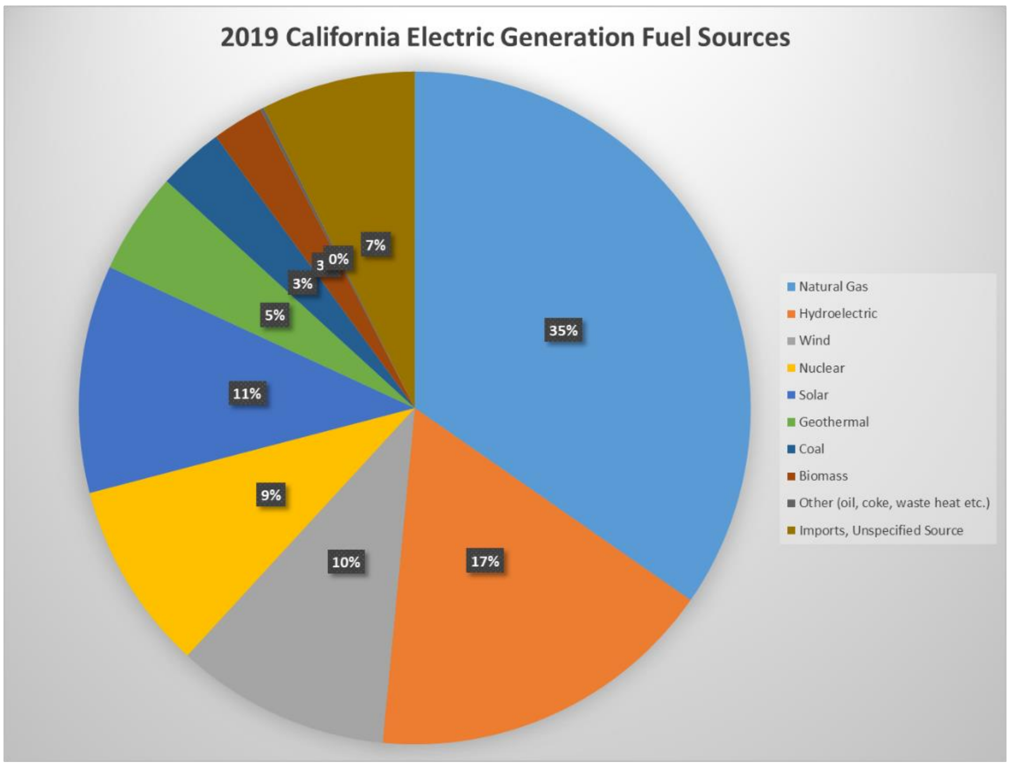
Cold Weather Renewables

By John Benson, March 2021

1. Introduction

Going forward most regions must transition to very low greenhouse gas (GHG) electric generation (a.k.a. 'renewables) in order to avoid the worst effects from climate change. I have lived in California most of my adult life, and my state has been increasing the percentage of electric generation we receive from very low GHG generation for a couple of decades (see figure below)[1]. However, since I've traveled much in my career, I understand that one renewable generation mixture definitely does <u>not</u> fit all regions.



California will lean heavily on photovoltaic (PV) generation in the future. When coupled with battery energy storage systems (BESS), PV works well to cover my state's peak electric demand period (late afternoon through early evening) during our peak demand season (summer). In other regions, the peak demand season is not necessarily summer, and the peak demand period may extend into the night – not so good for PV. Also, many regions are quite cloudy during much of the time. California is evolving to PV with trackers, and these are not as effective during cloudy periods. Also PV variability increases with clouds.

Probably most readers know that "cold weather" and California should rarely be used in the same sentence, much less the same paper. This paper is about the coldest regions in North America, and how they might implement renewables. Thus California will not be mentioned again.

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[1] Data for the above chart: California Energy Commission, "2019 Total System Electric Generation", https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2019-total-system-electric-generation

2. Challenges

When I worked for Landis & Gyr Systems, some of our customers were in the far north. In the small SCADA group, both my manager (of the business unit) and I (manager of application engineering) traveled quite a bit. A few of our best customers were in Alaska. When it came to Alaska, the business unit manager seemed to take all of the trips in the temperate months, and my trips were typically in the dead of winter, so I know about potential challenges in this place and time.

2.1. Present Energy Use

I will focus on Alaska for this section, since I'm familiar with utilities here, and venture into Canada in other sections below. Based on what little I know about Canada, I expect that energy use is similar to Alaska, except Canada has significant nuclear generation (about 15%) and this is mainly in the eastern provinces. Also as large as Canada is, the generation mix varies substantially in different regions.

Most of the text below comes from this source.[2] *Alaska, the largest U.S. state, is one-fifth the size of the Lower 48 states, and, with its Aleutian Island chain, is as wide as the Lower 48 states from east to west. It is the only U.S. state with land north of the Arctic Circle, and it has the highest mountains and longest coastline of any state…*

See the map below. Note that a sizable portion of the Alaskan Coast is above the Arctic Circle, giving the U.S. (and Canada) a major vote in what happens in the Arctic.

[2] U.S. Energy Information Administration (EIA), "State Profile and Energy Estimates", https://www.eia.gov/state/analysis.php?sid=AK#:~:text=In%202010%2C%20the%20Alaska%20legislature%20enacted%20a%20non-binding,Alaska%2C%20in%20mountainous%20regions%20with%20high%20annual%20

The oil and natural gas industry is a key part of Alaska's economy. The state's North Slope contains 6 of the 100 largest oil fields in the United States and 1 of the 100 largest natural gas fields. Alaska's Prudhoe Bay field is among the 10 largest oil fields in the nation.

Alaska has other substantial energy resources. Its recoverable coal reserves rank 14th among the states. Alaska's many rivers offer some of the best hydroelectric power potential in the nation. Large swaths of the Alaskan coastline have significant wind energy resources, and the state's many volcanic fields offer geothermal energy potential. Because of its small population, Alaska's total energy demand is among the 10 lowest states. However, with its harsh winters, energy-intensive oil and natural gas industries, and small population, the state's per capita energy consumption is the fourth highest in the nation, after Wyoming, Louisiana, and North Dakota.

2.1.1. Oil

Alaska ranks 11th among the states with the lowest total petroleum demand, but it has the third-highest per capita petroleum consumption. The state has five operating refineries, with a combined processing capacity of about 164,000 barrels of crude oil per calendar day. Two of the refineries, in the Prudhoe Bay region, supply fuel for crude oil drilling operations. Motor gasoline demand is primarily met by a refinery in Kenai. Diesel and heating fuels are also produced there as well as in two other refineries, located at Valdez and near Fairbanks. Alaska is the largest jet fuel-consuming state on a per capita basis. The state is a major fueling stop for military aircraft as well as for commercial passenger and cargo flights between the United States and Asian countries. Alaska also consumes petroleum to produce electricity. In 2019, petroleum liquids generated about 15% of the state's utility-scale electricity. Small diesel-fueled generators also produce electricity in isolated communities. One-third of the state's households relies on fuel oil, kerosene, or propane for heating.

2.1.2. Natural Gas

Alaska's proved natural gas reserves totaled 9.4 trillion cubic feet at the start of 2020, the 11th largest among the states. Alaska ranks third in the nation (after Texas and Pennsylvania) in natural gas gross withdrawals, but most of the state's gas production is not brought to market. Natural gas volumes from the North Slope far exceed local demand, and there is no pipeline to transport the natural gas to consumers in the south. About 90% of the state's natural gas withdrawals—most of it extracted during oil production is reinjected into oil reservoirs to help maintain crude oil production rates. The rest of the gas production is marketed. About 78% of Alaska's natural gas consumption occurs in the natural gas and crude oil production process. The electric power sector accounts for 9% of the state's natural gas consumption, and more than two-fifths of Alaska's utility-scale electricity is generated by natural gas. The remaining 13% of natural gas consumption is almost evenly divided among the residential, industrial, and commercial sectors. About half of Alaskan households, most of which are located in the state's cities, heat with natural gas.

From this source,[3] I identified two projects to build a natural gas pipeline from the North Slope to Southeast Alaska. The one that appears to be most active is the Alaska LNG project. This would build an 869 mile long pipeline from the North Slope (Point Thomson

[3] Alaska Department of Natural Resources, Division of Oil and Gas, Pipeline Services, https://dog.dnr.alaska.gov/Services/Pipelines

Unit and Prudhoe Bay Unit production fields) to the Kenai Peninsula (approximately 3 miles southwest of Nikiski and 8.5 miles north of Kenai). This pipeline is currently planned to be operational by 2025. This would connect to existing natural gas pipelines, and provide a LNG terminal on the Kenai Peninsula to export the liquefied natural gas.

2.1.3. Coal

…Alaska has only one operating surface coal mine, the Usibelli mine, which produces about 975,000 tons of coal per year. In 2019, none of Alaska's coal was exported. Instead, it was used in the state at coal-fired power plants and by commercial and institutional users…[2]

2.1.4. Electric Generation

In 2019, natural gas fueled 44% of Alaska's total utility-scale electricity generation and hydroelectric power generated 27%. Petroleum liquids accounted for 15%, coal was 11%, and other renewables—mostly wind and biomass—accounted for 3% of Alaska's generation…

Author's Comment: If you look at the above mix, Alaska's electric generation is probably cleaner than many other U.S. states. If the natural gas pipeline is described above is built as planned, this could displace the coal generation making it even cleaner.

The electricity infrastructure in Alaska differs from that in the Lower 48 states because Alaskans are not linked to large, interconnected grids through transmission and distribution lines. Although a grid called the Railbelt, where about two-thirds of the state's population lives, serves an area that stretches from Fairbanks to Anchorage and down to the Kenai Peninsula, even that grid is isolated from the electric grids in Canada and the Lower 48 states.

2.2. Current Renewables

In 2010, the Alaska legislature enacted a non-binding goal for 50% of the state's electricity to be generated from renewable and alternative energy sources by 2025. In 2019, about 30% of Alaska's utility-scale electricity generation came from renewable energy sources, and about nine-tenths of those renewables was hydropower with much smaller amounts from wind and biomass.

Note from the author: One of my goals when I started this paper was to identify which renewables might be applicable for colder regions. The coldest area that I've traveled to is the Fairbanks area, where -50°F is not that unusual in the winter. I identified a small wind farm operated by Golden Valley Electric Association (utility for the Fairbanks area). This will be covered in the next section.

3. Future Renewables

Although Alaska and northern Canada are likely to be behind many states in the lower 48 in the deployment of renewables, they do have a path forward, and may (eventually) reach net-zero GHG-emissions.

3.1. Technologies

3.1.1. Solar

When it comes to PV or solar-thermal generation, one of the main challenges is lack of sunlight in the winter, especially close to the Arctic Circle (Fairbanks and points north). PV may occupy some niche application for coastal areas that need a renewable energy source to help cover a summer peak, but its contribution will probably be minimal.

3.1.2. Hydro

Hydro already provides 90% of Alaska's current renewable power, and much of the power for coastal Canada, so it will provide significant new renewable power in the future to both regions, especially in coastal areas.

3.2. Wind

This becomes an interesting trade-off here. In the U.S. Upper Midwest, where the winters are really cold (nearly as cold as much of the area within a few hundred miles north of the Canadian Border) standard commercial wind turbines do a reasonable job of supplying renewable power, as long as (1) they have a cold-weather kit, and (2) it doesn't get below -20°F. What happens if it gets below -20°F? The turbines stop generating power, and become loads. Read the really good article linked below for more information.

https://energynews.us/2019/02/27/midwest/wind-turbine-shutdowns-during-polar-vortex-stoke-midwest-debate/

There are three pieces of good news here:

1. When it gets below -20°F, the wind velocity typically drops dramatically, so the turbines would not be generating much power anyway.
2. With climate change related warming, cold-spells where it gets below -20°F will be increasingly rare.
3. There are cold-weather turbines that can produce power below -20°F.

In the subsections below we will focus on two small wind farms that operate in the coldest regions.

3.2.1. Golden Valley Electric Association

The time was the early 1980s, and I was the application engineering manager for Moore Systems, owned by Landis & Gyr, and soon to change its name to Landis & Gyr Systems (later TELEGYR, now the Power TG Division of Siemens). We were starting to travel to potential customer sites with a demonstration unit for our small SCADA System, the TELEGYR 6500. This was based on purpose-built microcomputers that used technology similar to the original IBM PC. However, being a very robust design, the demo unit was a bit heavy (over 500 lbs.) We decided to tour Alaska with this, in the dead of winter, of course (we got extra points for visiting then).

We started in Anchorage and then went to Fairbanks to visit the City of Fairbanks and Golden Valley Electric association (GVEA). The former eventually bought a TELEGYR 6500, and the latter used one of these systems until we could deliver their TELEGYR

8500 Energy Management System (EMS) that was based on a DEC VAX. The latter was an unusually large and powerful system for a utility as small as GVEA (less than 40,000 customers in 2004), but they have always been on the leading edge of technology. In addition to their EMS, their use of advanced technology includes:

- In 1985 a consortium that included GVEA completed the Alaska Intertie, which connected GVEA to the utilities in Southeast Alaska.[4] This eventually became part of the Railbelt Energy G&T System.
- In 2003, GVEA completed the world's largest Battery Energy Storage System.[5]
- GVEA completed the Eva Creek Wind Farm in 2012. This 24.6 megawatt project is in a region that occasionally gets down to -50°F.[6]

Note that the turbines for the GVEA project were Senvion MM92, Cold Climate Version Machines. Senvion was acquired by Siemens Gamesa in 2020. I was able to find an earlier presentation from Senvion, and the standard MM92 is apparently only rated down to -20°F. This means either the GVEA turbines have some non-standard modifications or they shut down the turbines when it gets below -20°F. Below are links to articles about two other projects in Canada that use these turbines.

Senvion turbines are spinning at Quebec's first 100% community wind farm

https://www.windpowerengineering.com/senvion-turbines-spinning-quebecs-first-100-community-wind-farm/

Senvion to deliver MM92-type turbines to Ontario wind farm

https://www.windpowerengineering.com/senvion-deliver-mm92-type-turbines-ontario-wind-farm/

3.2.2. Diavik Diamond Mine Wind Farm Northwest Territories Canada

Lac de Gras is in Canada's far north, just south of the Arctic Circle. This is coldest region that I could find that hosted a wind farm. The 9.2 MW project was developed by Diavik Diamond Mines Inc. to help diversify the energy supply at the company's mining operation at Lac de Gras.[7]

This project *consists of four ENERCON wind turbines that are integrated into the mine's existing diesel-powered system and will offset diesel use when the wind is blowing, saving the company an estimated $5-6 million a year in fuel costs. Diavik expects the $33 million project, which is the world's most northern large scale wind-diesel hybrid power system, to reduce its reliance on diesel by around 10 per cent and lower the mine's carbon footprint by about six per cent.*

[4] Alaska Energy Authority, "Alaska Intertie", http://www.akenergyauthority.org/What-We-Do/Railbelt-Energy/Alaska-Intertie/
[5] ABB, Inc., "World's Largest Battery Energy Storage System Fairbanks, Alaska, USA, 2011, https://library.e.abb.com/public/3c4e15816e4a7bf1c12578d100500565/Case_Note_BESS_GVEA_Fairbanks-web.pdf
[6] GVEA, "Eva Creek Wind Project", https://www.gvea.com/eva-creek-wind/
[7] CanWEA (Wind Energy Association), "Diavik Wind Farm: Wind energy helps reduce carbon footprint", https://canwea.ca/wp-content/uploads/2013/12/canwea-casestudy-DiavikMine-e-web2.pdf

ENERCON makes turbines that can operate down to -40° (note that -40° is the cross-over point for degrees Fahrenheit and Celsius). These have a very heavily modified design as described in the brochure linked below.

https://www.enercon.de/fileadmin/Redakteur/Medien-Portal/broschueren/pdf/EC_Cold_Climate_en.pdf

3.2.3. Wind-Diesel Hybrid Generation

The last subsection discussed wind turbines as used in a wind-diesel hybrid configuration. Although this particular project has a peak wind capacity of almost 10 MW, it would be reasonable to scale it down to a much smaller size using a "village-size" one- to three-unit diesel generator, one or more 10-15 kW turbines, and perhaps "Powerwall-size" (7 kW, 13.5 kWh) or larger BESS to enhance efficiency. Most existing villages in Alaska and Canada use diesel-only, but by adding turbine(s) and a monitoring automatic controller, the amount of diesel fuel use can be greatly reduced.

In fact the above described "High-Penetration Wind-Diesel Hybrid Power System" has been built in several villages in Alaska, and probably elsewhere, starting around Y2K. Go through the links below for more information.

Wales, Alaska High-Penetration Wind-Diesel Hybrid Power System

https://www.nrel.gov/docs/fy02osti/31755.pdf

Alaska's Energy Labs

https://www.hcn.org/issues/46.21/alaskas-energy-labs

From an earlier project investigating small wind-turbines, I know that there is a robust market for these. Bergey is one of the largest U.S. manufacturers, and they make a 10 kW off-grid unit that will operate down to -40°. Go through the link below for more information.

http://www.bergey.com/products/off-grid-turbines/excel-10-off-grid/

3.3. Nuclear

This generation-type is only applicable to the largest population centers in Alaska or far northern Canada, and only small modular reactors (SMRs) should be considered. One SMR that might be the best fit comes from NuScale. This is mainly because it is very scalable (pun intended). It is composed of independent power modules that are each 77 MW electric. A given plant can have any number of these, up to 12 (924 MW). Thus a 4-unit plant (308 MW) might be suitable to power the Railbelt utilities.

On Jan 14, *NuScale Power, and its partner Fluor, received an order from their first customer, the Utah Associated Municipal Power Systems (UAMPS), for a cost-reimbursable development agreement to provide estimating, development, design and engineering services for their first SMR as part of their Carbon-Free Power Project (CFPP).*[8]

[8] James Conca, NuScale Press Release via Forbes, "NuScale Small Modular Nuclear Reactor Moves Another Step Forward", Jan 14, 2021, https://www.forbes.com/sites/jamesconca/2021/01/14/nuscale-small-modular-nuclear-reactor-moves-another-step-forward/?sh=1bc0be7c5264

This includes the planning work needed to prepare a combined construction and operating license application which must happen for the licensing, manufacturing and construction of the power plant. Much of the work of the SMR will be to load-follow UAMPS' large wind farms.

CFPP will deploy NuScale Power Modules on property of DOE's Idaho National Laboratory to provide cleaner, safer and cost-effective carbon-free power for UAMPS member utilities. UAMPS is an energy services inter-local of the State of Utah that provides power pooling, scheduling, resource management and other electric services to its members, consisting of 48 member utilities located in the states of Utah, Idaho, California, Nevada, Wyoming and New Mexico.