ISSN 0276-1084

VOL. 29 NO. 4

FEBRUARY 2011

GEO-HEAT CENTER QUARTERLY BULLETIN

GEOTHERMAL RESOURCES OF ARIZONA AND WASHINGTON STATE

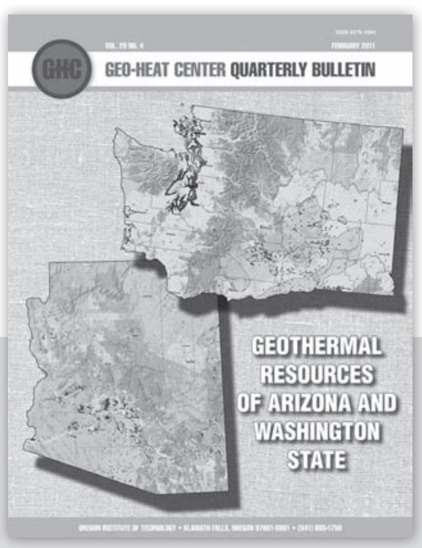
VOL. 29 NO. 4 FEBRUARY 2011

GEO-HEAT CENTER QUARTERLY BULLETIN

ISSN 0276-1084

A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

CONTENTS



Cover - Geothermal Resources of Arizona and Washington State

PUBLISHED BY

GEO-HEAT CENTER
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Phone: (541) 885-1750
E-mail: geoheat@oit.edu

All articles for the Bulletin are solicited. If you wish to contribute a paper, please contact the editor at the above address.

EDITOR

Tonya "Toni" Boyd
Cover Design – SmithBates Printing & Design

WEBSITE:

http://geoheat.oit.edu

ACKNOWLEDGEMENT

This material is based upon work supported by the Department of Energy (National Nuclear Security Administration) under Award Number DE-EE0002741.

SUBSCRIPTIONS

The *Bulletin* is mailed free of charge. Please send your name and address to the Geo-Heat Center for addition to the mailing list.

If you wish to change your *Bulletin* subscription, please complete the form below and return it to the Geo-Heat Center.

Name ____

Address ____

City, State, Zip ______________________________________

Country____

THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL BENEFITS OF GEOTHERMAL USE IN WASHINGTON STATE

Linda Riley, Oregon Institute of Technology, KlamathFalls, Oregon

Geothermal waters in Washington have been enjoyed by many for centuries. Native Americans used naturally occurring hot springs for healing, cleaning, cooking and even negotiating. "Sol Duc" is a Native American word for "sparkling water." Early developments included grand hotels and sanatoriums to treat the ill.

Schuster and Bloomquist (1994) compiled a resource database including 975 thermal wells and springs, which was an increase of 165% over the number of entries reported in 1981. Most of the thermal springs occur in the Cascade Range, associated with stratovolcanoes. In contrast, 97% of the thermal wells are located in the Columbia Basin of southeastern Washington. These thermal wells are strongly associated with the Columbia River Basalt Group and the Columbia Basin (Shuster and Bloomquist, 1994).

According to the National Renewable Energy Laboratory (NREL, 2005), the Columbia River Basin boasts more than 900 low-temperature (less than 100°C or 212°F) thermal wells. There are also 30 known low-temperature hot and mineral springs in the Cascade Range. NREL (2005) also states that high-temperature (greater than 150°C or 302°F) resources have been identified in this area, but have yet to be developed; three of these areas may be particularly good for development of electric power generation. These sites include the Mount Adams area in the southern Cascades, the Wind River area east of Vancouver, Washington, and the Mount Baker area in the northern Cascades (NREL, 2005).

ECONOMIC BENEFITS

The economic benefits to Washington result primarily from the connection between the hot springs and the tourism industry. Sol Duc Hot Springs resort was founded in the early 1900s with a 164-room five-star hotel and resort. It now consists of 27 cabins, multiple RV hookups and a river suite, and attracts 50,000 visitors annually. Located in the Olympic National Forest, Sol Duc Hot Springs provides a favorite base camp for many hikers and outdoor enthusiasts.

Soap Lake, though not a true hot springs, has been attracting visitors since the early 1900s. In its heyday, celebrations, socials and gatherings were held continuously. World War I veterans flocked to Soap Lake when word got out that the mineral waters and mud of the lake were an effective treatment for Buergers disease. The 3-mile long lake maintains a constant summer temperature of 87˚F (31˚C) and a heavy mineral content (NREL, 2005). Spas along the lake attract tens of thousands of people annually (NREL, 2005). The Soap Lake Chamber of commerce reports that the town is experiencing a resurgence as more people turn to natural and healthier lifestyles.

The first spa in Washington was developed in 1901 with the completion of the St. Martin Hotel at Carson Hot Mineral Springs. Cabins and a bath house were added in 1923 and are still in use today. Continuing as a foundation for economic growth, an 18-hole golf course was added in 1974. Carson Hot Mineral Springs enjoys a range of 30 to 100 visitors per day throughout the year.

The Original Hotel St. Martin at Carson Hot Mineral Springs.

The economic benefits associated with Goldmyer Hot Springs began with its privatization as a patented mining claim and the Goldmyers ran a lodge in the early 1910s for miners and loggers in the area. Its popularity almost led to its destruction until ownership transferred to a non-profit organization who now limits access to 20 people per day.

Bonneville Hot Springs resort, renovated in 1991, is now an upscale resort and spa offering 78 "exquisitely appointed" guest rooms and suites and a whole host of treatments including: mineral baths and wraps, massages, facials and therapies. Geothermal water is also used for direct heating of the 13,000 square foot European-style spa facility.

The developed hot and mineral springs of Washington provide about 11 billion Btu of geothermal energy per year (NREL , 2005). Although this production results in cost savings through the offset of other energy usage, the energy produced makes up a small percentage of the statewide energy consumption and the economic impact is therefore relatively small in comparison to that of the tourism industry (NREL, 2005).

NREL (2005) projected that if the State's estimated geothermal electric potential of 300 MW were to be fully developed, the economic and energy impact would be significant. The 300 MW could produce about 2.5 billion kilowatt-hours (kWh) of electricity a year, which is enough to provide more than 265,000 average U.S. homes with electricity.

Low-temperature resources could be used directly to heat buildings, grow plants in greenhouses, heat water for aquaculture, and for other application that often incorporate heat pumps.

ENVIRONMENTAL BENEFITS

Because the spas and resorts are able to use the heat naturally occurring in the water, they do not have to heat water using electricity or natural gas, therefore preventing greenhouse gas emissions.

The revenues generated from the hot springs and resorts also depend directly on the careful maintenance of the natural springs. This maintenance directly relates to varying levels of area protection and conservation.

The Goldmyer hot springs was subjected to overuse, misuse and mismanagement in the 1960s and 70s. In response, the Northwest Wilderness Programs Inc. (NWWP), a non-profit organization, was formed by Veida, John and Josehine Morrow to carefully manage access and use of the springs. Now, access is limited to 20 people per day. In addition, the NWWP provides visitors with information about the ecology of the ancient forest ecosystem, and a plant identification guide is available for walking tours. If not otherwise busy with facilities maintenance, caretakers are often happy to lead ecological walks through one of the last remaining old growth forest areas in the Pacific Northwest.

Rock-lined pools at Goldmyer Hot Springs.

Similarly, the tourism of Soap Lake depends directly on the mineral water and mud contained in the lake. The Soap Lake community therefore carefully protects the quality of the lake (assuring that irrigation drainage does not end up in the lake) and the use of the waters and mud. The mud, a result of minerals deposited from glacial floods, cannot be replaced.

SOCIAL BENEFITS

Though difficult to measure quantitatively, geothermal resources provide many social benefits. Historically, hot springs served as gathering places and ceremonial sites for Native American communities. Hot springs continue to draw people together, creating foundations of tourism for local towns and improving quality of life through recreation. The mineral waters, muds and spas serve as the primary basis for the Soap Lake local economy and community gatherings. In the early 2000s, a Korean man visited the lake and, fascinated by its healing history, included the lake in a Korean-language tour guide, prompting more Koreans to visit (White, 2008).

Hot and mineral springs have and continue to be used for medicinal and healing properties. At Carson Hot Springs, St. Martin's wife, Margaret, recovered from neuralgia. Michael Earles, owner of the Puget Sound Mills and Timber Company in the late 1800s, claimed he was cured of a fatal illness after visiting Sol Duc Hot Springs. Soap Lake became well known for its ability to relieve symptoms of Buergers disease, suffered by many World War I Veterans. Many people continue to visit Soap Lake for the reported healing mud and water. They also come to enjoy the laid-back atmosphere of the town, its thriving arts community and the abundant sunshine and fresh air.

THE FUTURE

According to NREL (2005), high-temperature geothermal resources have the potential to produce approximately 300 megawatts (MW) of electricity. In September of 2010, the Geothermal Energy Association reported that the Snohomish County Public Utility District (PUD) is drilling geothermal test wells with hopes to use geothermal energy to power 35,000 homes by 2020. The PUD would be the first utility in Washington State to develop geothermal power. The PUD is spending $350,000 to drill five test holes. The desired 50-MW plant will cost between $150 million and $200 million. The plant would likely be built in 10-MW phases with the first potentially completed by 2016 (GEA, 2010).

In addition to high-temperature resources, there may be an even greater potential for direct-use applications from low-temperature thermal wells in the Columbia River Basin (NREL, 2005). Direct-use applications can include heating buildings, growing plants in greenhouses, crop and food drying and aquiculture.

Rather than prioritize limited areas within the Columbia Basin for detailed studies, Schuster and Bloomquist (1994) make three recommendations for greatly expanding geothermal use in the state. The recommendations are: (1) match existing thermal wells with proposed retrofit or new construction, (2) measure temperature gradients, obtain well-test data and drill cuttings, and collect water samples for chemical analysis, and (3) inform state residents and policy makers about uses of geothermal energy.

The Washington Geothermal Energy Status and Roadmap - a working-draft report produced by the Washington State University Extension Energy Program and the Washington State Department of Natural Resources – also identified information and action needed for future geothermal development. These needs were divided into categories including exploration and characterization of geothermal geology, geothermal leases and permitting, and geothermal policy (Sjoding, et. al., 2009).

There is great potential for future development of

Washington's geothermal resources. With updated data from existing wells, support for exploration and new or revised policies and incentives, Washington may expand the economic, environmental and social benefits that result from geothermal resources.

ACKNOWLEDGEMENTS

This material is based upon work supported by the Department of Energy under Award Number DE-EE0002741.

DISCLAIMER

REFERENCES

Geothermal Energy Association (GEA), 2010, *Geothermal Energy Weekly: Washington*, Available at: www.geo-energy.org/pdf/updates/2010/Geothermal%20Energy%20Weekly%20September%2030%202010.pdf

Lund, J.W., Freeston, D.H., and Boyd, T.L., 2010, "Direct Utilization of Geothermal Energy 2010 Worldwide Review", *Proceedings of the World Geothermal Congress 2010*, Bali, Indonesia.

National Renewable Energy Laboratory (NREL), 2005, *Geothermal Technologies Program: Washington*, Available at: www.osti.gov/bridge/purl.cover.jsp;jsessionid=F5C13FB1CF63955CDFC9C1B8418E06D8?purl=/15011452-WfqPOX/native/

Schuster, J. E. and Bloomquist, R. G., 1994, "Low-Temperature Geothermal Resources of Washington", Washington Division of Geology and Earth Resources *Open-File Report 94-11*, 53 p.

Sjoding, D., Hamernyik, E. and Norman, D. 2009, "Washington Geothermal Energy Status and Roadmap", *Washington State University Extension Energy Program and Washington State Department of Natural Resources*, Available on-line. www.energy.wsu.edu/Documents/WashingtonGeothermalEnergyStatusAndRoadmap.pdf

White, F. 2008, "Soap Lake: Slow down and take a soak", *Tri-City Hearld*. Available on-line. www.tri-cityherald.com/2008/09/08/309090/soap-lake-slow-down-and-take-a.html

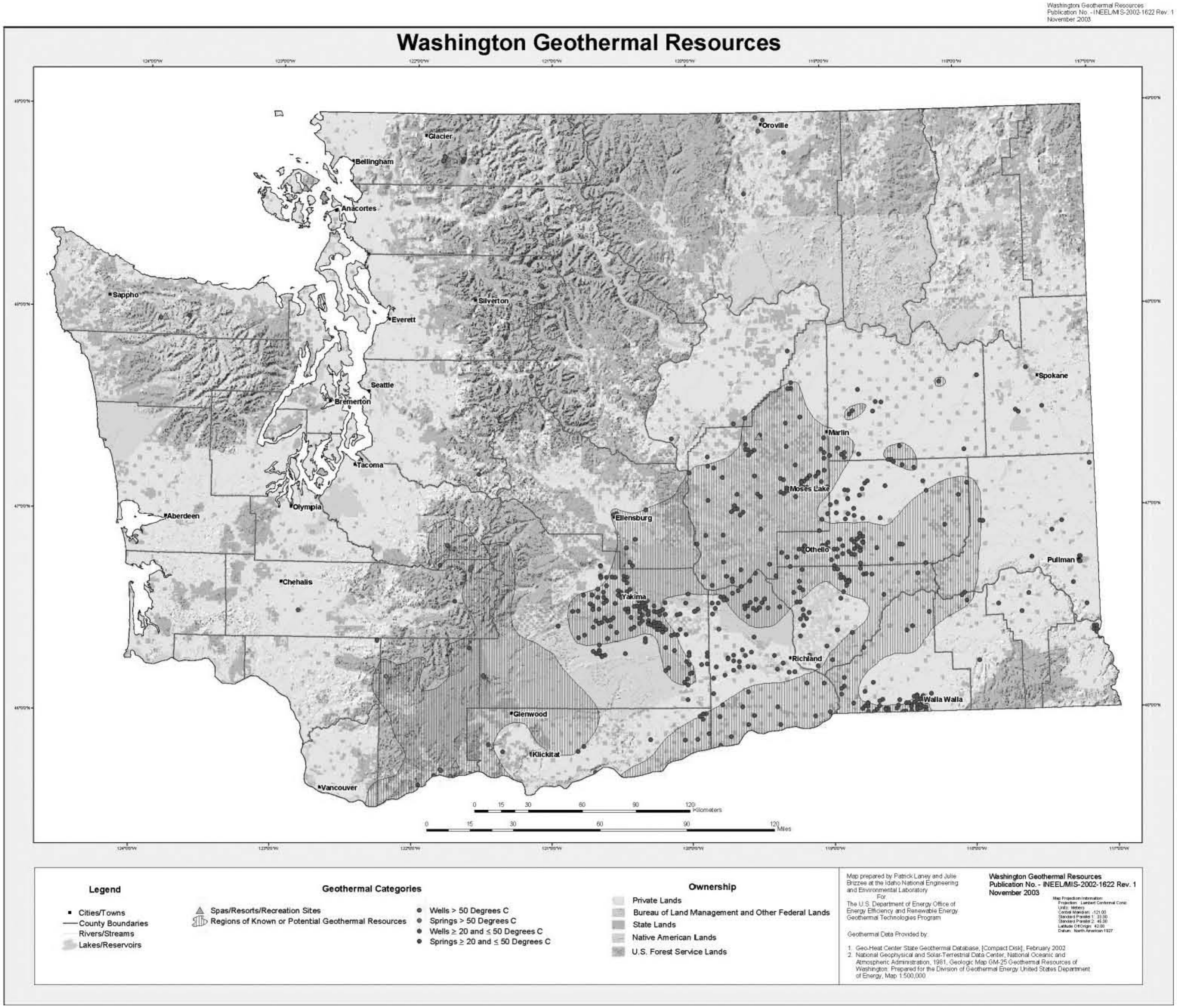
Table 1. Energy Production and Carbon Emissions Offsets by Geothermal Utilization in the State of WashingtonNotes:

Name	Temp.	Flow	Energy		Annual Emissions Offset[3] (lb.)		
			Peak Capacity	Annual	NO_x	SO_x	CO_2
Carson Hot Mineral Springs Resort[1]	119°F (48°C)	Unknown. Well is pumped 24 hrs/day.	1.0 X 10^6 Btu/hr 0.29 MWt	7.0 X 10^9 Btu/yr 2.1 GWh/yr	7.2	7.6	4.286
Goldmyer Hot Springs	117°F (47°C)	5 gpm (18.9 L/min)	2.0 X 10^4 Btu/hr 0.006 MWt	1.4 X 10^8 Btu/yr 0.04 GWh/yr	0.136	0.144	81.6
Sol Duc Hot Springs	133°F (56°C)	50 gpm (189 L/min)	8.0 X 10^5 Btu/hr 0.23 MWt	5.6 X 10^9 Btu/yr 1GWh/yr	5.5	5.8	3,266
Bonneville Hot Springs[2]	97°F (36°C)	100-150 gpm (378- 570 L/m)	6.5 X 10^5 Btu/hr 0.19 MWt	4.6 X 10^9 Btu/yr 1.3 GWh/yr	4.4	4.7	2,653
Totals			2.5 X 10^6 Btu/hr 0.72 MWt	1.7 X 10^{10} Btu/yr 5.0 GWh/yr	17.2	18.2	10,287

1. Flow rate was unknown according to facilities staff at time of publication. Capacity and Annual Energy figures were taken from Geo-Heat Center Database.

2. Capacity was calculated using an average flow rate of 100 gallons per minute.

3. Emission factors from Lund et al. (2010)


Washington Geothermal Resources
Publication No. - INEEL/MIS-2002-1622 Rev. 1
November 2003
Washington Geothermal Resources
Oroville
Glacier
Bellingham
Anacortes
Sappho
Silverton
Everett
Spokane
Seattle
Bremerton
Marlin
Tacoma
Moses Lake
Ellensburg
Olympia
Aberdeen
Othello
Pullman
Chehalis
Yakima
Richland
Walla Walla
Glenwood
Klickitat
Vancouver
0 15 30 60 90 120 Kilometers
0 15 30 60 90 120 Miles
Legend
Cities/Towns
County Boundaries
Rivers/Streams
Lakes/Reservoirs
Geothermal Categories
Spas/Resorts/Recreation Sites
Regions of Known or Potential Geothermal Resources
Wells > 50 Degrees C
Springs > 50 Degrees C
Wells ≥ 20 and ≤ 50 Degrees C
Springs ≥ 20 and ≤ 50 Degrees C
Ownership
Private Lands
Bureau of Land Management and Other Federal Lands
State Lands
Native American Lands
U.S. Forest Service Lands
Map prepared by Patrick Laney and Julie Brizzee at the Idaho National Engineering and Environmental Laboratory
For
The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Geothermal Technologies Program
Geothermal Data Provided by:
1. Geo-Heat Center State Geothermal Database, [Compact Disk], February 2002
2. National Geophysical and Solar-Terrestrial Data Center, National Oceanic and Atmospheric Administration, 1981, Geologic Map GM-25 Geothermal Resources of Washington: Prepared for the Division of Geothermal Energy United States Department of Energy, Map 1:500,000
Washington Geothermal Resources
Publication No. - INEEL/MIS-2002-1622 Rev. 1
November 2003
Map Projection Information:
Projection: Lambert Conformal Conic
Units: Meters
Central Meridian: -121.00
Standard Parallel 1: 33.00
Standard Parallel 2: 45.00
Latitude Of Origin: 42.00
Datum: North American 1927

THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL BENEFITS OF GEOTHERMAL USE IN ARIZONA

Andrew Chiasson, Geo-Heat Center, Klamath Falls, Oregon

Geothermal waters in Arizona have been used by many people for centuries. Today, the documented direct uses of geothermal waters are related to aquaculture, greenhouse heating, and spas.

ECONOMIC BENEFITS

The aquaculture industry in Arizona enjoys significant economic benefits of geothermal energy. Desert Springs Tilapia in the Hyder Valley produces about 1 million pounds of Tilapia using the benefits of geothermal (Fitzsimmons, 2011). The facility makes use of three geothermal wells, capable of producing about 5,000 gallons per minute (gpm) at temperatures ranging from 95˚F to 106˚F (35˚C to 41˚C). In addition, the warm water is also used for irrigation of crops such as wheat, sour gum, and olives. Desert Springs Tilapia employs about 10 people.

Desert Sweet Biofuels (credit: desertsweetbiofuels.com)

Desert Sweet Biofuels (formerly Desert Sweet Shrimp), located near Gila Bend, is using geothermal energy for venturing into commercial algae production for biodiesel (Allison, 2011 and Fitzsimmons, 2011). This facility employs about four people.

About five other small aquaculture operations exist in the Safford area, each employing two to three people. These operations produce about 100 to 1,000 pounds of "pond-stocking" fish such as catfish, bass, and minnows. The Geo-Heat Center database had records of an aquaculture operation in Marana (near Tucson), which is no longer in operation (Fitzsimmons, 2011).

Geothermal energy has recently been employed at the Willcox Greenhouse for heating (Witcher, 2011). This is a 7.5 acre facility that employs about 40 people and primarily grows tomatoes. Based on the recommendations of a feasibility study funded by the US Department of Energy, the greenhouse drilled a well in 2010 to a depth of 4,000 feet and tapped geothermal water at temperatures in excess of 135˚F (57˚C). The well currently produces about 1,000 gpm, but likely has a much greater capacity (Witcher, 2011).

Willcox Greenhouse (credit: J. Witcher)

Arizona has several small spas, a few historic resorts, and numerous undeveloped hot springs (Bischoff, 1999). The small spas include Essence of Tranquility and Kachina Mineral Springs near Safford, and El Dorado near Tonopah. Also, Muleshoe Ranch, northwest of Willcox, includes hot springs now operated for tourism by The Nature Conservancy (NREL, 2006).

The most famous geothermal site in Arizona was privately-owned Castle Hot Springs, 50 miles northwest of Phoenix (NREL, 2006). For several decades, many famous people visited there to play golf and soak in the hot waters. This facility is recently under new ownership which is adding an aquaponics operation that will raise tilapia, along with tomatoes, cucumbers, and lettuce (Fitzsimmons, 2011). Other historic resorts included Buckhorn Mineral Wells in Mesa and Agua Caliente near Sentinel.

The numerous geothermal businesses across Arizona employ many people. Using a standard multiplier of 2.5 (GEA, 2005), geothermal businesses create an estimated 210 direct, indirect, and induced jobs in the state.

Buckhorn Mineral Wells - photo by Susan C. Weber

ENVIRONMENTAL BENEFITS

In addition to energy savings, geothermal energy usage prevents the emissions of greenhouse gases (GHG) and air pollutants, helping to keep a healthy living environment in Arizona. If these businesses used fossil fuels to generate the heat that geothermal water provides, not only would most be unable to afford to stay in business, but they would emit at least 82,800 tonnes of carbon dioxide each year — the equivalent of 195,550 barrels of oil. In addition, they would emit 139 tonnes of nitrogen oxides and 137 tonnes of sulfur dioxides each year into Arizona's air (Table 1).

SOCIAL BENEFITS

Social benefits are difficult to measure quantitatively. One key social benefit from geothermal energy use in Arizona, however, is improved quality of life through recreation. Geothermal provides many unique recreational opportunities enjoyed by tens of thousands of people each year, attracting tourists to the state.

THE FUTURE

Arizona has significant geothermal potential for future uses, from the growing deployment of geothermal heat pumps, to new and expanding applications of direct use geothermal, to development of high temperature resources for electrical power generation.

According to NREL (2006), geothermal resources with potential for electrical power generation in Arizona include the eastern San Francisco Volcanic Field near Flagstaff and several areas in southeastern Arizona. One of these is the Clifton area near the New Mexico border.

The Geo-Heat Center lists 14 communities in Arizona that are within 5 miles (8 kilometers) of a geothermal resource with a temperature of 122°F (50°C) or greater, making them possible candidates for district heating or other geothermal use. Arizona has a strong aquaculture and greenhouse industry, which can experience significant growth with expanded use of geothermal energy for heating.

Historically, geothermal heat pumps have not been widely used in Arizona but demand is currently growing (Allison, 2011). One advantage of geothermal heat pumps is that no water is consumed in cooling (as opposed to evaporative cooling systems), thereby conserving precious water resources in the Arizona desert. With consumptive water uses in conventional cooling systems becoming more and more stringent, geothermal heat pump usage is almost certain to increase.

REFERENCES

Allison, L. 2011. Personal Communication. L. Allison, PhD, RG State Geologist & Director, Arizona Geological Survey.

Bischoff, M., 1999. Touring Arizona Hot Springs. Falcon Publishing, Inc., Helena, Montana.

Fitzsimmons, K., 2011. Personal Communication. K. Fitzsimmons, PhD, Environmental Research Laboratory, College of Agriculture and Wildlife Sciences, University of Arizona.

Geothermal Energy Association (GEA), 2005. Geothermal Industry Employment: Survey Results & Analysis.

Lund, J.W., Freeston, D.H., and Boyd, T.L., 2010. Direct Utilization of Geothermal Energy 2010 Worldwide Review. Proceedings of the World Geothermal Congress 2010, Bali, Indonesia.

National Renewable Energy Laboratory (NREL). 2006. Geothermal Technologies Program: Arizona.

Witcher, J., 2011. Personal Communication. J. Witcher, Consulting Geologist.

ACKNOWLEDGEMENTS

This material is based upon work supported by the Department of Energy under Award Number DE-EE0002741.

DISCLAIMER

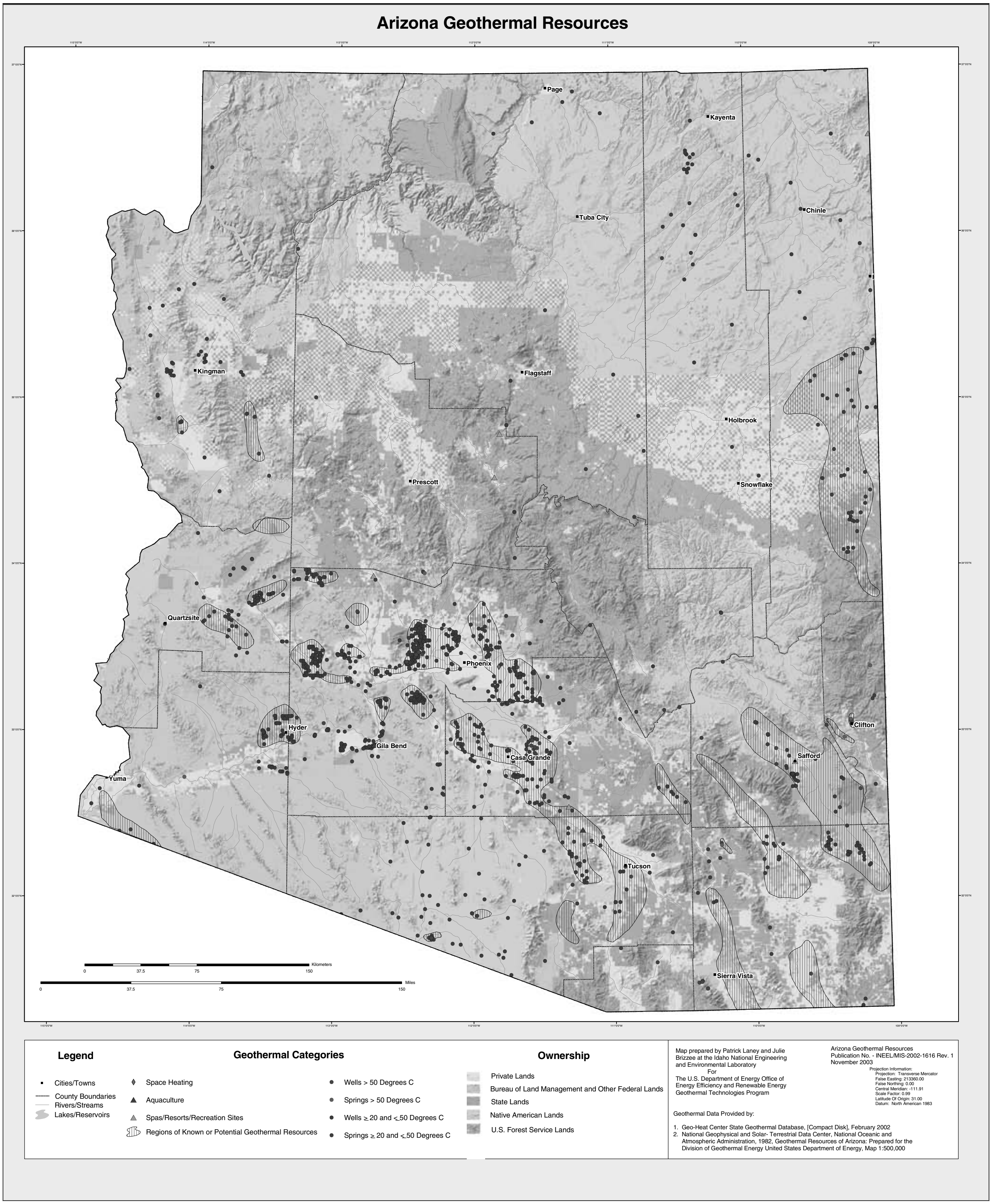
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Table 1.
Energy Production and Carbon Emissions Offsets by Geothermal Energy Utilization in the State of Arizona.

Site	Location	Application	Temp. (F)	Annual Energy Use		Annual Emission Offsets** (metric tonnes)		
				10^9 Btu/yr	10^6 kWh	NO_x	SO_x	CO_2
Desert Sweet Biofuels	Gila Bend and Yuma	Algae	105	24.5	7.2	11	12	6,648
Desert Tilapia	Hyder Valley	Aquaculture	100	140.2	41.1	64	67	38,040
Safford, Misc. Aquaculture	Safford	Aquaculture	105	35.0	10.3	16	17	9,497
Willcox Greenhouses	Willcox	Space Heating	>135	35.0	10.3	16	17	9,507
Buckhorn Mineral Wells	Mesa	Resort/Space Heating	140	5.0	1.5	2.3	2.4	1,357
Castle Hot Springs	Near Wickenberg	Resort/Pool	131	2.5	0.7	1.1	1.2	678
Buckhorn Mineral Wells	Mesa	Resort/Pool	112	7.0	2.1	3.2	3.4	1,899
El Dorado	Tonopah	Resort/Pool	112	7.0	2.1	3.2	3.4	1,899
Kaiser Hot Springs	55 mi. SE of Kingman	Resort/Pool	99	7.0	2.1	3.2	3.4	1,899
Essence of Tranquility	near Safford	Resort/Pool	115	7.0	2.1	3.2	3.4	1,899
Kachina Mineral Springs	near Safford	Resort/Pool	108	7.0	2.1	3.2	3.4	1,899
Roper Lake State Park	near Safford	Resort/Pool	100	7.0	2.1	3.2	3.4	1,899
Potter's Aztec Baths	Clifton	Resort/Pool	150	7.0	2.1	3.2	3.4	1,899
Ringbolt Hot Springs	below Hoover Dam	Resort/Pool	110	7.0	2.1	3.2	3.4	1,899
Verde Hot Springs	20 mi. W of Strawberry	Resort/Pool	100	7.0	2.1	3.2	3.4	1,899
Totals				**305**	**89**	**139**	**147**	**82,821**

**Emission factors from Lund et al. (2010).

Arizona Geothermal Resources
Publication No. - INEEL/MIS-2002-1616 Rev. 1
November 2003



SYSTEMS FOR ELECTRICAL POWER FROM CO-PRODUCED AND LOW TEMPERATURE GEOTHERMAL RESOURCES

Timothy Reinhardt, U.S. DOE, Geothermal Technologies Program, Washington, D.C.
Lyle A. Johnson, Rocky Mountain Oil Test Center, Casper, Wyoming
Neil Popovich, National Renewable Energy Laboratory, Golden, Colorado

ABSTRACT

The Geothermal Technologies Program (GTP), the Rocky Mountain Oilfield Testing Center (RMOTC), and the National Renewable Energy Lab (NREL) are working together to advance the production of power from coproduced and low temperature geothermal resources. To this end, and through a collaborative effort, RMOTC is being used as a test-bed for promising low temperature geothermal power production technologies. These technologies produce electricity by leveraging existing oil and gas field infrastructure as well as the resource geofluid which is coproduced in the process of harvesting hydrocarbons. GTP is providing the direction and oversight for the work. RMOTC is providing the facility, resource and manpower to operate the test units, while NREL is providing the technical analysis and insight to help overcome challenges currently faced with low temperature geothermal power production systems. Details of the role of each participant are given in the paper.

Presently, the initial geothermal power production unit being tested under the collaborative program is an air-cooled nominal 250 kW Ormat unit installed at RMOTC. To date, the total produced power from the unit is 1,918 megawatt hours of power from 10.9 million barrels of coproduced hot water. The online percentage for the unit, eliminating downtime caused by field activities, has been at 97%. This Ormat unit will continue to be operated at RMOTC for an additional 2 years under the collaborative agreement with DOE's Geothermal Technologies Program.

Additionally, infrastructure at the RMOTC test site has been prepared for the installation of a second, water-cooled nominal 250 KW Pratt & Whitney unit that is scheduled for delivery in late January 2011. Under this program, the second, water cooled unit will be installed and tested for 3 years. This added capability will provide operational data and experience that can be transferred to potential users of air or water cooled systems in both oil/gas fields and low temperature geothermal settings.

Looking to the future, RMOTC will continue geothermal testing, develop a test facility for smaller geothermal systems, develop plans for EGS applications and testing, and implement new initiatives. In parallel, GTP will provide funding for continued testing of program related geothermal activities at the site. The geothermal subprogram will also continue to provide guidance and oversight on all projects, as well as engage with National Labs, universities and industry to foster advances in technology by implementing innovative concepts and ideas at the RMOTC test site. NREL's future activities will be focused on addressing current challenges to the geothermal systems. NREL's efforts will be focused on recording/analyzing data from Organic Rankine Cycle (ORC) and other geothermal power systems, and implementing improvements to the systems to improve their performance and promote the use of these renewable low temperature geothermal energy technologies. Ultimately, these plans are an attempt to provide the geothermal community with the means to achieve development and widespread deployment of economically viable, innovative, and scalable technologies that will capture a significant portion of the low temperature and coproduced geothermal resource base over the next two decades.

BACKGROUND

During the 1970's, the publicly available information concerning geothermal power production and resources was limited. In response to this less than favorable environment for geothermal industry growth, the U.S. Government initiated the geothermal research and development (R&D) program. The intent of the geothermal program was to understand geothermal resources, improve geothermal science and engineering technology, and to ensure information was available to developers, utilities, financial institutions, regulators, and other stakeholders necessary to spur development of the industry.

Today, the Geothermal Technologies Program (GTP), as that initial R&D program has come to be known, develops innovative geothermal energy technologies to find, access, and use the Nation's geothermal resources. Through research, development, and demonstration efforts, the GTP is working to provide the United States with an abundant, clean, renewable energy source. The GTP works in partnership with industry, other government agencies, academia, and DOE's national laboratories to establish geothermal energy as an economically competitive contributor to the U.S. energy supply. In pursuit of these goals, the program has partnered with RMOTC and NREL to demonstrate technically feasible and economically viable geothermal energy production from oil and gas wells at the RMOTC test site.

NREL's role in the GTP program is based on NREL's overall mission to develop renewable energy and energy efficiency technologies and practices, advance related science and engineering, and transfer knowledge and innovations to address the nation's energy and environmental goals. NREL seeks to accomplish this via its efforts to evaluate the state of the geothermal industry and to promote the geothermal industry thru technical analysis and information dissemination. NREL's function in this specific project is to help DOE evaluate new geothermal technologies and address current challenges facing these technologies. In this role, NREL is designing and installing data monitoring systems that will be used by NREL to collect and analyze data on geothermal power plants operating at RMOTC. Current geothermal challenges that NREL is addressing are related to power output improvements throughout the year and improving power output in warm climate operating environments.

The data presented in this paper is the result of both a Cooperative Research and Development Agreement (CRADA) between Ormat Nevada, Inc. and the DOE and a collaborative agreement between RMOTC and DOE's GTP to extend and expand testing of geothermal systems. In RMOTC's oil field and many oil fields in general, a large volume of water is produced with the oil. In a majority of these oilfields, water is a waste stream and has a temperature below 250 °F. Because of the large volume, modeling predicts that this water should be hot enough to be capable of generating significant electrical power for facility consumption. To verify this concept, DOE's Rocky Mountain Oilfield Testing Center (RMOTC) and GTP developed a program to test power generation from oil field waste streams.

The initial geothermal power production unit installed was an air-cooled, factory integrated, skid mounted standard design 250 kW Ormat Organic Rankine Cycle (ORC) power plant. This unit was installed at the Naval Petroleum Reserve No. 3 (Teapot Dome Oil Field), north of Casper Wyoming. It was put into service in September, 2008 and operated until February 2009 when the unit was shut down because of operational problems. During this initial period (Phase 1) the unit produced 586 MWhr of power. Operational problems that caused Phase 1 termination resulted in changes in the control system, repairs to the generator/turbine system and field and well system upgrades. The unit was restarted in September 2009. The results since restart, Phase 2, are presented in this paper.

The field in which the Ormat and future units will be installed is a 9,481-acre operating stripper well oil field offering a full complement of associated facilities and equipment on-site. There are 730 well bores in nine producing reservoirs ranging in depth from 250 to 5,500 feet at the field. The wellbores consist of 150 producing wells with the remainder temporarily shut-in or being used for testing. In this field, two formations, the Tensleep and Madison, produce sufficient hot water for the practical generation of geothermal energy. Current produced water from the Tensleep formation is 45,000 barrels of water per day (BWPD), with an average production temperature of ~200°F. The Madison formation is a non-oil producing zone with a flowing resource of 200-210°F water. It is projected that with minor work on existing wells, the rate for the combined Tensleep and Madison produced water would be between 126 and 210 MBWPD.

RESULTS AND DISCUSSION

Geothermal energy production, a $1.5 billion a year industry, generates electricity or provides heat for direct-use applications including aquaculture, crop drying, and district heating. Continuing to build on the technical research base that has been developed over the last several decades, GTP, RMOTC and NREL's activities will provide information and understanding necessary to create new and more efficient and reliable technologies and to enable the U.S. geothermal industry to compete for base-load electricity generation. Recent funding increases, including the American Reinvestment and Recovery Act (ARRA) of 2009, have acted as catalysts that will allow the GTP and its partners to pursue these goals.

The ARRA provided funding for efficient and renewable technologies, including geothermal. Through ARRA, GTP received approximately $380 million to reduce geothermal development risk by investing in a wide portfolio of geothermal programs; 151 projects were selected for negotiation. Using ARRA resources, GTP funded 10 projects to demonstrate energy production from oil and gas fields, geopressured fields, and low temperature resources in a technically feasible and economically viable manner. In total, over $18 million dollars was made available on a cost-share basis for these projects.

Early in 2010, additional financial support was made available through a Funding Opportunity Announcement (FOA), in the following topic areas: low temperature geothermal fluids at temperatures up to 300°F (~150°C); geothermal fluids produced from productive, unproductive, or marginal oil and gas wells, mining operations or other hydrocarbon or mineral extraction processes; and highly pressurized or "geopressured" fluid resources that show potential for cost-effective recovery of heat, kinetic energy, and gas. Out of this FOA process, 7 awardees were selected, with total DOE cost-share of up to $20 million dollars.

In light of this more promising climate for low temperature geothermal development, the present collaboration takes on an even greater importance. The preliminary results below demonstrate that significant results can be achieved over a short time-span and with relatively modest funding. Further data collection and analysis, particularly after commissioning of the second unit, will provide invaluable knowledge to the geothermal community. This is especially true of Levelized Cost of Electricity (LCOE) reductions as they apply to coproduced geothermal applications.

The power output results of the Ormat unit installed at RMOTC are divided into two operational phases. The Ormat unit was put into operation at RMOTC in September 2008 as an air cooled unit. The first operational phase was from September 2008 to February 2009. The first operational phase includes the period from initial startup of the unit until shut down for repair and maintenance and field related work. The second operational phase is from September 2009 to the present. For Phase 1, the net power output averaged 171 kW with a range of 80 to 280 kW. The operational data for the two phases is listed in Table 1. During Phase 1, the unit produced over 586 megawatt hours of power from 3.0 million barrels of coproduced hot water. The online percentage for the unit during this period was 91% considering both field and unit related down time. The down time attributed to unit issues was only 3%. Therefore, the unit had a 97% online percentage. The system related downtimes were largely the results of the operator's learning curve until the shutdown in February 2009.

To date, Phase 2 has averaged 185 kW net power output with a range of 80 to 275 kW, Table 1. During this time, the unit has produced over 1,332 megawatt hours of power from 7.8 million barrels of coproduced hot water. Total produced power from the unit is 1,918 megawatt hours of power from 10.9 million barrels of coproduced hot water. The online percentage for the unit, eliminating downtime caused by field activities, has been a 97%.

The results of this testing have been very promising in demonstrating power production from coproduced fluids in an oil field. Further testing and system improvements should provide even greater and more consistent power production. The online percentage, which currently stands at more than an acceptable 97%, may even be increased by a percentage or two.

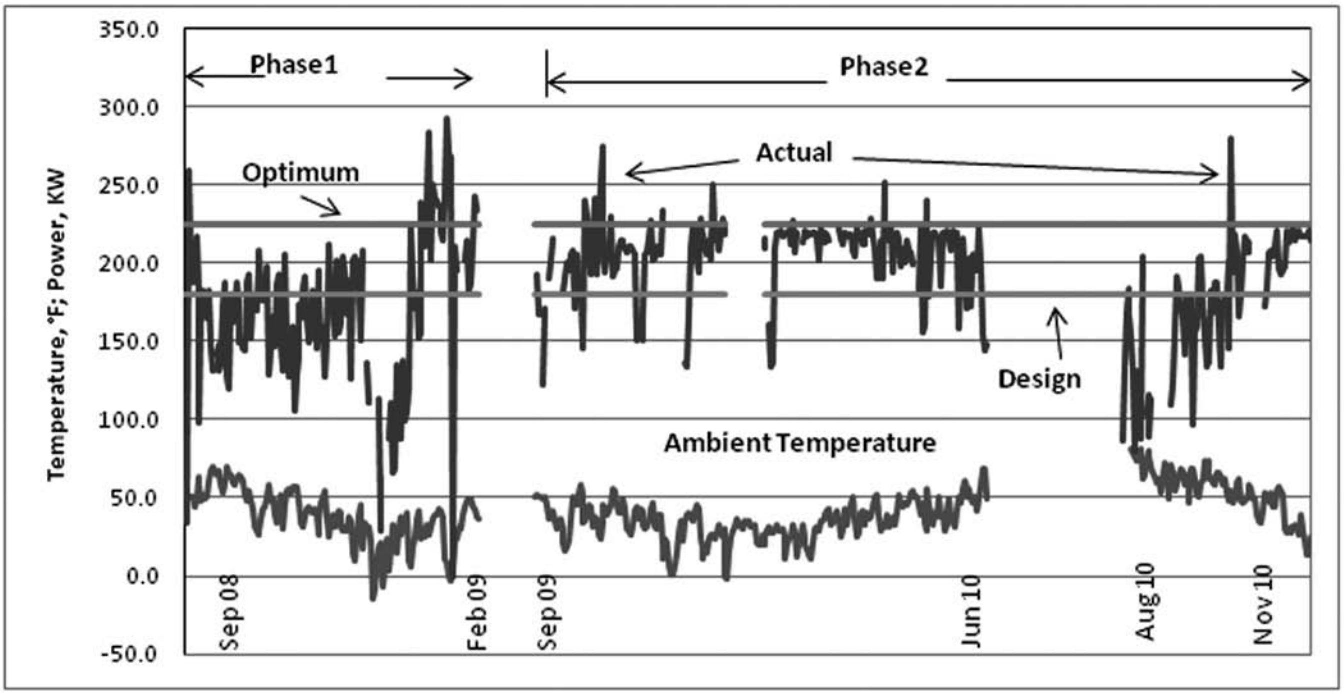


Figure 1: Operating Parameters

Table 1. Design and Operational Data

	Design	Operational Results	
		Phase 1	Phase 2
Flow rate, bpd	40,000	12,000 to 40,000	11,000 to 50,000
Total hot water used, bbl		3,047,192	7,860,737
Inlet water temperature, °F	170	195 to 198	196 to 198
Outlet water temperature, °F	152	80 to 170	47 to 150
Average ambient temp., °F	50	-7 to 85	-2 to 81
Generator gross power, kW	180	105 to 305	105 to300
Daily avg. net power output, kW	132	80 to 280	80 to 275
Overall avg. net power, kW		171	185
Total power produced, MWhr		586	1,332

FUTURE PLANS

GTP's Low Temperature and Coproduced subprogram intends to provide the geothermal community with the means to achieve development and widespread deployment of economically viable, innovative, and scalable technologies that will capture a significant portion of the low temperature geothermal resource base over the next two decades. In order to achieve this goal, the subprogram has identified three avenues, or activity areas, that must be pursued in order to turn this goal into a reality. These areas are advancing technologies, fostering deployment, and informing policy. The RMOTC project will continue to address challenges in both the advancing technologies and fostering deployment areas of the subprogram portfolio.

The GTP subprogram will work to achieve its low temperature power production goals thru a coordinated effort with RMOTC staff. The program will provide funding for continued testing of program related geothermal activities at the site. In addition, future Financial Opportunity Announcements (FOAs) may become available to help companies implement unit testing at the facility. Finally, the subprogram will provide guidance and oversight on all projects, as well as seek to discover and employ innovative concepts and ideas at the RMOTC test site, specifically those related to system improvements. RMOTC plans to continue to operate the unit for an addition 2 years under the collaborative agreement with DOE's Geothermal Technologies Program. Also under this program, a second power generation unit of the same nominal generation capacity but water cooled will be installed and tested for 3 years. This period of performance will provide operational data and experience to transfer to potential users for both air and water cooled systems in both an oil field and low temperature geothermal settings. During this time, RMOTC will be developing a test facility for smaller geothermal systems and developing plans for EGS applications and testing.

NRELs future geothermal activities on this low temperature/coproduction project will be focused on data collection, data analysis and resolving fundamental challenges associated with geothermal technologies. The instrumentation and data systems will be installed on the Ormat and UTC ORC units in the second quarter of 2011. The sensors being procured will monitor temperatures, pressures and flows of the brine and working fluids. Sensors will also be installed to monitor the power output of the unit and the parasitic power consumed by the unit. A weather station will be installed to collect data on ambient weather conditions and the effect of ambient conditions on power output of the unit. Baseline data and long-term data will be collected and stored in NREL databases. Non proprietary data from these units will be made available to the public thru integration with the National Geothermal Data System (NGDS). Publically viewable data display screens of the Ormat and UTC ORC units are being planned to showcase the operation and power output of these coproduction systems. Key data analysis to be reported includes system efficiency calculations, base load power offset, and LCOE determination.

NREL will also be involved in implementing system improvements to the Ormat and UTC ORC units to address current challenges faced in the geothermal industry. After NREL installs the instrumentation and data systems are installed, baseline data will be collected and analyzed to evaluate potential system improvements. Hybrid cooling technology evaluation is the target of NREL's modeling and analysis of the Ormat ORC system. NREL is currently evaluating commercially available hybrid cooling systems that can be retrofitted to the Ormat unit to improve its annual power output. NREL is evaluating hybrid cooling technologies by modeling the performance of the Ormat system in Aspen. The modeling is being performed to evaluate the effectiveness of changing the cooling system from an air cooled condenser to a hybrid air/water cooled system. Modifications/improvements to the UTC PureCycle ORC system are also planned, but no specific process modification/system improvement has been down selected. Overall, NREL's future activities will be focused on recording/analyzing data from these geothermal ORC systems to improve their performance and promote the use of these renewable low temperature geothermal energy technologies.

ACKNOWLEDGMENTS

Reprinted with permission from the Stanford Geothermal Workshop, 2011.

GEO COMES OF AGE

THE GEOTHERMAL EXCHANGE ORGANIZATION IS THE VOICE OF THE U.S. GEOTHERMAL HEATING AND COOLING INDUSTRY

Ted J. Clutter, Geothermal Exchange Organization

There's a kid with a fresh face on the block in Washington, DC—a non-profit trade association plying the halls of government seeking recognition for the renewable energy, efficiency and environmental benefits its members have to offer. GEO - the Geothermal Exchange Organization - is the reincarnation of the former Geothermal Heat Pump Consortium, a government/industry partnership that was primarily aimed at utility support for demand-side energy conservation programs during the 1990s.

"With recent political upheavals in Washington, DC—and the growth of geothermal heat pump installations in the United States to approximately 100,000 units per year," says ClimateMaster, Inc. President and GEO Chairman Dan Ellis, "major equipment manufacturers, distributors and utilities saw the need to refocus Consortium activities toward industry advocacy."

Dan Ellis, ClimateMaster, Inc. President and GEO Chairman

"The current economic and political environment will have significant impacts on the geothermal heat pump industry for the foreseeable future," says WaterFurnace International President Tom Huntington, "We must aggressively educate our elected and professional officials about the benefits of geothermal heat pumps as they consider renewable energy legislation and regulatory policies."

Geo-Enterprises President and CEO Phil Schoen agrees: "By working together, we can secure new opportunities to help grow our industry." Indeed, a major GEO accomplishment was a 30% federal tax credit for residential geothermal heat pump installations, and a 10% break for commercial uses in the latest federal energy bill. Both credits will remain in force until 2016, and have helped the industry to survive and even thrive during the recession.

"GEO's government affairs and outreach strategies are more important than ever to knocking down barriers to growth of the geothermal heat pump industry," says Enertech Manufacturing President Steve Smith. GEO works in four primary areas of outreach to elected officials, government agencies and the public:

ADVOCACY

GEO's legislative and regulatory goals include:

- Qualification of geothermal heat pumps in pending renewable energy and climate legislation.
- Development of model geothermal heat pump policy, legislation and regulations.
- Support of government agencies and initiatives for geothermal heat pump research.
- Accelerated installation of geothermal heat pump systems in government buildings.
- Coordination of grassroots advocacy for the geothermal heat pump industry by GEO Members.

PARTNERSHIPS

GEO actively seeks strategic alliances with allied organizations, institutions and agencies to pursue benefits for the industry, especially:

- Development of joint positions regarding federal and state legislation and regulations.
- Collaboration with electric utilities to promote geothermal heat pump installation programs.
- Work with the U.S. Department of Energy on design and installation standards, and methods for monitoring geothermal heat pump efficiency.

PUBLIC OUTREACH

GEO's public education efforts include GeoExchange® branding and a public awareness campaign, including:

- Education of regulatory officials and legislators about the unique renewable energy advantages of geothermal heating and cooling, and the need for continued installation tax credits.
- Organization of and participation in legislative renewable energy education events at the federal and state levels.
- Encouragement of news media coverage about geothermal heat pumps and industry issues by publications, radio and television.
- Presentations about geothermal heat pumps at venues beyond the industry, including conferences, trade shows, workshops and business meetings.
- GEO's toll-free information consumer hotline, information-packed website, and our unique online GeoExchange Directory.

QUALITY STANDARDS

GEO actively works with the International Ground Source Heat Pump Association and other allied organizations to promote codes and standards for geothermal heat pump installation training, certification and accreditation.

Current issues of importance to GEO include potential climate legislation and a nationwide Renewable Energy Standard. "We want to make sure that geothermal heat pumps are recognized for the peak power use they can save by renewable heat exchange with the earth," says Gulf Power (Southern Co.) Marketing Manager Keith Swilley. GEO is also actively seeking government and university partnerships for geothermal heat pump efficiency and standards research and development.

GEO offers it members the opportunity to assist the association's efforts with a Grassroots Legislative Action Team, and annual training on the most effective ways to educate elected and appointed officials. A bimonthly e-mail newsletter keeps members informed about legislative issues and industry news, and periodic Action Alerts help members educate their local political representatives.

Members also receive GEO Outlook magazine, produced by the International Ground Source Heat Pump Association; listing in the association's online GeoExchange® Directory; exclusive use of the GeoExchange® trademark and logo; and access to the online GeoExchange® Forum - a popular platform for discussions about geothermal heat pumps systems and installation.

GEO membership is open to all companies, businesses, commercial and non-profit organizations entities involved in the geothermal heat pump industry. More information can be found online at: www.GeoExchange.org. Or call GEO at: (888) 255-4436.

GEO-HEAT CENTER
Oregon Institute of Technology
Klamath Falls, OR 97601-8801