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Heating Up the Economy with Geothermal Energy: A Multi-Component Sustainable Development Project at Akutan, Alaska

A. Kolker1 and R. Mann2

1AK Geothermal, LLC, Portland, OR
2RMA Consulting Group, Anchorage, AK

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ABSTRACT

The City of Akutan is located on Akutan Island, a volcanic island in the eastern Aleutians, 790 miles southwest of Anchorage. The economic base of Akutan is the Bering Sea fishery, home to the world’s largest fishing fleet and North America’s largest seafood processing plant located in Akutan. The City and the fishing industry are entirely dependent on diesel fuel imported into the area for power and heat—with an average total demand of 4.3 MW (~7-8 MW peak). The City of Akutan has identified renewable energy development as the only sustainable alternative for displacing diesel fuel, and is presently managing the initial steps of geothermal energy exploration and development.

Fortunately, Akutan’s geothermal system is considered one of the most promising high-temperature sites in Alaska for geothermal resource development. Several thermal springs and fumaroles are located ~6 km (4 mi) from Akutan village, and even closer to Akutan Harbor, one of the few sheltered, deep-water harbors in the Aleutians. A state-funded exploration program was carried out at the Akutan geothermal area in the early 1980s, which concluded that an extensive hydrothermal reservoir is likely present at shallow crustal depths beneath Akutan volcano with reservoir temperatures of up to 200°C. More recent seismic and geodetic studies have delineated a large-scale rifting structure on the island. Synthesis of these different studies provides useful targets for planned exploration work.

This paper discusses the City’s ongoing efforts to develop the Akutan geothermal resource and describes several project scenarios currently under consideration, defining the issues and challenges related to exploration and development of this remote resource.

I. Introduction

Akutan Island is located in the Eastern Aleutian Islands of Alaska (Figure 1). Like nearly all rural communities in Alaska, the City of Akutan depends on diesel fuel for its survival. Combined power generation, home heating and fish processing consume more than four million gallons of diesel fuel each year on Akutan Island.

Financial assistance is provided to electric utilities in most rural Alaska communities that rely on diesel fuel for power generation through the state’s Power Cost Equalization (PCE) program. The PCE program is designed to pay a portion of the electric generation costs for a basic level of service for rural customers and community facilities. In 2007, the PCE program allocated $26.7 million dollars to Alaskan communities (Alaska Energy Authority, 2008). As energy costs have risen throughout Alaska, the PCE program may not be financially or politically sustainable. As an alternative, the Alaska legislature created the Alaska Renewable Energy Grant Fund to stimulate the development of renewable energy and reduce the cost of power in rural communities (AS 42.45.045)

As part of a comprehensive renewable energy strategy, the City of Akutan is developing hydroelectric power generation. However, Akutan has determined that its long-term growth and sustainability rests with the development of geothermal energy. Therefore, the City has applied for and received approval of energy grant and loan funds totaling $3.7 million. These funds...
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will be used to conduct a thorough exploration of the geothermal resource, including exploratory drilling. The City of Akutan is managing the exploration phase of the project, slated to begin in summer 2009.

This paper discusses the City’s ongoing efforts to develop one of the most promising geothermal resources in the Aleutian Volcanic Arc, and proposes a new development model in which a single geothermal energy source is tapped for a multi-component project, partitioned into several small-scale applications. Each application can be viewed as a separate project, with discrete funding sources, business plans and staged development. We will describe the nature of the geothermal resource, review three distinct development scenarios, identify stakeholder interests, and discuss the proposed public-private funding of the project.

II. The Akutan Geothermal Resource

Akutan volcano is part of the Aleutian Volcanic Arc, which is Alaska’s most promising setting for geothermal energy. Fifty-six 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). Akutan volcano is one of the most active volcanoes in the Aleutians, with 32 historic eruptions. It is a composite stratovolcano with a summit caldera ~2 km across and 60-365 km deep (Newhall and Dzurisin, 1988; Miller et al., 1998). Most of the reported eruptions included small-to-moderate explosions from the active intracaldera cone. Several fumarolic areas are present along its south and southwest flank (Lu et al., 2000).

Several thermal springs are located in Hot Springs Bay Valley (HSBV). HSBV is located ~6 km from Akutan village and ~4 km from Akutan Harbor, one of the few sheltered, deep-water harbors in the Aleutians (Figure 2). The fumarole field lies between the volcano’s summit and HSBV. Temperatures of the hot springs range from 40-84°C, and fumarole temperatures as high as 99°C have been measured. No drilling has yet occurred at Akutan, so resource parameters are still unknown and must be estimated. A 10 MW plant size was proposed in 1994 based on existing information about the resource potential and projected energy demand for Akutan.

A state-funded exploration program was carried out in HSBV in the early 1980s. The exploration included detailed geologic mapping of the hot springs area, shallow (<150m) geophysical surveys, soil and fluid geochemical studies, and hydrologic investigations. Geophysical exploration of the HSBV (shallow-ground conductivity measurements, electrical resistivity surveys, and seismic-refraction profiles) revealed a low-resistivity zone 1.4 km x 0.5 km in area, 40-75 thick in the northwest corner of the lower valley and extending more than 4 km beneath the region of hot spring activity. This zone is interpreted to be a hot water reservoir capped by 40-70 m of impermeable volcanic debris flows. The hot springs upwelling expression is sinuous in form and appears to be controlled by a buried stream bed. Fluid geochemistry and geothermometry indicate that the deep thermal reservoir(s) supplying fluids to the fumaroles and the hot springs are interconnected, with reservoir temperatures of up to 200°C (Motyka & Nye, 1988).

In March 1996, a swarm of volcano-tectonic earthquakes (>3000 felt by local residents, $M_{\text{max}} = 5.1$) beneath Akutan Island produced extensive ground cracks but no eruption of Akutan volcano. InSAR images that span the time of the swarm reveal complex island-wide deformation, suggesting inflation of the western part of the island and relative subsidence of the eastern part. The axis of the deformation approximately aligns with new ground cracks on the western part of the island and with Holocene normal faults that were reactivated during the swarm on the eastern part of the island. The deformation is thought to result from the emplacement of a shallow, east-west-trending, north-dipping dike plus inflation of a deep magma body beneath the volcano (Lu et al., 2000). Studies of $^{3}$He/$^{4}$He ratios in Akutan fumarole gasses indicate degassing of relatively fresh near-surface magma (>6 Rc/Ra; Symonds et al., 2003). This implies that unlike many other composite stratovolcanoes, Akutan’s magmatic plumbing system includes two lateral rift zones, similar to the classic rift zones at Hawaiian volcanoes and elsewhere. These rift zones are aligned along the regional least-compressive-stress axis (John Power, pers. comm.), and serve as active magmatic conduits at shallow crustal depths (Figure 2).

**Figure 2.** Map of Akutan Island, showing the geothermal area and pertinent geologic features.
Synthesizing the results from the 1988 geothermal study with this new geologic understanding of Akutan’s magmatic plumbing system and observations from a recent geologic reconnaissance of the island, has led to a new conceptualization of the Akutan hydrothermal system. NW-trending rifting appears to be providing the large-scale permeability as well as the magmatic heat source - crucial for the development of an extensive hydrothermal reservoir beneath the volcano. The structure controlling upwelling of hydrothermal fluids is probably the NW-trending normal fault, revealed during the 1996 earthquake swarm, which cuts near-perpendicularly across HSBV (Figure 2). All of the hot springs are topographically lower than the fault’s surface trace across HSBV, suggesting they represent outflow of the thermal fluid. Motyka and Nye (1988) concluded that the fumaroles are likely fed directly by gases and steam boiling off the deep hot reservoir and that these fluids then mix with cool groundwaters to produce the hot spring waters further down the valley.

The dip of the NW-trending faults is unknown. Exploration work planned for summer 2009 will target these structures, determining a dip angle and testing the hypothesis that they are controlling upwelling. If this hypothesis is correct, the hydrothermal reservoir could be closer to Akutan village than previously imagined.

### III. Profile of Eastern Aleutians and Akutan

Akutan is a volcanic island in the eastern Aleutians, 790 miles southwest of Anchorage (Figure 1). The City is incorporated as a 2nd class city, with a population of 112 Native and 713 total (U.S. Census, 2000), and a 2007 estimated population of 859, including resident fishery workers. Subject to a pending annexation, the City encompasses 148 square miles, including the site of the proposed geothermal development.

The economic base of the eastern Aleutians and Akutan is the Bering Sea Fishery. The port of Unalaska/Dutch Harbor is the most active fisheries port in the world, and Akutan hosts the largest seafood plant in North America, Trident Seafoods Corporation. Expansion of the Bering Sea fishery, potential OCS oil and gas exploration, and mineral exploration in Western Alaska will drive economic development in the region.

In response, the City of Akutan is expanding its supporting infrastructure, including an airport and transportation system, a harbor, access roads and utility upgrades costing more than $150 million. Development of the Akutan geothermal project will greatly reduce the current dependency on diesel fuel, and offset the need to expand diesel consumption to support new infrastructure.

The base cost of power in the City of Akutan is presently $0.323/kWh. For residential customers after PCE, that cost is reduced to $0.128/kWh. Due to differing levels of PCE funding, that number varies from month to month (for example, in 2007 it was only reduced to an average of $0.181/kWh). In 2007, the total annual cost of diesel fuel for power generation was $131,680, after $56,378 in PCE funds were received by Akutan residents.

Based on statewide annual averages, Akutan consumes approximately 225,000 gallons of fuel oil per year for heating. In 2007, the price of heating fuel was $3.65/gal, translating into an approximate cost to the community of $821,250 annually.

### IV. Multi-Component Geothermal Development and Development Scenarios

The Akutan Geothermal Project is envisioned as a combined heat-and-power project. Kolker (2008) found that if cost-benefit analyses of geothermal vs. diesel generation projects in rural Alaska included direct use of the geothermal fluids, the outcome was substantially more favorable towards geothermal development. This is because heating fuel costs are even higher than the costs of fuel for power generation. Based on 2007 values, the total minimum cost in heating fuel for Akutan would be approximately $24.6 million over the next 30 years. This is a minimum because it assumes present rates with zero escalation. Heating is an issue that should be treated with special attention as it is a matter of survival for Akutan residents. Hence, direct uses such as heating, industrial applications, and greenhouse development must be prioritized as project components.

Because the population of Akutan Island (which includes the City of Akutan as well as the hundreds of Trident Seafoods employees on the Island) has identified a multiplicity of needs that would be met by geothermal development, no one application of geothermal energy can be prioritized over another. The project will require a multi-component approach, wherein each separate project component relies on different funding sources, with staged development and discrete business plans.

Because the Akutan geothermal project is viewed as a multi-component system, with electricity generation not necessarily prioritized over other applications, there is no one clear approach to development. Hence, we present three project development scenarios presently under consideration.

All scenarios involve reinjection of fluids back into the geothermal reservoir to ensure the renewability of the energy supply. Most likely, piping will be installed to run spent thermal fluids back from the village for reinjection into the geothermal reservoir. Alternatively, cold creek water or even seawater could be used as a reinjection fluid if the system allows (that is, if the available amount of heat and the rate of heat transfer is sufficient to recharge the system on the same time scale as production). Whatever the fluid, reinjection is a crucial component of system design because geothermal reservoir sustainability will be key to the project’s success.

At Akutan, the heat sink for the power plant would be an infiltration gallery utilizing cold water from nearby creek(s). Creek water at 40-50 °F (4-10 °C) could be used for cooling during summer months, and in the winter the system could be switched to run off an air-cooled condenser system to achieve higher efficiency and output. This idea is being demonstrated at Chena Hot Springs, AK.
Scenario 1

Scenario 1 represents a conventional, ‘cascaded-use’ approach to geothermal development at Akutan. In this scenario, fluids pumped to the surface via production wells are first utilized onsite for power production. Spent fluids from the power plant are then piped to the village for direct use, and piped back to the ‘reservoir’ area for reinjection (Figure 3). Alternatively, cold creek water or seawater could be used as a reinjection fluid, if this is found to be technically feasible.

While Scenario 1 is conventional, it is very capital intensive. Its feasibility will depend entirely on where the geothermal ‘reservoir’ is located. If exploration suggests that production wells must be located some significant distance from the village, this scenario will present substantial technical and economic challenges. Additionally, this scenario requires a large degree of coordination between the different projects and stakeholders. This could preclude the desired multi-component-project approach. Rather, this approach necessitates the building of an onsite power plant before any other project components can be considered. This unnecessarily prioritizes power generation over other equally important project components.

Scenario 2

Scenario 2 represents a somewhat unconventional approach to geothermal development. In this scenario, production fluids are immediately piped to the village for direct use and power production. Spent fluids are then piped back to the ‘reservoir’ area for reinjection. Alternatively, cold creek water or seawater could be used as a reinjection fluid if this is found to be technically feasible (Figure 4).

This scenario is unconventional because there would inevitably be some heat loss from piping fluids to the village; because corrosion and/or scaling of pipes could be problematic; and other reasons. However, in the case of Akutan, these drawbacks may be outweighed by the benefits of having the entire system located in the village. Such benefits include better management of the entire system, better coordination among components and stakeholders, and most importantly, the development can be broken into pieces. While all the project components depend on production wells and piping to the village, they do not depend on one another. Once the wells and piping system are in place, each project component can be developed separately by different stakeholders through different funding sources, in staged development and with discrete business plans. This scenario is most conducive to a multitude of industrial applications, such as refrigeration (for cold storage of fish and/or processing), the production of alternative fuels, and other applications.

Scenario 3

Scenario 3 represents a simpler approach to geothermal development at Akutan. In this scenario, production fluids are simply used onsite for power production, and piped back to the ‘reservoir’ area for reinjection. The only direct use application of geothermal fluids in this scenario is onsite greenhouses, and perhaps resort development (Figure 5).

This scenario is clearly simpler than the other two; however the multitude of direct use benefits would be sacrificed. This could have an impact on project economics since geothermal district heating projects provide a significant monetary benefit to the communities in rural Alaska (Kolker, 2008). Geothermal heating would save Akutan a minimum of $24.6 million over 30 years in avoided heating fuel costs, a benefit that would be lost by this scenario. Other economic development opportunities would also be lost, such as refrigeration for fish storage and processing. Other, more marginal opportunities, such as the production of alternative fuels, would be complicated but not necessarily impossible in this scenario.

V. Funding Sources for the Akutan Geothermal Project

Funding for the Akutan geothermal project is expected to come from three sources: public loans/grants, stakeholder participation, and private developers/investors. The infusion of funds should occur in concert with the stages of development, as shown below:

<table>
<thead>
<tr>
<th>Project Component</th>
<th>Funding Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration and feasibility phase</td>
<td>Public grants/loans</td>
</tr>
<tr>
<td>Production drilling</td>
<td>Public grants/loans</td>
</tr>
<tr>
<td>Power plant design construction, operations and maintenance</td>
<td>Private developers/investors</td>
</tr>
<tr>
<td>District heating design and construction</td>
<td>Public grants/loans, stakeholder participation</td>
</tr>
<tr>
<td>Greenhouse design and construction</td>
<td>Stakeholder participation</td>
</tr>
<tr>
<td>Cold storage design and construction</td>
<td>Stakeholder participation</td>
</tr>
<tr>
<td>Tourism/recreation</td>
<td>Stakeholder participation</td>
</tr>
<tr>
<td>Other industrial applications</td>
<td>Private developers/investors, stakeholder participation</td>
</tr>
</tbody>
</table>

This strategy allows for public investment in identification of and access to the resource as a public benefit for reducing energy

Figure 3. Geothermal development at Akutan, Scenario 1.

Figure 4. Geothermal development at Akutan, Scenario 2.

Figure 5. Geothermal development at Akutan, Scenario 3.
subsidies, promoting sustainability and reducing carbon emissions. When the size, location and capacity of the resource are known, private development groups and investors will be invited to propose development plans for designing, building and operating the primary power resource. As part of the comprehensive development plans, stakeholders and others interested in building and operating specific applications will be offered partnership agreements and/or equity participation.

This funding approach will ensure that the project is scalable, both in terms of operations and return on investment. It also allows for expanding use of what might otherwise be stranded geothermal resources.

VI. Conclusions

Outside of Alaska, few communities have a more compelling need to develop renewable energy than the rural communities of Alaska. Breaking the dependence on diesel fuel means much more than cutting the cost of energy. Economic development, the preservation of Native culture, and perhaps the long-term survival of Akutan are now dependent upon the development of sustainable resources. Although exploration and feasibility analysis of the resource are currently being completed, it appears that development of the Akutan geothermal resource offers Akutan and the eastern Aleutians a sustainable future. Assuming the availability of the resource, we can conclude the following:

- Development of the Akutan geothermal resource presents an opportunity to maximize the public-private benefits of renewable energy development.
- A multi-component development approach presents the best opportunity for an efficient and financially viable use of the resource.
- Public-private funding and stakeholder participation are keys to the success of the project.
- Akutan geothermal development will compliment the expansion of public infrastructure at Akutan, and serve as a catalyst for local and regional economic development.

- Multiple scenarios are available that make the project scalable and produce the added benefits of energy security, heating security, food security and community self-sufficiency.

The Akutan geothermal development project presents a unique opportunity to combine the benefits of energy and economic sustainability with the preservation of Native culture and rural community values, the reduction of carbon emissions, and broad stakeholder participation. The City of Akutan hopes to take full advantage of this powerful combination of tangible and intangible benefits of geothermal energy.

References


