ALASKA ENERGY AUTHORITY

Alaska Geothermal Development : A plan

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* The order in which these projects appear is subject to change.

** The Pilgrim Hot Springs project could become a higher priority if the 60-mile transmission line to Nome became less prohibitively costly (see p. 21)

Problem statement

The Problem: Development of the most economic geothermal resources in Alaska for the benefit of its residents.

In 2007, power generation in rural Alaska is largely by diesel gensets. The cost of electric power in rural Alaska is among the highest in the United States. In many communities, this is unsustainable, especially as the costs of fossil fuels increase.

Despite the proven existence of high-potential reservoirs, geothermal resources in Alaska remain largely unexploited. Recent technological advances have opened up many opportunities to use Alaska's lower-temperature resources, which were previously not considered economic for power generation. For example, Chena Hot Springs installed the first geothermal power plant in Alaska in 2006. It uses the lowest temperature geothermal resource ever tapped for power generation in the world. Chena Hot Springs is one of over 30 hot springs in the Central Alaska Hot Springs Belt (CAHSB). Concerns about climate change and the likelihood of carbon taxes on fossil fuel use make geothermal energy an even more attractive option. Unfortunately, prospective geothermal projects also face significant challenges: the distance between resources and users, the high cost of exploration, and the high capital cost of development, to name a few. The uncertainty regarding future fossil fuel prices and carbon taxes adds to the challenge. To assist in focusing on the geothermal prospects with potential to deliver the most benefits to Alaskans, the Alaska Energy Authority (AEA) offers below a list of 14 projects. This list was assembled from available data and could change based on future exploration.

Introduction: geothermal energy

Geothermal energy, which is earth-heat energy, exists in large amounts deep in earth's crust. It also exists at shallow levels in the crust at some locations: typically, though not always, in areas of active volcanism. Geothermal energy is used in many countries around the world for power generation. It is also used for non-electric applications such as direct use of the thermal energy for heating. Spent fluids from power plants may also be used for direct use (See: http://www.eere.energy.gov/geothermal/).

Geothermal Energy from Hydrothermal Systems

Geothermal heat is usually exploited for energy via hydrothermal systems. In hydrothermal systems, heat is transferred by convection to the earth's surface via circulating groundwater. Hydrothermal systems contain hot fluid or vapor or both, depending on pressure and temperature conditions. They have three components: 1) a heat source 2) circulating groundwater, and 3) a 'plumbing system' of vertical permeability enabling convection of groundwater around the heat source. The heat source can be shallow (magma) or deep (3-4 km or greater).

Geothermal power plants use one of three technologies to generate electricity from hydrothermal fluids: (1) dry steam, (2) flash, and (3) binary cycle systems. In ***dry steam*** plants, hydrothermal vapor is tapped and routed directly through turbine/generator units to produce electricity. ***Flash steam*** plants use hydrothermal fluid at temperatures greater than 182 °C that is delivered under high pressure to the surface. The fluid is then depressurized, causing some of it to flash to steam, which then drives turbines/generators.

Most geothermal areas, however, contain water below 182 °C. These fluids must be run through the ***binary-cycle***, where hydrothermal fluid and a secondary ("binary") fluid pass through a heat exchanger, causing the binary fluid to vaporize, which then drives a turbine. The temperature requirements for binary systems depend on site characteristics (available condensing temperature, volume of geothermal fluid, etc.). The binary system at Chena Hot Springs uses geothermal fluid at ~80°C.

Geothermal Energy from Non-Hydrothermal Sources

Enhanced Geothermal Systems (EGS), also known as Hot Dry Rock (HDR), or petrothermal resources, is a concept that was developed by Los Alamos National Laboratory in the 1970's. The idea is to tap into earth's abundant geothermal energy without utilizing less-abundant hydrothermal resources. This requires 1) engineering a fractured reservoir into a high-heat flow region by down-hole explosive devices; 2) injecting water into the engineered reservoir; 3) pumping hot water and/or steam to a power plant and reinjecting spent fluids. There are few EGS systems in production in the world: some examples are Cooper basin (Australia) and Soultze basin (France).

Geopressurized systems do not use steam. Instead, hot brine (minimum 350 °F) trapped in deep subsurface formations is pumped to the surface and used to power hydraulic turbines. Since the brine is not circulating in the subsurface, these systems are more akin to oil deposits than circulating hydrothermal fluids – that is, the brine is a finite resource (non-renewable because there is no recharge of groundwater). Using geopressured fluids for geothermal power is perhaps most appropriate in the case of abandoned oil wells, where deep holes have already been drilled.

Sustainable Geothermal Energy Production

The sustainability of a geothermal resource is dependent on the energy recharge rate. If recharge occurs at the same rate as production from the resource, the resource is renewable (Barbier, 2002). Hydrothermal systems require recharge in terms of both water and heat. In geothermal power plants, spent fluid is typically reinjected into the system to "recharge" the system with water, thereby keeping the resource "renewable." Production declines in geothermal fields, such as at the Geysers (California) and Larderello (Italy) have been attributed to overproduction and/or improper re-injection (Stefansson, 2000). Non-hydrothermal geothermal sources, by contrast, should be considered non-renewable because recharge of heat and water do not occur at the same rate as production.

Geothermal energy in Alaska

Background and Previous Work

Alaska's geologic setting is highly favorable for the existence of exploitable hydrothermal energy. There are over 100 known hot springs in the state (NGC, 1980). Most exploratory geothermal work in Alaska occurred during the period 1970-1985. During this period, Alaska's Division of Geological and Geophysical Surveys (ADGGS) of the Department of Natural Resources catalogued and sampled all known surface expressions of geothermal systems in the state. Preliminary exploration work was conducted in Southeast Alaska, the Seward Peninsula, and the Aleutian arc. Preliminary exploration studies were started for Interior Alaska but never completed.

Geothermal Resources of Alaska: An Overview

The ***Aleutian Volcanic Arc***, which includes the Aleutian Islands as well as volcanoes on Alaska Peninsula and W. Cook Inlet, is Alaska's most promising setting for geothermal energy. However, most geothermal sites in the Aleutians are too remote from population centers to be economically viable. 56 geothermal systems have been identified in the Aleutian arc; many more likely exist but remain unknown due to poor surface expression (Motyka et al, 1993). The bulk of geothermal exploration in the Aleutian Arc occurred at 3 sites: Mt. Adagdak, Mt. Makushin (Unalaska Island), and Akutan Island. Mt. Makushin is the only site that has been drilled. Temperatures close to 200 °C were discovered at ~400 m depth.

Central Alaska Hot Springs Belt (CAHSB). Though the CAHSB spans numerous geologic provinces, thermal springs in the CAHSB are remarkably similar. They all have temperatures between 30 and 88 °C (average ~55 °C) of alkali-chloride type waters (Miller et al, 1973). Most of the sites lie within discontinuous permafrost, occurring as elongate zones of springs and seeps. The local geology of most CAHSB sites is poorly defined. Due to lack of data, the heat source driving the geothermal activity has not been established. They are probably fault-related and may also be related to radioactive heating by nearby plutons. While none of the Interior CAHSB hot springs show any relation to recent volcanism, the extreme western part of Alaska may be an active rift zone with abnormally high crustal heat flow and the possible presence of shallow magma.

The ***Wrangell Volcanic Cluster*** is another potential geothermal resource in Alaska. There are few thermal springs associated with the Wrangell volcanic complex, and only Mt. Wrangell itself has an active thermal area. The Eastern Copper River Basin (ECRB), close to the western part of the Wrangell volcanoes, has been the subject of geothermal exploration because it contains mud volcanoes, unusual features associated with pressurized groundwater and/or hydrothermal aquifers (Wescott and Turner, 1983).

Alaska Panhandle. Most of the geothermal activity in Southeast Alaska is thought to originate from circulation of meteoric waters through deep-seated fracture and fault systems (Motyka et al, 1980). However, there has been no geothermal exploration at most of the sites in the panhandle with the exception of temperature and geochemical surveys of spring waters. Minor, isolated episodes of recent volcanism occur near Mt. Edgecumbe and at small vents on Revillagigedo Island. These areas have not been explored for geothermal potential due to the lack of surface manifestations.

Resource Capacity of Alaskan Geothermal Systems

The capacity of a geothermal resource, whether in terms of electrical or heat energy, depends on regional heat flow, vertical permeability (faulting/fracturing of geothermal host rock), and the recharge rate of both heat and water. None of these parameters are known for the bulk of Alaska's geothermal sites. Based on analogous systems in the Pacific Ring of Fire, geothermal systems near Alaskan volcanoes are probably capable of generating up to 150 MW of electricity. The geothermal potential of most of Alaska's non-volcanic geothermal areas is unknown. This lack of geologic information has precluded any real possibility of estimating resource capacity (Miller et al, 1975; Economides et al, 1982). Hence, further exploration work is necessary in order to assess the capacity of all but a few of Alaska's geothermal resources.

Geothermal development costs in Alaska*

Resource Evaluation	
Land costs (exploration leases)	$3 / acre + bid
Roads and access	$500,000-$1,000,000 / mile
Prospecting & field analysis	$100-$200 / kW (Hanse 2005)
Shallow gradient hole drilling	$0.8-2 M / well (GeothermEx, 2004)
Exploration drilling (success rate 20-25%)	$0.8-2 M / well (GeothermEx, 2004)
Well testing	$70,000-100,000 / well (GeothermEx, 2004)
Resource confirmation and development	
Confirmation drilling (success rate 80%)	$0.8-2 M / well (GeothermEx, 2004)
Administration	7.5 % total confirmation costs (GeothermEx, 2004)
Production and Transmission	
Drilling production & injection wells	$2 M / well (GeothermEx, 2004)
Physical plant	$350-$500 / sq. ft (Dilley, 2007)
Turbines / generators	$1300 -$6000 / kW (Holdmann, 2006; USGS, 2007)
Shipping	$50 / kW (Holdmann, 2006)
Gathering system (pipes, pumps)	$250 / kW (Hanse 2005)
Transmission line	$500-$750,000 / mi (Dilley, 2007)
Access Roads	$500,000-$1,000,000 / mile

Prospecting and field analysis includes:

- Geochemical surveys (gas, water, soil and rock) and isotope studies
- Chemical geothermometry using water composition data
- Temperature-gradient drilling (shallow, slimhole wells) and heat flow surveys
- Geologic logging of shallow boreholes
- Geologic cross section or subsurface modeling using supplementary geologic and geophysical data (gravity, seismic, etc.; note that this data is often lacking in AK)
- Hydrologic studies
- Geophysical surveys to locate fluid and fluid pathways
- Remote sensing surveys (satellite or aerial imagery)

Criteria used to prioritize Alaskan geothermal projects

1. Population size and other beneficiaries
2. Generation system (load size, operator, etc.)
3. Geothermal resource factors
4. Distance between resource and load
5. Land ownership
6. Fuel costs
7. "Project champion"
8. Anticipated future changes to the community

*All costs reported in 2007 dollars.

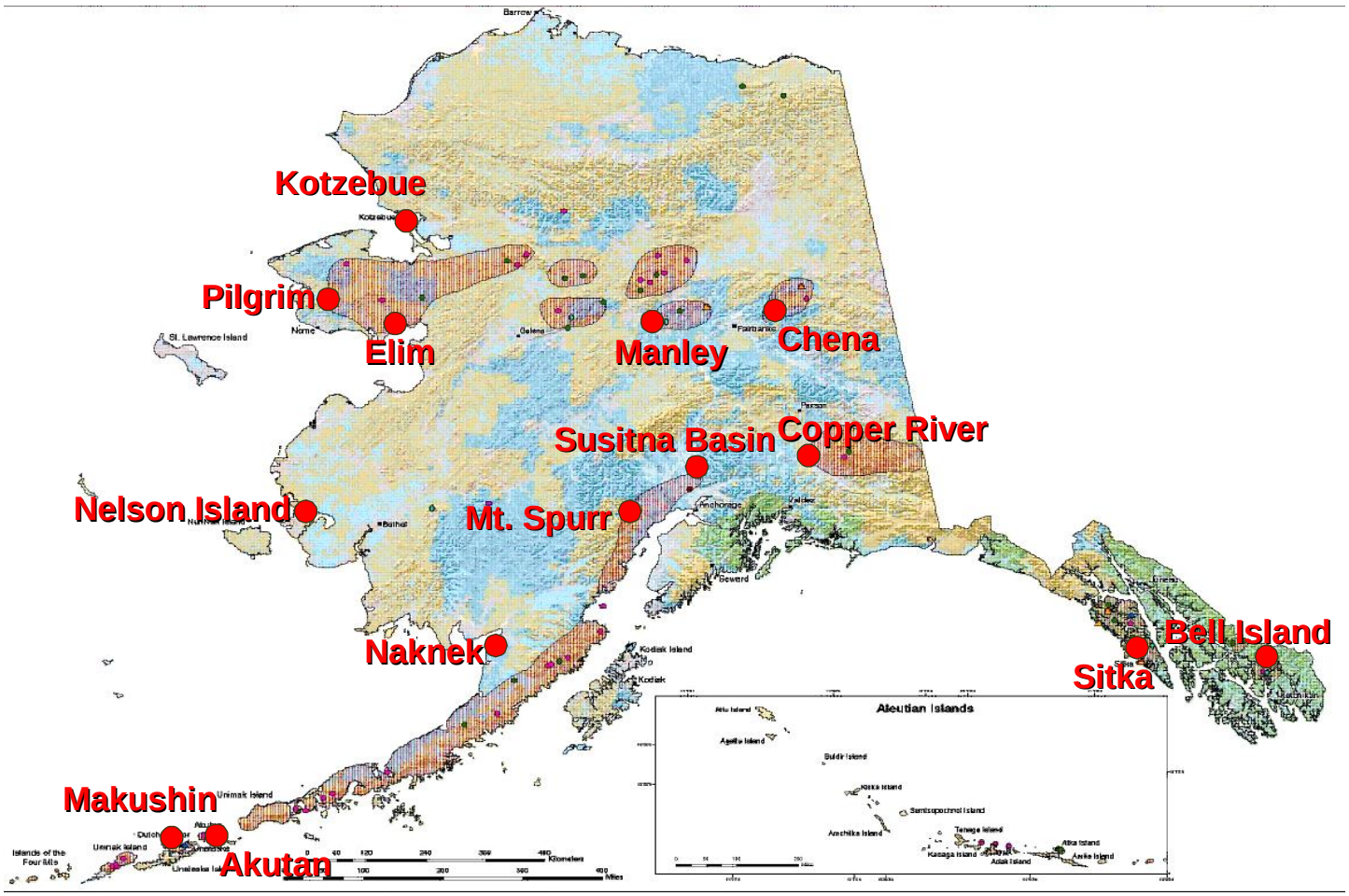

Figure 1. Location map for geothermal projects described in this report. Sites overlaid on the Geothermal Resources Map of Alaska, (NOAA, 1983).

Priority # 1: Geothermal exploration and resource confirmation at Mt. Spurr

Beneficiaries: *Railbelt grid (power), Native Village of Tyonek (heating)*
Population size: *Railbelt grid: 400,000*
Generation system: *Railbelt grid: 1.1GW capacity, 450MW average load*
Geothermal resource factors: *Resource potential unknown, 20-200 MW possible*
Distance between resource and load:~*30 miles (Beluga plant, Chugach Electric Assn.)*
Land ownership: *State of AK, BLM, some private ownership*
Fuel costs: *Railbelt grid ($0.06-0.07/kWh)*
"Project champion": *Alaska Energy Authority*
Anticipated future changes to the community: *Declining Cook Inlet gas reserves, increasing Railbelt load, possible utility management structure changes*

Background and Previous Work

Mt. Spurr, ~80 miles west of Anchorage, is an active volcano with several recent eruptions; however, the geothermal potential Mt. Spurr is unknown. Mt. Spurr is located approximately 30 miles from Chugach Electric Association's Beluga generation plant and transmission lines that are part of the Railbelt electrical grid that runs from the Kenai Peninsula to Fairbanks. Mt. Spurr was preliminarily explored for geothermal in the 1980's. Those studies found overlapping geochemical and geophysical anomalies on the south and southeast flank of the volcano that could be interpreted as evidence of a hydrothermal system, but alternatively they could represent other geologic phenomena such as an extensive subsurface ash deposit or clay layer (Turner and Wescott, 2004). Additional exploration is needed to determine if there is a resource at Mt. Spurr, and the nature of that resource if it exists.

A geothermal lease sale was conducted for the Mt. Spurr area in 1980. The lease was sold to the sole bidder and no exploration was ever conducted on the leased land. In 2007, as a result of a negotiations initiated by one of the nation's leading geothermal developers, the state requested applications for a proposed lease in the Mt. Spurr area. At least two applications were submitted for each of the 15 tracts, so a competitive lease sale must be held. This sale is scheduled for February 2008. In August 2007, the Alaska Energy Authority sponsored the Mt. Spurr Geothermal Workshop for Railbelt electrical utilities, developers, and other stakeholders to talk about issues related to geothermal development at Mt. Spurr. Additional goals were 1) to spread the word about the lease sale; 2) to facilitate partnership between developers and utilities; 3) to discuss other energy prospects in West Cook Inlet and facilitate partnership. Over 70 people attended, with representatives from all but one of the major Railbelt utilities. One outcome of the conference was the widespread recognition that the leasing process is not conducive to its intended goal of geothermal exploration (see p. 19).

Future work priorities

The top priority for the Mt. Spurr prospect is a continuation of the exploration efforts that were initiated in the 1980's, and confirmation of a geothermal resource. Hence, the geothermal leases to be issued in February 2008 must be written to facilitate these goals. Specifically, the lease terms should (1) provide incentives for exploration; (2) require that exploration results are made available to the public during or after the lease term; (3) require development of the resource if it is found. The risk is that a leaseholder may "sit on" the lease for years, with no benefit to the state (see p. 19).

Priority # 2: Geothermal drilling on Unalaska Island

Beneficiaries: *City of Unalaska, Dutch Harbor,*
Population size: *3,940*
Generation system: *7.97 MW (Unalaska Electric Utility) and numerous fish processors*
Geothermal resource factors: *Up to 200 MW possible*
Distance between resource and load: *14 miles from Mt. Makushin to the electrical grid*
Land ownership: *Ounalashka Corporation*
Fuel costs: *$0.29/kWh*
"Project champion": *City Government*
Anticipated future changes to the community: *Unknown*

Background and previous work

The U.S. Department of Energy discovered a 390-degree-Fahrenheit geothermal water source on the flank of Makushin Volcano in 1982. A power production project has been proposed at the Makushin geothermal area at least a half a dozen times since the early 1980's. Most recently, in 2005 Iceland America Energy, a subsidiary of Enex Corp., acquired geothermal rights on the slopes of the volcano and proposed a 50-megawatt power station, coupled with a heat exchanger that would enable hot fresh water to be pumped to town to heat buildings. Iceland America has since withdrawn from the project, but the city of Unalaska has expressed renewed interest in the Unalaska geothermal site.

Future work priorities

The City of Unalaska is now investigating the feasibility of two different scenarios: 1) a geothermal power plant on the flank of the volcano or 2) a power plant in the valley floor next to the volcano. City Manager Chris Hladick is working with consultant Mike Hubbard and with the California-based exploration company Geothermex, Inc. This consortium is planning to drill shallow exploratory temperature gradient wells in the valley floor (4-6 slim-hole wells up to 1,000-foot depth). This is contingent upon funding, estimated at $3M. In summer 2007, AEA facilitated a dialog between Mr. Hladick and Beth Maclean of BLM about cost-sharing BLM's drill rig for geothermal exploration on Unalaska.

Priority # 3: Geothermal exploration/confirmation at Akutan Volcano

Beneficiaries: *City of Akutan, Trident Seafood*
Population size: *741*
Generation system: *300 kW capacity diesel (Akutan Electric), Trident Seafood Plant*
Geothermal resource factors: *Resource potential unknown, up to 200 MWe possible?*
Distance between resource and load: *Unknown*
Land ownership: *Akutan Corporation, privately leased*
Fuel costs: *$0.32/kWh*
"Project champion": *City of Akutan*
Anticipated future changes to the community: *Unknown*

Background and previous work

The City of Akutan currently has two power generation facilities; a diesel facility (150 kW) and a facility that contains a 105 kW hydro plant with a 125 kW diesel generator. Both power plant facilities feed Akutan's power distribution grid. The average power generation year-round in 2006 was 46 kW. Trident Seafoods, a large processor on the island, currently generates its own power via diesel but the company has expressed interest in purchasing power in the future from Akutan Electric Company.

Akutan volcano is an active volcano with 32 historic eruptions. Several thermal springs and a small fumarole field are located in Hot Springs Bay valley, which lies 4 km northwest of Akutan Harbor, ~8 km from Akutan village. The fumarole field lies between the volcano's summit and Hot Springs Bay valley. Temperatures of the hot springs range from 40-84°C, and fumarole temperatures as high as 99 °C have been measured Geothermal exploration was conducted at Akutan in the mid-1980's (Motyka and Nye, 1988). These studies suggested that a deep reservoir could extend more than 4 km

beneath the geothermal area (Motyka & Nye, 1988). It is likely that the fumaroles are fed directly by gases and steam boiling off the deep hot reservoir and that these fluids then mix with cool meteoric waters to produce the hot springs waters further down the valley. Chemical geothermometry gives estimated reservoir temperatures between 180º to 200 ºC

Future work priorities

The next logical step is confirmation of the resource at Akutan by shallow exploration drilling and deep geophysical surveys. These studies are necessary to both define the capacity of the geothermal resource at Akutan and to help locate production wells. It is also necessary to gather together the stakeholders (Trident Seafoods, Aleut Regional Native Corporation / Aleutians East Borough, Akutan Village Corporation, Native Village of Akutan, City of Akutan, and private leaseholders) to plan project development. Depending on the temperature and pressure of the geothermal fluid encountered, hydrothermal fluids on Akutan Island could be developed for power generation using either a binary ORC (Organic Rankine Cycle) turbine similar to the one at Chena Hot Springs or a flash cycle power plant (if temperatures exceed 180 °C). A 10 MW plant size was proposed in 1994 based on existing information about the resource potential and projected energy demand for Akutan. This output could be escalated incrementally to 40 MW or more depending on demand.

Priority # 4: Feasibility study for Manley Hot Springs

Beneficiaries: *City of Manley, Bean Ridge Native Corporation*
Population size: *78-125*
Generation system: *480 kW capacity diesel (Manley Utility Co.); Ave.= 28kW (fy06)*
Geothermal resource factors: *Chena-type (400 kW) or larger*
Distance between resource and load: *Unknown*
Land ownership: *Some privately owned; Bean Ridge Native Corporation*
Fuel costs: *$0.25/kWh*
"Project champion": *Manley city council*
Anticipated future changes to the community: *Decreasing population; loss of school?*

Background and Previous Work

AEA applied for technical assistance from the US Department of Energy's GeoPowering the West (GPW) Initiative and the National Renewable Energy Laboratory (NREL) to conduct a feasibility study of geothermal project opportunities for Manley. Millennium Energy LLC, a renewable energy consulting firm, was tasked to investigate the potential of geothermal development at Manley Hot Springs, including the following applications: district heating, greenhouse heating, lodge or resort development, swimming pool development, community cold storage, and/or power production. The first step in this investigation was to conduct a scoping study to determine whether all of the aforementioned applications should be looked at in a cursory, qualitative manner -- or if conducting a detailed technical and economic feasibility study on the most likely application would be the best course of action. This study was completed in spring 2007.

Future work priorities

The scoping study identified 5 potential geothermal projects at Manley: power production, district heating, greenhouse and/or resort development, and cold storage. The community of Manley was informed that the next step is an economic feasibility study for those 5 projects. The community approved the feasibility study; however, the DOE funding for the study was cut and it has not been done. This study should be completed. Furthermore, a feasibility study for Manley would be a useful template to apply to other remote communities near hot springs in Central, Western, and Southeast Alaska.

Priority #5: Deep drilling at Chena Hot Springs

Beneficiaries: *All CAHSB prospects; Chena Hot Springs resort*
Population size: *300*
Generation system: *400 kW capacity geothermal generation (Chena Power – private)*
Resource factors: *Currently producing low-temperature fluid; hotter fluid expected at depth.*
Distance between resource and load: *none*
Land ownership: *Privately owned*
Fuel costs: *(diesel) $0.30/kWh (no PCE)*
"Project champions": *Resort proprietor*
Anticipated future changes to the community: *Resort expansion; possible transmission to Fairbanks if sufficient output is attained*

Background and Previous Work

The Chena Hot Springs (CHS) geothermal power plant project has been hailed as a success in terms of local, renewable energy usage. As a result, many geothermal projects are springing up to follow suit all across the Central Alaska Hot Springs Belt (CAHSB), and the resort at CHS plans to expand its production of geothermal energy by as much as 500%. These are exciting but ambitious prospects considering the limited understanding of the CAHSB resource.

CHS is located in the eastern part of the CAHSB. An extensive study of the *shallow* hydrologic system at CHS was carried out 2005-2006 out as part of a D.O.E.-funded Geothermal Resource Evaluation and Definitions program (GRED III). Geologic mapping, geochemistry, airborne and ground-based geophysics, hydrology, reservoir engineering, remote sensing, and thermal gradient studies were all conducted as part of the GRED III study. A total of 16 shallow (< 400 m) wells have been drilled in the area, 11 as part of the GRED III project. This study was conducted concurrently with installation of the power plant at CHS. Results of those studies have recently been published (see Erkan et al, 2007 and Kolker et al, 2007).

Future work priorities

Future work is necessary to determine a general resource capacity for CAHSB geothermal systems based on a generalized resource model and incorporating recent technological advances in utilizing low-temperature resources. The model would have to include, among other things: 1) a heat transfer mechanism; 2) fluid pathways; 3) recharge rates of heat and water.

The hot springs in the CASHB most likely reflect a mixture of thermal fluids and cold groundwater (Miller et al, 1973; Kolker et al, 2007). At CHS, only shallow wells

have been drilled (max. ~300 m) and thus the deep reservoir fluid – that is, geothermal fluid uncontaminated by groundwater infiltration – has still not been encountered. A deep well (1000 m or deeper) was planned for summer 2007, but this was cancelled due to budget cuts in the USDOE's geothermal program. Since Chena Hot Springs represents one of 30+ hot springs that have potential to power communities in Alaska, a deep well is of utmost importance in terms of characterizing the geothermal resource.

Priority # 6: Geothermal exploration in Southern Seward Peninsula area

Beneficiaries: *Village(s) of Elim and/or Golovin, White Mountain, Koyuk*
Population size: *Elim: 294; Golovin: 154; White Mountain: 224; Koyuk: 368*
Generation system: *Elim: 721 kW capacity diesel [Alaska Village Electric Cooperative(AVEC)]; White Mountain: 745 kW capacity diesel (White Mountain Utilities); Koyuk: 771 kW capacity diesel (AVEC)*
Geothermal resource factors: *Chena-type (400 kW or greater)*
Distance between resource and load: *Various*
Land ownership: *Various*
Fuel costs: *approximately $0.25-0.30/kWh*
"Project champion": *City of Elim*
Anticipated future changes to the community: *Unknown*

Background and Previous Work

There are 4 hot springs clustered in the Southern part of the Seward peninsula, relatively close to several communities. These hot springs are: Elim ("Kwiniuk"), 105 °F; Clear Creek, 145 °F; White Mtn., 120 °F; and Battleship Mtn. 66°F. None of the springs have been explored for geothermal potential beyond basic temperature and chemistry surveys. Elim Hot Springs was visited in a reconnaissance trip by Gerry Huttrer of Geothermal Management Company, Inc. in 2002, who gave the following report:

> Unfortunately, this spring is too cool, too small and too remote to be of any use to the residents of Elim except for balneology. Some exploration could be conducted to seek more fracture systems, but $250,000 could easily be spent on geoscientific studies without finding more evidence of a hotter resource. Drilling, should it be considered, would cost a great deal as a helicopter, at $650/hr., would be required to get a rig in place. Accordingly, further consideration of geothermal development at Kwiniuk springs is not recommended.

Future work priorities

Because Mr. Huttrer did not assess any of the other hot springs in the area with hotter water, and because his visit preceeded the geothermal development at Chena Hot Springs, his assessment deserves a fresh look. The four hot springs should be individually assessed and one of the four chosen as a potential power site.

Once deep drilling occurs at Chena Hot Springs (priority #5), a general resource capacity for CAHSB geothermal systems will help indicate whether geothermal power and heat production on the Southern Seward peninsula is economically feasible, and where. If it is, a technical feasibility study should be done, similar to the one conducted for Pilgrim hot springs and proposed for Manley.

Priority # 7: Geothermal exploration on Northern Alaska Peninsula

Beneficiaries: *Villages of Naknek, King Salmon, and other nearby communities*
Population size: *Naknek: 577; King Salmon: 409*; *South Naknek: 74*
Generation system: *10.5 MW capacity diesel (Naknek Electric Association)*
Geothermal resource factors: *No known resource; PGRAs ~50 miles away*
Distance between resource and load: *Unknown*
Land ownership: *N/A*
Fuel costs: *$0.25 / kWh*
"Project champion": *Naknek Electric Association*
Anticipated future changes to the community: *Population decline; loss of fishing economy and jobs*

Background and Previous Work

The Northern Alaska Peninsula has many active volcanoes and deep faults. It is therefore a promising area for geothermal exploration. However, there are no known geothermal expressions (e.g., hot springs, fumaroles) within 50 miles of Naknek or King Salmon. The closest known potential geothermal resource area is located at Gas Rocks, over 40 miles from Naknek on the south shore of Becharof lake; but further exploration work would be necessary before this resource is deemed viable for energy use. Other potential geothermal resource areas are given in a report by the author to NEA (Kolker, 2006). Gas rocks and all other potential geothermal resources in Northern Alaska Peninsula lie within federal lands (Becharof National Wildlife Refuge, Katmai National Park and Preserve). Since the Naknek-King Salmon area is located in thick deposits of unconsolidated glacial sediments, subsurface geologic structures (such as faults, fractures, bedrock contacts, etc.) are "buried" and therefore unknown.

The proposed geothermal project at Naknek includes 450 miles of transmission between 24 villages in southwest Alaska, including 24 miles of transmission under Lake Iliamna. The cost has been estimated at $200M.

Future work priorities

At the time of this writing, a memorandum of understanding (MOU) is being drafted between the National Park Service (NPS) and the USDOE to identify potential geothermal areas on NPS lands. June 2007: DOE requested information from AEA about geothermal sites in National Parks and Preserves in Alaska. Since all of the potential geothermal resources near Naknek appear to be within Federal lands, future work for this project should include exploring the possibility of geothermal development on Federal lands to benefit the Naknek-King Salmon region.

Priority #8: Feasibility of economic development at Pilgrim Hot Springs

Beneficiaries: *City of Nome and other Western Seward Peninsula communities.*
Population size: *Nome = 3,540*
Generation: *10 MW capacity diesel*
Geothermal resource factors: *Known resource, likely 1-10 MW output possible*
Distance between resource and load: *Power transmission: ~60 miles*
Land ownership: *Catholic Church*
Fuel costs: *$0.24/kWh*

"Project champion": *Pilgrim Hot Springs Corporation*
Anticipated future changes to the community: *A new gold mine (presently under construction) outside of Nome will add up to 8MW of additional load*

Background and Previous Work

Pilgrim Hot Springs is a Known Geothermal Resource Area located within Mary's Igloo Native tribal lands. A geothermal resource of ~150 °C is presumed to exist at about 5,000 ft. depth, however this was not encountered in any of the 6 wells that were drilled in the area in the 1970's due to poor geologic understanding of the area (Motyka and Moorman, 1980). Through the USDOE GeoPowering the West (GPW) Initiative, AEA conducted a feasibility study of geothermal project opportunities for Pilgrim Hot Springs. The consulting firm HDL Inc. was tasked to prepare a preliminary feasibility study of geothermal power production from Pilgrim Hot Springs and transmission to Nome. The study evaluated the previous scientific studies conducted in the area to assess the feasibility of this proposed development. It was completed in spring 2007. The study showed that the transmission ~60 miles to the city of Nome would cost up to $45 million, dwarfing even the high drilling costs and making the project economically unfeasible.

Future work priorities

Unless something changes with respect to the cost of transmitting geothermal power to users (see p. 20), power transmission to Nome appears to be prohibitively costly (Dilley et al, 2006). However, further and more detailed analysis of the idea of exporting geothermal power from Pilgrim over an intertie should be conducted. The State should also consider conducting a feasibility study of creating economic opportunity for Mary's Igloo tribe and other regional residents in the form of agriculture and other development based on geothermal heat and power. This could be a stepping stone to power generation for a mine or for Nome.

Priority # 9: Geothermal exploration at Goddard Hot Springs and Mt. Edgecumbe

Beneficiaries: *City of Sitka*
Population size: *8,893*
Generation: *34.84 MW capacity hydro with diesel backup (Sitka Electric Department)*
Geothermal resource factors: *Goddard: Chena-type (400 kW or more); If resource exists at Mt. Edgecumbe it should be high-grade (up to 200 MW power)*
Distance between resource and load: *Sitka–Goddard: 15 miles; Sitka–Mt. Edgecumbe ~10 miles (across Sitka Sound)*
Land ownership: *Goddard owned by city of Sitka*
Fuel costs: *$ 0 – 0.25 /kWh depending on energy source (hydro or diesel)*
"Project champions": *City of Sitka*
Anticipated future changes to the community: "*The city needs to increase its electrical generation capacity and the… proposals currently being explored are presenting huge licensing and financial challenges." –Kerry Maclane, community development consultant*

Background and Previous Work

Mt. Edgecumbe volcano is one of the few active volcanoes in Southeast Alaska but has not been active in historic time (Wood and Kienle, 1990). The volcano is located

~10 miles west of Sitka, across Sitka Sound. There are no known hot springs or fumaroles on or near the volcano. Because of this lack of surface expression, there has been no geothermal exploration at Mt. Edgecumbe volcano.

Most of the geothermal activity in SE Alaska is thought to originate from circulation of meteoric waters through deep-seated fracture and fault systems (Motyka et al, 1980) as opposed to volcanic origins. Goddard Hot Springs is one such system, located approximately 15 miles south of Sitka. The hot springs are owned by the city of Sitka. Goddard is one of the hottest springs in Southeast Alaska, but the shallow hydrothermal system is thought to be of limited extent. Limited geothermal exploration was conducted at Goddard in the early 1980's (Economides et al, 1982).

Future work priorities

The City of Sitka has expressed interest in exploring the resource potential of nearby geothermal sites, and there is strong support from members of the Assembly for such a project. The community is interested in power as well as cascaded uses of geothermal such as chilling (for seafood processing) and heating (buildings and greenhouses). Goddard Hot Springs appears to be suitable for binary power production similar to Chena Hot Springs – but Mt. Edgecumbe could be better. Initial exploration efforts should focus on producing data that would facilitate choosing between the two sites. More standard exploration work would follow.

Priority # 10: Exploration at Bell Island Hot Springs

Beneficiaries: *Proposed Swann-Tyee Intertie; Bell Island resort*
Population size: *N/A*
Generation: *N/A*
Geothermal resource factors: *Chena-type (400 kW) or greater if resource is drilled*
Distance between resource and load: *The Swann-Tyee Intertie crosses ~3 miles from the hot springs; however, it might be possible to produce power from closer to the intertie.*
Land ownership: *private*
Fuel costs: *N/A*
"Project champion": *Alaska Energy Authority*
Anticipated future changes to the community: *N/A*

Background and Previous Work

Bell Island contains some of the highest temperature hot springs in Southeast Alaska (only nearby Bailey Bay is hotter). There are six hot springs sites on Bell Island. The temperatures range from 67-74 °C and are presently used to heat a lodge and several cabins of the Bell Island fishing resort. Chemical geothermometry gives reservoir temperature estimates between 134-142 °C, which is suitable for binary power production. An estimate of thermal energy is reported as 1.06 10^{18}J and the convective heat discharge at the surface is 0.50 MW (Motyka and Moorman, 1987).

Future work priorities

Bell Island is of interest because it is within 3 miles of the right of way for a proposed intertie between Swann Lake and Tyee Lake hydroelectric projects. Very little

geothermal exploration work has been conducted at the site. Geothermal exploration should begin by constraining the lateral extent of the geothermal reservoir and whether it would be possible to produce power for the intertie with a minimum of transmission.

Priority # 11: Drilling for district heating purposes at Kotzebue

Beneficiaries: *City of Kotzebue*
Population size: *3,104*
Generation: *20.39 MW capacity diesel (Kotzebue Electric Association)*
Geothermal resource factors: *Resource unknown*
Distance between resource and load: *Unknown*
Land ownership: *Unknown*
Fuel costs: *$0.32 / kWh*
"Project champion": *City of Kotzebue*
Anticipated future changes to the community: *Community wishes to establish "pilot" renewable energy projects to serve as demonstrations to other villages in region*

Background and Previous Work

The city of Kotzebue and Kotzebue Electric Association staff has been actively collaborating with local, state, and federal agencies to encourage project development. They have collected available geologic information (seismic, gravity, and other information) and submitted two separate grants to USDOE for funding.

A geothermal district heating system in Kotzebue was studied in the 1980's. That study explained that the proposed Kotzebue geothermal project "does not involve geothermal systems and geothermal wells as they are normally considered in geothermal exploration. That is… fault and fracture systems, influx of meteoric waters into the system, and resultant hot waters … are not involved. Rather, this geothermal system must rely on large volumes of warm water that can be produced from a sedimentary basin where the original formation waters are trapped." (ESI, 1981b).

There is an oral tradition that claims that hot fluid was once encountered at 300 ft depth beneath the city of Kotzebue. The water was reportedly found during foundation work for a hospital (?) in the 1950's. In direct contradiction to this rumor, AEA reports mention that the Kotzebue region sits atop approximately 1000 feet of permafrost. This author was unable to find any driller's logs from the Kotzebue area to sort out the mutually contradictory claims, and the source of the rumor remains mysterious.

Future work priorities

The next step in the proposed Kotzebue geothermal district heating project should be to verify the rumored hot water beneath the city of Kotzebue by shallow drilling. If that is verified, future work should focus on the following questions: (1) How thick is the permafrost beneath Kotzebue? What is the relationship between permafrost and thermal waters? How would circulation of heat below Kotzebue affect the permafrost? (2) If warm water is extracted from subsurface formations, subsidence at the surface could be a real danger as Kotzebue is less than 10 feet above sea level. How would the engineering of the system prevent this from happening?

The city of Kotzebue plans to complete the exploratory phase in summer 2008. This includes drilling a 2,300 ft bore hole using a BLM drill rig (the availability is not

yet confirmed). In winter 2008, the project design phase will be implemented. The type of project (UTC turbine for electricity generation or a district heating system) and its design will depend on the volume and temperature of available fluids. Construction is slated to begin summer 2009.

Priority # 12: Geothermal exploration at proposed relocation sites

Beneficiaries: *Newtok, Shishmaref*
Population size: *Newtok: 323; Shishmaref: 615*
Generation: *Newtok: 265 kW capacity diesel (Unqusrag Power Company); Shishmaref: 971 kW capacity diesel (AVEC)*
Geothermal resource factors: *Newtok: resource unknown; Shishmaref: resource in Bering Strait National Preserve*
Distance between resource and load: *N/A*
Land ownership: *N/A*
Fuel costs: *Newtok: $0.64/kWh; Shishmaref: $0.47/kWh;*
"Project champion": *Denali Commission (Newtok)*
Anticipated future changes to the community: *The villages of Newtok and Shishmaref must be relocated due to catastrophic erosion at the present village site. Relocating to a site with a renewable energy source would be favorable.*

Background and Previous Work

The northern part of Nelson Island has been proposed as a potential relocation site for the village of Newtok. There has been no geothermal exploration at the site, and there is no surface manifestation of a geothermal resource. However, its geologic setting could be favorable for the development of a "blind" geothermal system capable of producing heat and/or power for a village site.

Serpentine Hot Springs, approximately 40 miles from Shishmaref, is one of the hottest springs in Western Alaska, suggesting that the area may have significant geothermal potential. It could also be an potential relocation site for the village of Shishmaref, since the villagers have cultural ties with the area. However, the hot springs are located within the boundaries of the Bering Land Bridge National Preserve, so the National Park Service must support the project before any assessments can be made about the feasibility of geothermal heat and/or power production.

Future work priorities

The Newtok (Nelson Island) and Shishmaref (Serpentine Hot Springs) prospects are in the initial stages of discussion. For Newtok, subsurface data from Nelson Island will have to be obtained before an exploration plan can be initiated. This data will be available through the US Army Corps of Engineers by early 2008. For Shishmaref, the first step as of 2007 would be to discuss the scenario with the community and get their feedback. The second step would be to work with the National Park Service to consider either a land swap or some other arrangement.

Priority # 13: Geothermal exploration in the Susitna Basin

Beneficiaries: *Willow and Wasilla (heating); Railbelt grid (power)*
Population size: *Willow: 1,973 Wasilla: 6,775; Railbelt grid: 400,000*

Generation system: *Railbelt grid: 1.1GW capacity, 450MW average load*
Geothermal resource factors: *Resource potential unknown*
Distance between resource and load: *Willow-possibly within a few miles of resource.*
Land ownership: *unknown*
Fuel costs: *Railbelt grid= $0 – 0.25/kWh depending on energy source (hydro, gas, diesel, naptha, coal)*
"Project champion": *None*
Anticipated future changes to the community: *Declining Cook Inlet gas reserves, increasing Railbelt load, future network changes*

Background and Previous Work

The Susitna Basin is a sedimentary basin ~60 km northwest of Anchorage. There are no known volcanic centers in the region, but the area is cut through by the Castle Mountain fault, a large-scale feature that stretches from the Alaska Peninsula to the Wrangell Mountains. No surface expressions of a geothermal resource have been found in the area, but four dry wildcat wells encountered anomalously high temperatures in the lower Susitna basin. A temperature gradient was calculated for the area at 123 °C / km, more than four times the average crustal gradient of 30 °C / km. A substantial geothermal resource was thought to exist in the Willow-Big Lake area (Turner and Wescott, 1982). The likely heat source for a hydrothermal system would be deep fault-controlled hydrothermal convection. However, the nature of the geothermal system supplying the reservoirs is not understood.

Future work priorities

A simple field analysis conducted with a minimum of costs using existing driller's logs for all wells in the area and existing geophysical data. If such a field analysis looks favorable for a geothermal heating or power project, the next step would be an exploratory drilling program. A shallow, low-grade reservoir could be tapped for direct use by nearby Nancy Lake State Recreation Area and, possibly, the community of Willow. The lateral extent of the system would have to be determined to know whether it could supply heat and/or power to Wasilla. If sufficient temperatures are attained by drilling, this resource could produce power for Anchorage and the Railbelt.

Priority # 14: Geothermal exploration at Eastern Copper River Basin

Beneficiaries: *Glennallen and Copper Valley Electric Association (CVEA) network*
Population size: *Glennallen:525*; *CVEA network*
Generation System: *8,927 kW capacity hydro with diesel backup (CVEA)*
Geothermal resource factors: *Resource potential unknown*
Distance between resource and load: *Glennallen ~20 miles from Upper Klawasi spring*
Land ownership: *Unknown*
Fuel costs: ?*$0 – 0.25/kWh depending on energy source (hydro, naptha, diesel)*
Anticipated future changes to the community: *Unknown*

Background and Previous Work

The Copper River valley is a sedimentary basin situated on the flanks of Mt. Drum, a volcano which was active as late as 200,000 years ago and which is thought to

have retained significant amounts of residual heat at high levels within the volcano. The Eastern Copper River Basin (ECRB) contains mud volcanoes, unusual features associated with pressurized groundwater aquifers which may or may not be related to a hydrothermal system. High heat flow from the Wrangell volcanoes, the presence of large groundwater aquifers, impermeable layers that could serve as cap rocks, and the chemistry of waters discharged from the Klawasi group of mud volcanoes all point to the presence of a hydrothermal resource. The only published surface expression of a geothermal resource in the Copper River Basin is reported to be max. 30 ^{o}C (Klawasi spring water). However, oral reports that the mud volcanoes are often "too hot to touch" and periodically "erupt" bubbling/boiling mud imply a hotter maximum temperature**.**

Future work priorities

Glennallen is about 20 miles from Upper Klawasi spring. If hydrothermal reservoirs exist at the Klawasi springs, they are probably artesian aquifers lying at depths of up to 2 km, and are significantly cooled on ascent by mixing with groundwater and/or permafrost (Motyka et al, 1986). Further exploration work is needed to determine if there is a resource in the ECRB, and the nature of that resource if it exists.

General Recommendations

When the 14 geothermal prospects outlined in this report are considered as a whole, a number of common themes emerge. First, there is a noticeable lack of exploration data for most of Alaska's geothermal resources – and often what little data exists is not publicly available. The exploration data that exists is almost exclusively from the 1970's and early 1980's. Second, many advances in geothermal assessment and technology over the last few decades have escaped the notice of Alaska's energy community. For example, Alaska lacks a high-resolution heat flow map such as those that have been generated for most states in the U.S. from borehole data, despite the fact that abundant data of this type exists for Alaska. Third, there is no systematic way to choose between different power generation options for a given location. The state government needs some systematic method of assessing power alternatives that encompasses market externalities, long-term costs and benefits, and other factors vital to making long-term decisions about energy supply. Fourth, most Alaskan geothermal projects "stall out" at the drilling phase. Drilling is a critical component of geothermal exploration and development, but drilling costs are often prohibitive – this is compounded in Alaska due to remoteness of site, high construction costs, etc. Fifth, transmission costs are typically the most prohibitive cost component of a geothermal development proposal. Finally, the sustainability of many of Alaska's resources is unknown. Below are several recommendations for the state of Alaska that would directly address these issues:

1. Update geothermal leasing process to facilitate exploration and development.

The recent Mt. Spurr Geothermal workshop revealed that the present leasing process does little to facilitate exploration and/or development at prospective geothermal sites in Alaska. Many of the existing lease terms are more appropriate for oil and gas lease but inappropriate for geothermal lease sales; e.g., the terms neither provide incentives for exploration, nor do they require exploration results be made available to

the public during or after the lease term expires. This means that Mt. Spurr could be locked up in a private lease for another 10 years with no benefit to the state. Secondly, in the case of the Mt. Spurr leases, the terms include a 10-15 % royalty on power sales. This is among the highest in the country for geothermal leases. Nevada, by contrast, exacts a 3.4% royalty (this doesn't include Production Tax Credits, which effectively brings the royalty down to 1.7% - Gary Thompson, pers. comm.). For Mt. Spurr, this alone "kills the project" in the eyes of several developers. These factors and others should be re-assessed if geothermal exploration and resource confirmation is truly a goal of the state.

2. Develop an online interactive public database of geothermal data as part of the Alaska Energy Inventory project.

Since most of the publicly available data on Alaska's geothermal potential was collected before 1985, very little of that data is electronic and it is therefore difficult to access for most interested parties. The Division of Geological and Geophysical Surveys has digitized most of their publications, but many datasets within the AEA library, the University of Alaska Fairbanks Rasmussen Library, the UAF Geophysical Institute Library, and elsewhere have not been digitized. These publications should be inventoried and digitized as part of the State's Alaska Energy Inventory project.

3. Develop a high-resolution heat flow map for Alaska from oil & gas well data.

A large amount of heat flow data exists for Alaska in the form of bottom hole temperatures from oil & gas exploration wells. This data could greatly improve current low-resolution heat flow maps and provide much needed new data to move us forward with understanding Alaska geothermal resource opportunities. This data is presently being compiled by DGGS for a large number of wells across the North Slope. This data should also be compiled for Alaska's geothermal areas, specifically for Interior Alaska and the Cook Inlet area. This map should be added to the geothermal database (see above).

4. Create a model for long-term Cost-Benefit Analyses (CBAs) of "base case" (diesel) vs. geothermal energy case.

Like other renewables, the long-term benefits of geothermal energy projects are dwarfed by prohibitively high capital costs. The CBA model should include capital costs, O&M costs, life-cycle costs of the system, fuel costs, and any anticipated costs (carbon taxing, etc.) within a project lifetime of ~30 years. It should also include externalities that may affect costs. Many of the long-term benefits of geothermal energy (community self-reliance, job opportunities, etc.) may not be captured by private investors, so they are not typically addressed in conventional CBAs. On the flip side, there are many negative externalities that are also not absorbed by the private sector (embedded costs of fuel, pollution costs, etc). These should be included in any long-term planning effort.

5. Develop cost-share program for geothermal drilling.

One of the primary barriers to geothermal development in Alaska is the cost of drilling. David Lockard and Amanda Kolker of AEA met with Beth Maclean of the U.S. Bureau of Land Managment (BLM) and Art Clark of the US Geological Survey (USGS) to discuss utilizing two drill rigs owned by BLM and operated by USGS. These drill rigs

were acquired for "rural energy projects" and have thus far only been used in coal bed methane exploration on Alaska's North Slope. The BLM is interested in using the rigs for geothermal exploration drilling at rural sites in Alaska.

Additionally, the state of Alaska should consider implementing a cost-share program for geothermal drilling. Many federal and state cost-sharing programs have been implemented for geothermal drilling; in fact, eight out of the twelve geothermal developments of the past decade in the Western US were financed via cost-shares, some as high as 80% federally- and/or state-funded (Marshall Reed, personal comm.).

6. Consider power transmission lines from geothermal sites to users as capital improvement projects.

Renewable energy sources are highly site-specific. Often, power generated by a renewable supply must be transmitted a significant distance to users. This is especially true in Alaska where population centers are scarce and geothermal sites tend not to be laterally extensive. Unfortunately, transmission lines in Alaska are expensive (see p. 6). Hence, transmission is usually the most prohibitive cost component of a geothermal development proposal in Alaska (dwarfing even the high costs of drilling). Thus, the state should consider transmission lines for renewable energy projects as large-scale capital improvement projects Such projects tend to have certain near-term monetary costs but highly uncertain and hard-to-quantify future benefits.

7. Monitor existing geothermal projects for sustainability.

In order to monitor the sustainability of geothermal power in Alaska, temperature and pressure logs should be obtained for all producing geothermal wells at regular intervals (no less than twice annually). These should be evaluated to track any declines in the resource. These logs have been generated on a monthly basis for Chena Hot Springs and provide invaluable information about field stability (Holdmann, pers. comm.).

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