergy-orc.com/technology/orc.

Ormat. "Organic Rankine Cycle." Ormat. Accessed March 9, 2016. http://www.ormat.com/organic-rankine-cycle.

Rana Zucchi, Global Energy Concepts, and Kotzebue Electric Association Brad Reeve, DOE Project Officer - Doug Hooker. 2007. “Final Technical Report - Kotzebue Wind Power Porject - Volume I”. United States. doi:10.2172/918467. http://www.osti.gov/scitech/servlets/purl/918467.

Reeve, Brad. "Kotzebue Electric Association Wind Projects." Lecture, Wind Diesel Conference, Anchorage.
http://acep.uaf.edu/media/62312/KEA-Wind-Projects-Presentation.pdf

Resz, Heather A. "Renewable Energy in Alaska." *Alaska Business Monthly*, April 2016, 58-61.

Savage, Harlin. *The Terror Lake Case*.
http://www.snre.umich.edu/ecomgt/cases/pubs/acus/Terror_Lake.pdf

Schwabe, Paul. *Solar Energy Prospecting in Remote Alaska*. Report. Washington, DC: U.S. Department of Energy, 2016, http://energy.gov/sites/prod/files/2016/02/f29/Solar-Prospecting-AK-final.pdf.

Stricker, Julie. "Kotzebue Microgrid Local Alternatives Paying off." Alaska Business Monthly. October 2, 2014. Accessed April 19, 2016. http://www.akbizmag.com/Alaska-Business-Monthly/October-2014/Kotzebue-Microgrid/.

Su, Wenchong, and Jianhui Wang. "Energy Management Systems in Microgrid Operations." *The Electricity Journal* 25, no. 8 (October 2012): 45-60. Accessed September 8, 2016. http://www.sciencedirect.com/science/article/pii/S104061901200214X.

TDX Power. "History and Culture." TDX Power. Accessed May 03, 2016. http://www.tdxpower.com/history-culture.

"The Wind Farm That Continues to Grow - Kotzebue Electric Association." Kotzebue Electric Association. 2013. Accessed April 09, 2016. http://www.kea.coop/articles/the-wind-farm-that-continues-to-grow/.

U.S. Energy Information Administration. "Alaska State Energy Profile." U.S. Energy Information Administration. August 18, 2016. Accessed August 29, 2016. http://www.eia.gov/state/print.cfm?sid=ak.

Vaught, Douglas. Kodiak, Alaska Site 1 Wind Resource Report. Report. Alaska Energy Authority (AEA). Eagles River, Alaska, 2006. Accessed August 22, 2016.
http://www.akenergyauthority.org/Content/Programs/AEEE/Wind/WindResourceAssessment/Kodiak Site 1 Wind Report Nov 06 by V3.pdf.

"Wind ." Renewable Energy Alaska Project (REAP). Accessed April 19, 2016. http://alaskarenewableenergy.org/why-renewable-energy-is-important/alaskas-resources/wind/.

"Wind Energy Production." Kotzebue Electric Association. 2013. Accessed April 09, 2016. http://www.kea.coop/articles/wind-energy-production/.

"Winds in Kotzebue." Kotzebue Electric Association. 2013. Accessed April 09, 2016. http://www.kea.coop/articles/winds-in-kotzebue/.

Wood, Elisa. "The Vital Role of Reciprocating Engines in Remote Communities." Microgrid Knowledge. September 12, 2016. Accessed September 13, 2016. http://microgridknowledge.com/reciprocating-engines-in-remote-communities/.

Young, Colin, and Will Galton. "2 MW Flywheel System Integration." Lecture, Alaska Rural Energy Conference, Fairbanks, Alaska, April 27, 2016. http://www.akruralenergy.org/2016/2016_REC_Integrating_an_Electric_Crane_with_a_Flywheel_in_Kodiak-Colin_Young.pdf