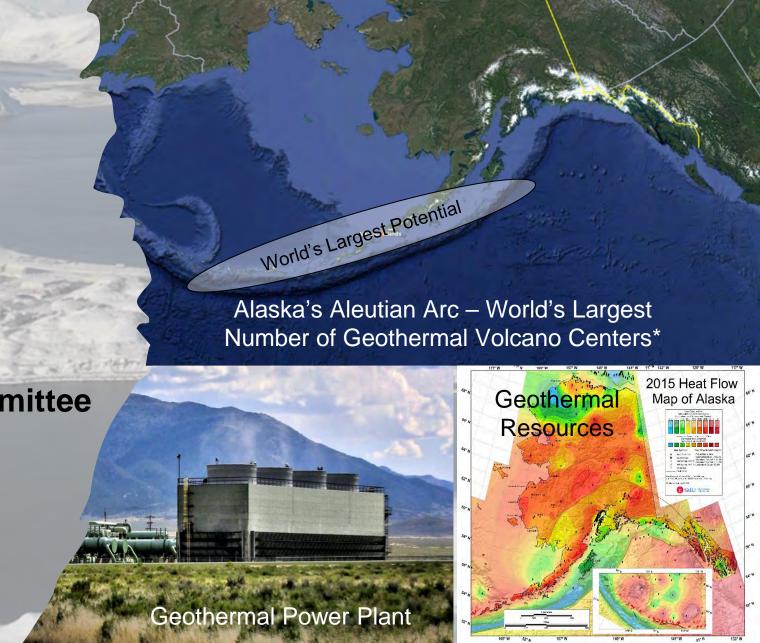
Alaska's Geothermal Resources

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Alaska Senate Resources Committee

April 12, 2023

Juneau, Alaska



* Shevenell et al., 2015, DOE EERE GTO, DE-EE0006725 Final Report.

Video link:

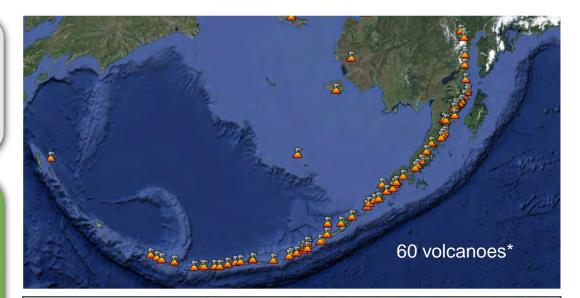
https://www.alaskageothermal.info/video

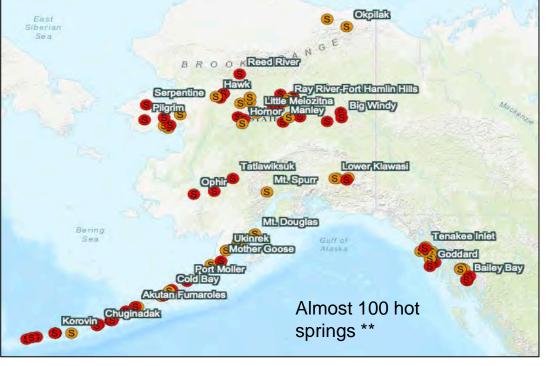
Alaska Has Significant Geothermal Phenomena

Alaska has abundant geothermal phenomena including hot springs and active volcanos. Economic resources are commonly, but not necessarily, associated with these phenomena. This is an area of ongoing discovery.

In general, economic hydrothermal systems in Alaska are related to geologically young volcanoes, fractured granitic bodies, and large sedimentary basins.

DGGS and USGS have conducted exploration efforts to uncover Alaska's promising geothermal potential.**





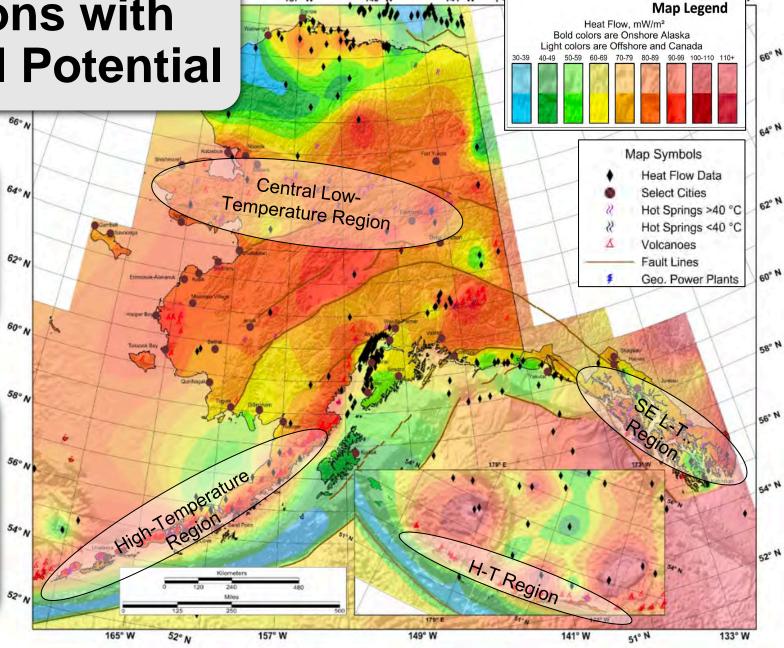
^{* 59} volcanos with an estimated 250,000 MW thermal, Smith and Shaw, USGS Circular 790, 1978.

^{**} From: https://geoportal.dggs.dnr.alaska.gov/portal/apps/webappviewer/index.html?id=28ed3938684448bb8d8fabad2c505e4d

Three Major Regions with Alaskan Geothermal Potential

In a 2015 report, Batri et al.*, presented an updated heat flow map of Alaska identifying potential regions for geothermal energy.

A low-temperature (L-T), fractured granitic belt (Chena Hot Springs to Pilgrim) in central Alaska, a L-T SE Alaska region and, of course, the Aleutian Islands with high temperatures.



^{*} Heat flow and temperature-depth curves throughout Alaska: Finding regions for future geothermal exploration, Batir et al., Journal of Geophysics and Engineering, June 2016.

Alaskan Geothermal Resources, How Much?

In 1978, as part of the newly formed USGS Geothermal Program, R.L. Smith and H.R. Shaw, estimated the total energy of volcanoes in Alaska's Aleutian region in a report titled, *Igneous-Related Geothermal Systems.**



26 Aleutian volcanoes assessed, and total volcanic energy was estimated as 10²² joules with Makushin volcano's at 3x10¹⁹ joules.

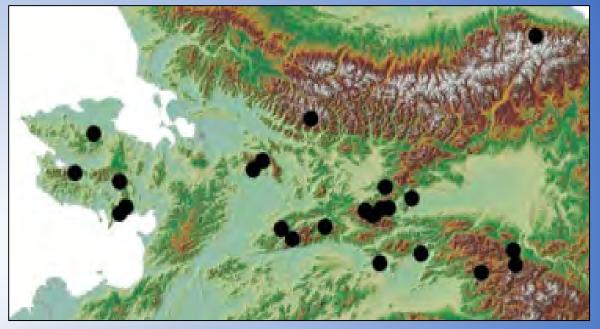
Later in 2016, a DOE-funded report** evaluated 59 Aleutian volcanos and six were identified with favorable conditions with Makushin and Akutan at the top of the list.

- * A report in the USGS Circular 790, Assessment of Geothermal Resources of the United States, L. J. P. Muffler, Editor.
- ** Geothermal Potential of the Cascade and Aleutian Arcs, with Ranking of Individual Volcanic Centers for their Potential to Host Electricity-Grade Reservoirs, Shevenell et al., DOE EERE Geothermal Technologies Program, DE-EE0006725 Final Report, 2015.
- ⁹ Favorable means strong potential to produce electricity.

Chena Hot Spring's Low-Temperature, Electricity Generation Is the Perfect Solution for the Central Alaska Region

Many low-temperature, but high flow rate hot springs, like CHS are spread out across central Alaska.*

Low-temperature geothermal electricity generation was not thought possible at less than 194°F, CHS moved the temperature to less than 167°C. and 'opened the door' for Central Alaska geothermal development.





Chena Hot Spring's binary, geothermal power plant, operating since 2006, at a nominal 350 MWe, has generated clean, carbon-free renewable energy for sustainable operations.

^{* 2008,} Assessment of Moderate- and High-Temperature Geothermal Resources of the United States, Williams et al., USGS, Fact Sheet 2008–3082.

Chena Hot Springs Pioneered Geothermal, Low-Temperature, Electricity Generation and Changed the World*

* Lowered low-temperature assessment temperature to 164°F for Alaska, From: 2008, A Review of Methods Applied by the U.S. Geological Survey in the Assessment of Identified Geothermal Resources, Williams, et al., USGS Open-File Report 2008–1296.

Chena Hot Springs, AK











Recycling



Clean H₂ Fuel





Balneology

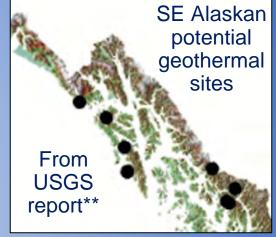
Geothermal Enables

South-Eastern Alaska Region Will Also Benefit from Chena Hot Springs Low-Temperature Geothermal System

In addition to Chena Hot Spring's binary, geothermal power plant for electricity, geothermal waters are further employed to heat buildings, outdoor walkways and grow food year-round and, cool the icehouse. This is called direct use of geothermal energy.

Heat flow estimates in the SE region of Alaska (except Juneau) might be able to generate electricity, but certainly SE cities would benefit from direct usage.*











^{*} Heat flow and temperature-depth curves throughout Alaska: Finding regions for future geothermal exploration, Batir et al., Journal of Geophysics and Engineering, June 2016.

^{** 2008,} Assessment of Moderate- and High-Temperature Geothermal Resources of the United States, Williams et al., USGS, Fact Sheet 2008–3082.

Aleutian Islands Have an Enormous Untapped Geothermal Potential

Alaska's Aleutian Islands are the largest island arc volcanic center in the World.** Total Aleutian volcanic energy was estimated as 10²² joules.* How to tap into this enormous source of energy for Alaska's benefit?

In 2016, Makushin scored first on a DOE-EERE-GTO funded report assessing island arc geothermal-potential, favorability list of over 59 Aleutian volcanos near population centers.



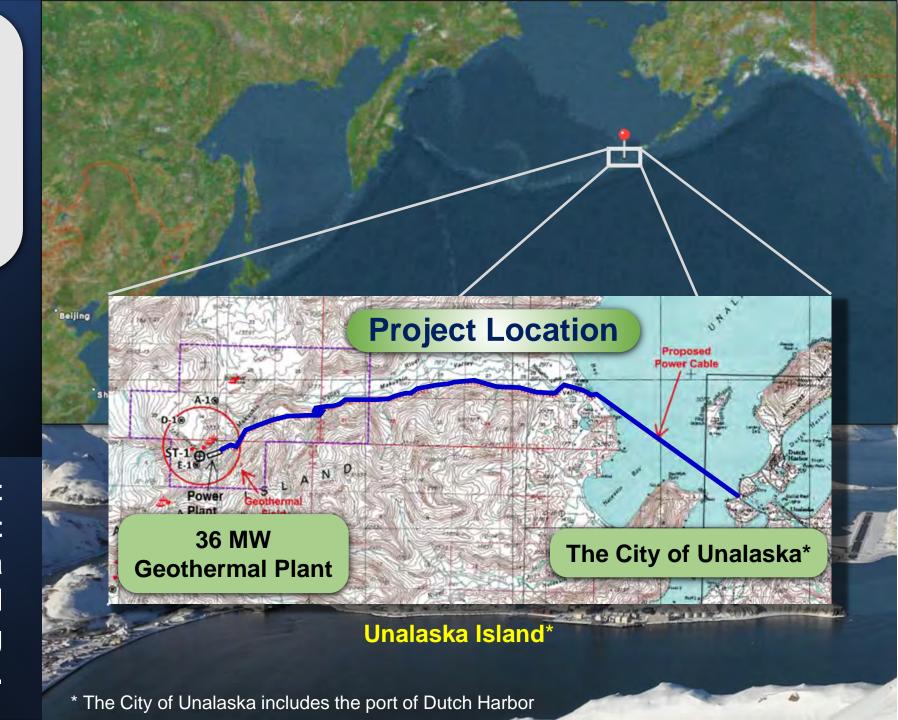
Geothermal favorability $^{\circ}$ map of the Aleutian Islands** Red color is best.

Makushin volcano is estimated at 3x10¹⁹ joules is the key.*

- * A report in the USGS Circular 790, Assessment of Geothermal Resources of the United States, L. J. P. Muffler, Editor.
- ** Geothermal Potential of the Cascade and Aleutian Arcs, with Ranking of Individual Volcanic Centers for their Potential to Host Electricity-Grade Reservoirs, Shevenell et al., DOE EERE Geothermal Technologies Program, DE-EE0006725 Final Report, 2015.
- ⁹ Favorable means strong potential to produce electricity.

Unalaska is Strategically Located in the Aleutian Chain

Unalaska is the largest deep water fishing port in U.S. and it's a globally significant and strategic shipping location.

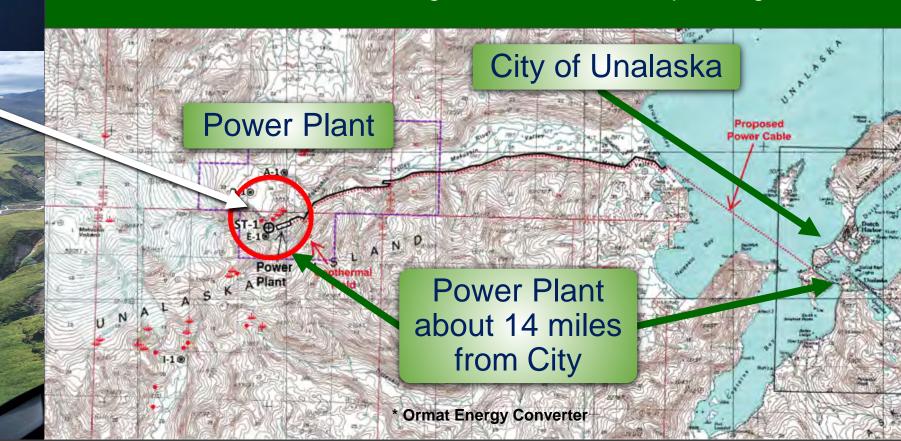


What is the Makushin Geothermal Project?

Power Plant Site

Makushin Geothermal Project (MGP) is a 100% renewable energy 30MWe geothermal power system:

- Powerplant utility corridor and three production/injection wells,
- Modular geothermal plant with multiple, cascading OEC* units,
- Power transmission/communications lines on land and underwater connection to City of Unalaska's power grid, and
- Automated controls and integration scheme with power grid.



Makushin Valley looking West

OCCP Aleutian Vision Summary



- Starts on Unalaska Island and Makushin Volcano's thermal energy.
- Next, the larger Makushin Geothermal Resource (MGR) and then the complete Volcano itself.
- Next, a move to Adak island to replace diesels.
- Finally, Aleutian volcanoes, more than any other place on Earth, are tapped for large-scale, industrial businesses such as green H₂ production and green ore smelting.

Eventually, eleven commercial business ventures are visioned with numerous OCCP-1 (30MWe) size power plants or much larger for heavy-use offtakers for a total of over 1 GW of capacity and attracting almost \$13B in power plant and facilities investment capital.

Hope You Enjoyed Alaska's Geothermal Resources

b.karl@chenapower.com

https://www.alaskageothermal.info



Additional Slides

Brief History of Geothermal Resources Work in Alaska

In 1954, a comprehensive survey of geothermal resources of Alaska sponsored by DOE and performed by the University of Alaska at Fairbanks (UAF), was released, *Preliminary Geothermal Energy Resources Map of Alaska by Turner, et al.**



In 1980, Reeder et al., published as part of DNR/DGGS, *The State of Alaska Geothermal Program* where a program and methodology were outlined that "...will lead to immediate geothermal energy development in Alaska." A regional hot spring reconnaissance project and 15 proposed site-specific hydrothermal projects were identified. Pilgrim Springs, Chena Hot Springs, and the Northern part of Unalaska Island were on the list.

Aleutian Geothermal Resources

In 1993, a detailed survey of geothermal resources of the Aleutian Islands was performed by Motyka et al., at ADDG*. Three meticulously crafted maps with detailed information offered up-to-date information on Aleutian geothermal resources. The Makushin resource had the most comprehensive and informative information.

Sedenka Island
S A N MAKUSHIN

The Makustilin geothermal area is the largest and most esponde high-lengerature geothermal resource in the Alexiena arc. Surface manifestations of the geothermal system include furnacies fields, warm ground, zones of interse hydrothermal seteration, bicartionate-euflate thermal springs, acid-sufface prings, mud pols, and sulfate-tich chloride springs, (Reeder, 1982a; Reeder, 1982b; Motyka, Moommar, and Poreda, 1983). The largest thermal fields lie at the heads of Glacies and Makustini reliefs and sulfate the heads of Glacies and Makustini valleys and after summit of lartice Makustini Volcano.

A test well drilled near the head of Maluschin valley as part of a state-funded goothermal exploration program produced 195°C water from a depth of 590 m (Republic Geothermal Inc. 1983, 1984, and 1985; Moylka and others, 1988). Bead on the producitivity of the test well, the resource as thought to be capable of ineeting the energy needs of nearby Indialests and Dutch Harbor. Battle Mountain: Gold Company purchased mach of the land at the head of Makeushin valley from the Ounelestika. Native Corporation and leased the goothermal resource to DESI Power Corporation (Pormet) Ormet Energy, Inc.). OESI has audimited plans to be Alexia Energy, Inc.). OESI has audimited plans to be Alexia Energy, Inc.). Alexia the fact of the Alexia Energy and the Power Corporation of a 12-MV base load goothermal goover plant, if developed, Matushin Valley will be the fact site in Alexia to issue goothermal energy for electric-power production. A synopsis of some thermal zones that comprise to the Maushin goldman across that

Shishaidin is a post-glacial stratovolcane composed predominantly of besaltid flows (Fourselle, 1990). Explosive activity generated lahars from the summit crater in 1975. Mud flows and more explosive activity continued intermittently, mill 1981 (Simkin and others, 1981). Ash was ejected during the most recent eruption (1987).

7. MAKUSHIN VOLCANO



Lat63°S3°15°N., long 166°S5'00°W., Unelaska 1250 of Quadrangle, sec. 6, T. 73 S., B. 120 W., Seward Meridian Maxushin Vocano is a large, glacier-clad stratovolcano located 27 km west of Unalaska village. Formancia activity in the sush of Unalaska village in the Company of University of Univers

Makushri volcano was built on a platform of late Trainary pyroclassics of the Unaleska Formation and a mid-Pleislocene gasbrio-norite platter (bye and others, 1984; Queen, 1989). The volcano consists of beast to deside flows and pyroclasto rocks (hye, 1990). Most of Makushin Volcano formed in late Pleislocene time; the small surfucial formation and the properties of the profrom 4280 to 7950 yr B P. The most recent activity was a small phreatic beptime eruption in 1987. combined tow or 225 pm, senerge in two stateows cooks in genty sloping alluvial cover on the southwest side of a broad, southeast-transling stacistic valley. The springs are located near the end of the Alaska Peninsula, 1 km inland from Hot Springs Bay and 16 m northeast of False Pess Vallege on Unimak teams. Lands containing the springs have been selected by the False Pess Nathe Corporation under terms of the Alaska Native Land Claims Settlement Act. An essement visits for a trail from Hot Springs Bay to the springs and land around the springs is reserved for public use.

Although the area is unmapped bedrock near the apring site is probably composed of Otastemany volcanic flows, including basalts, antiestes, and pyroclaetics (Burk. 1965). Outcopps on the indige above the spring are weathered and elightly chloritized andestric flows. No active volcances is near the zonion.

> holocrysta mapped b Egg Islan Tertiary b

OCB

8. LOWER GLACIER VALLEY



List 3'49'04" N. Jinog 168''54'26" W. Jinaiseki 1250 000 Caudangje, see. 18' T. 73 S. R. 120 W. Seward Meridian. Sulfate-ron chloride sorings with low discharge and moderate temperatures (20" ke 10'C) are found in three areas of middle to love Glacier Valley. Glaciar Valley is a 10 km long. 3 k 4 km wide. U-hapeged valley that trends northeas and heads on Makushin Volcans. Springs emergine and under the service through the service through the service through through the

The lower part of Siscer Valley contains debit flows, glacial diff, slatvium, and collavorum and is undertain by the Unalaska Formation, a this sequence of coarse to the sedimentary an eyroclastic rocks. The northernmost spring lee near the contact between a gebitor-horite pluton and the Unalaska Formation (Mortyka, Moorman, and Pereda 1983). Nearry Palusain Care has been active since the last Molocome gesication.



* Maps of Geothermal Resources of the Aleutian Arc, Alaska, Motyka, Liss, Nye, and Moorman, ADGGS, part of Professional Report 114.