GEO-HEAT CENTER

Oregon Institute of Technology Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

FINAL REPORT

U.S. DEPARTMENT OF ENERGY
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TECHNICAL SUPPORT AND TRANSFER OF GEOTHERMAL TECHNICAL KNOWLEDGE AND INFORMATION

PROJECT PERIOD: 04/01/2006 – 09/30/2007

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GEO-HEAT CENTER
OREGON INSTITUTE OF TECHNOLOGY
KLAMATH FALLS, OR 97601

John W. Lund, Project Director

GEO-HEAT CENTER
FINAL REPORT
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TECHNICAL SUPPORT FOR DEVELOPERS, OPERATORS AND END-USERS

This final report for USDOE Office of Science Grant No. DE-FG02-06ER64214 titled "Technical Support and Transfer of Geothermal Technical Knowledge and Information," covers a period of 18 months from April 1, 2006 to September 30, 2007. Six Quarterly Reports were submitted during this period which can be reviewed for more details on the accomplishments. The persons at the Geo-Heat Center (GHC) who were involved in carrying out the activities of this grants were: John W. Lund, GHC Director and Civil Engineer, Tonya "Toni" Boyd, Engineer, Gene Culver, Mechanical Engineer, Andrew Chiasson, Mechanical Engineer, and Debi Carr, Secretary.

Technical Support Summary

The GHC staff provided responses to 1442 technical support requests during the contract period (April 1, 2006 to September 30, 2007), which were six quarters under this contract. Our website, consisting of 1900 files, also contributes to our technical assistance activity. Downloaded files were 1,889,323 (3,448 per day) from our website, the total number of users was 1,365,258 (2,491 per day), and the total number of hits were 6,008,500 (10,064 per day). Graphs of technical assistance, users and downloaded files are attached at the end of this report, showing past trends in light color and values for this grant in dark colors.

These technical assistance requests/responses were from 48 states (except ND and WV), the District of Columbia and Puerto Rico, and included 230 international contacts (16%) from the following 56 countries: Australia, Bangladesh, Canada, Chile, China, Denmark, Djibouti, Egypt, Estonia, Ethiopia, Finland, France, Germany, Ghana, Greece, Hungary, Iceland, India, Indonesia, Iran, Italy, Jamaica, Japan, Kenya, Laos, Lithuania, Malaysia, Mexico, Monaco, Netherlands, Netherland Antilles, New Zealand, Norway, Pakistan, Peru, Poland, Romania, Russia, Saudi Arabia, Slovakia, Slovenia, South Korea, Spain, St. Lucia, Sweden, Switzerland, Sudan, Taiwan, Turkey, Uganda, United Arab Emirates, United Kingdom, Viet Nam and Zambia. A total of 687 contacts (48%) were by email of which 164 (11%) could not be identified as to location. Other forms of communication were by phone: 436 (30%), actual visit: 308 (21%), and mail/fax: 11 (1%). A breakdown of requests relative to applications is: General (501 – 35%), GHP (487 – 34%), Resource/Wells (110 – 8%), Electric Power (69 – 5%), Space Heating/Cooling (74 – 5%), Resort/Spa (55 – 4%), Equipment 46 – 3%), Greenhouses (27 – 2%), Aquaculture (19 – 1%), Industrial (18 – 1%), District Energy (15 – 1%), Snow Melt (14 – 1%), and Regulation/ Environmental (7 – 0.5%). Within the General category of requests, 363 (72%) from professional people or organizations, 71 (14%) were from students, 53 (11%) for database information, and 8 (2%) from other categories.

Of the total 289 inquiries/responses, 157 (54%) from individuals (including students), 77 (27%) were from private companies, 23 (8%) from organizations such as ASHRAE, NREL, GEA, GRC, etc., 17 (6%) from educational institutions, and 15 (5%) from government agencies (federal, state and local).

Details of Major Technical Assistance Projects

A number of technical assistance projects were highlighted in previous Quarterly Reports. Some of the more significant ones are listed below.

Jeld-Wen Geothermal Investigation: Geo-Heat Center staff met with the engineers of the local door and window manufacturer concerning the possibility of finding geothermal hot water on their property near Upper Klamath Lake to provide space and process heat at their plant. Unfortunately, no known geothermal resource exists near their property. They then indicated interest in investing in the proposed deep well and high temperature power plant on campus. The proposal included constructing about a 4,000-foot pipeline from campus to their facility to transmit hot water/steam from the OIT well. In a second meeting, they presented us with a cost estimate along with various tax incentives available to a private company for the electricity generation. Their proposal is under consideration by the OIT financial officer.

Apartment Complex on Old Fort Road, Klamath Falls, OR: Toni Boyd investigated and logged a well that is presently being used to provide space heating for three homes and six duplexes. The well appears to have caved-in near the bottom due to lack of casing for the bottom 200 feet, and thus does not provide enough heat during the coldest period to the buildings. After logging the wells before and after cleaning, it was suggested that a promoter pipe be installed in the well along with the downhole heat exchangers to increase the vertical fluid circulation and thus increase the output of the well. This is presently being undertaken by the well driller and owner.

Steamboat Springs, CO Pavement Snow Melting Project: John Lund visited Steamboat Springs, Colorado to follow up on his feasibility study presented to the City planners and ski area developers for heating walkways at the ski area to melt snow. Temperature gradient holes were being drilled to determine if sufficient temperatures were available for heating the pavement. After making a presentation to interested parties, the size of the project was reduced to 100,000 square feet from the original 200,000 square feet, and geothermal heat pumps were also discussed as an alternative, if sufficient temperatures geothermal resources were not available. A revised feasibility study was prepared and submitted to the City (attached). At the same time, the Heart Springs Municipal Swimming Pool heating system was being upgraded. We offered recommendations for the pool heating systems with revisions to their design.

Veterans Memorial Snow Melt System, Klamath Falls, OR: Toni Boyd and John Lund discussed the design of a snow melt system for a veterans memorial to be constructed in Veterans Park with the local Air Base engineers. Toni Boyd designed a snow melt system pipe configuration and the Geo-Heat Center provided the community project with 600 feet of 5/8-inch PEX pipe left over from another project.

Cheese processing facility, Klamath Falls, OR. We met with Larry Holzgang, Business Development Office of the Oregon Economic and Community Development Department along with James H. Renzas a California realtor (Location Management Services) to discuss the feasibility of using geothermal energy in a cheese processing facility and if there was a geothermal potential on property adjacent to the Klamath Falls airport. We indicated that the potential for a geothermal resource on the property was low, and instead suggest using geothermal heat pumps. We provided the realtor for his client with a recent study for the USDA Farm Bill on a geothermal dairy facility using geothermal heat pumps to indicate the potential of using this equipment and to apply for a renewable energy grant from USDA.

Over the Horizon Back Scatter radar site, Christmas Valley, OR. We met with Trey Senn of the Klamath/Lake County Economic Development Association and representatives of a California firm (TSS Consultants), interested in developing this abandoned site in Oregon and one just south of Klamath Falls in California as a site for solar power using solar photovoltaics. Numerous interested parties from Oregon and California such as country commissioners, economic development persons and state officials were also present. We indicated that we could investigate the geothermal potential at the two sites, to be used in a cooling mode for the project.

Downhole Heat Exchanger Research: The Geo-Heat Center continued on-going applied research and monitoring of PEX (cross-linked polyethylene plastic) downhole heat exchangers (DHE) by designing and installing the second known installation in Klamath Falls (and probably the world) in a geothermal well on Hillside Ave. The well provides both space heat and domestic hot water for two homes, and thus this is the first known PEX installation that provides hot water for two uses, as the first installation at another home in Klamath Falls was only used for space heating. Two PEX "u-loops" were installed in the well and manifolded together as shown in the photograph below. Note that in the photograph, the PEX service DHE loops are the white plastic tubes and the red tube is a single PEX slotted convection promoter and "access" tube for downhole water-level and temperature measurements. A data logger was also installed on the system for recording water temperatures entering and exiting the PEX DHE. Temperatures are being collected at 15-minute intervals, and thus far, the performance has been excellent. During a cold spell in early December of 2006, the air temperature dipped to near 0^{o}F and the DHE provided an average water temperature of about 168^{o}F to both homes, which dropped to about 158^{o}F during a period of heavy domestic hot water use.

In addition to the new PEX installation on Hillside Ave., the Geo-Heat Center is currently working with two other home owners interested in installing a PEX DHE.

Agri-Business Application: The Geo-Heat Center was contacted by a business owner in southern California about using geothermal energy in a unique application. The business currently raises predator mites that are sold to large agricultural crop producers to feed on other mites that are devastating to crops. The use of predator mites eliminates the need for toxic pesticides that have limited use. The predator mites are best grown on bean crops, and require a constant 90^{o}F growing environment in greenhouses. Thus, the business of incubating these predator mites is extremely energy intensive and cost-prohibitive, even in southern California. The Geo-Heat Center staff, in cooperation with the Klamath County Economic Development Association met with the business owners and explained the use and benefits of geothermal energy with tours and discussions. The business owners have completed an agreement to lease land and geothermal water from a local successful geothermal greenhouse and aquaculture operation. The project is now operational on the Liskey Ranch south of Klamath Falls and is using geothermal energy from wells on the property.

Meeting with Chevron Energy Solutions, Klamath Falls, OR: Geo-Heat Center staff met with Dan Hand, Project Development Manger for geothermal direct-use project with Chevron Energy Solutions. He was interested in developing projects in the west and sought our recommendation of sites that had high potential. We discussed numerous locations in the western states and indicated strengths and weaknesses of potential project development. He was especially interested in reports that we had for the Mt. Grant Hospital in Hawthorne, NV and the Onion Dehydration Plant proposed for eastern Oregon.

Parker River National Wildlife Refuge, Newburyport, MA: Decision-makers at the U.S. Fish and Wildlife Services were referred to the Geo-Heat Center by Oak Ridge National Laboratory. This facility has a geothermal heat pump system supplied by two standing column wells. Since its completion in 2003, the system at Parker River has experienced a number of problems and equipment failures and has resulted in accusations and "finger-pointing". During the first winter of operation, the system was occasionally unable to meet heating loads. Well water temperatures were measured to be as low as 36°F, and heat pumps were shutting down on freeze protection. The main cause of problems has been identified as poor quality of water supplied by the wells (high chloride concentration due to proximity to the Atlantic Ocean), which has resulted in corrosion/erosion of flow control valves. The maintenance staff was so fed up with the system that scrapping the whole thing and switching to conventional heating and cooling was being considered. Through numerous email and telephone correspondences with decision makers at the U.S. Fish and Wildlife Services, the Geo-Heat Center restored confidence in preserving the geothermal system, since such a system was the original intent of the building owners. Based on some analyses by the Geo-Heat Center, the building owners are currently pursuing converting the standing column wells to a closed-loop system.

Deep Well, Oregon Institute of Technology, Klamath Falls, OR: The administration on campus requested assistance in evaluating the potential to develop geothermal electric power on campus using the geothermal resource that is presently being utilized to heat the campus. We reviewed literature that suggested a deep and high temperature (above 150^{o}C or 300^{o}F) resource might exist below 3,000 feet based on geochemistry signatures. We prepared several position papers (attached) evaluating the potential and risks of drilling a deep well (up to 5000 feet) and then generating electricity with a 1.2 MWe plant. This would allow the campus to be completely energy independent. We then suggested several consultants (geologists, drilling engineer and economics) to make presentations to the administration, and to prepare in-depth reports on the potential and feasibility of this project, to be presented to potential investors.

Klamath Union High School, Klamath Falls, OR: At the request of the superintendent of the City School District, we prepared a letter report analyzing the potential for geothermal development and use at two sites being considered for a new high school campus. We subsequently met with the architect to discuss the potential at the northern (Linton) site near the Pelican Theater. Since no geothermal resource probably exists at economic drilling depths at this site, two options along with costs were discuss: 1) using geothermal heat pumps, and 2) piping geothermal water about one mile from the old campus site that has geothermal water. We also investigated the old campus site to evaluate the existing wells. Unfortunately, we were unable to obtain temperature readings, but have data from a previous study done by the Geo-Heat Center indicating that the well is around 160^{o}F. We will be assisting the architect in the future as planning and the design develop.

Sacred Heart Church, Klamath Falls, OR: The Sacred Heart Church, one of the largest customers on the Klamath Falls geothermal district heating system, expressed concern about the accuracy of new Btu metering being done by the city. They were considering disconnecting from the system and returning to boiler use, and requested an evaluation of their system by the Geo-Heat Center. We made two site visits, discussed the system with the Deacon and Pastor, and furnished a letter report to the church. In summary, our analysis showed nothing wrong with the system, and in fact, we estimated that they were saving 50% in energy costs with geothermal than if they were to switch back to the boiler. The Geo-Heat Center also obtained annual Btu usage for other customers on the district heating system for comparison to the church to demonstrate that their energy consumption was not excessive.

Lassen Motor Parts, Susanville, CA: A proprietor requested assistance from the Geo-Heat Center regarding cost/benefit of connecting to the City of Susanville geothermal district heating system. We visited the site, discussed options with the store owner, and furnished a letter report (attached).

Wastewater Lagoons, Delta, CO: An engineer requested assistance in determining the heating load required to keep the temperature of wastewater lagoons above 50^{o}F. There are three lagoons spanning about one acre in size. Direct-use geothermal heating and/or heat pumps were being considered by the treatment plant operators. Solar thermal heating was also being considered. The Geo-Heat Center conducted a well survey in the area to evaluate the geothermal resource, and used an hourly energy balance model to calculate lagoon heating loads. We also used a solar energy model to determine adequate size and cost of solar collectors. The most feasible solution appeared to be geothermal heat pumps in an open-loop configuration with groundwater wells.

Idaho Fish and Game, Boise, ID: At the request of the Idaho Energy Division, the Geo-Heat Center became involved with building planners for a new office building for the Idaho Fish and Game, located in Boise, ID. Geo-Heat Center staff met with building planners and participated in a site visit in August. A feasibility study for the building to use geothermal resources was completed in October 2006. The report was 18 pages in length, so only the Executive Summary is attached.

City of Ketchum Sun Valley, Idaho Pavement Snow Melting Project: Andrew Chiasson visited Ketchum to investigate and make recommendations for the use of geothermal heat pumps for a snow melting system for sidewalks along Fourth Street Heritage Corridor in the City. He prepared a feasibility study for Phase I of the construction (attached).

College of Southern Idaho, Twin Falls, ID Heating System: Andrew Chiasson visited the College of Southern Idaho to conduct a preliminary assessment of the feasibility of a geothermal heat pump system for space heating of the planned Human Services and Health Sciences building on campus. The report is attached.

Local Residential Assistance: The Geo-Heat Center staff has provided assistance to a number of local home owners with information on their geothermal well (we have an extensive data base of approximately 500 wells in Klamath Falls). We have also provided temperature profiles of wells and analyzed and suggested modifications to existing home heating systems.

Oregon Institute of Technology (OIT) Geothermal System: The Geo-Heat Center continued on-going engineering support of the OIT campus geothermal district heating system. The Geo-Heat Center provided technical assistance regarding: on-going digital logging of geothermal water temperature going to the injection wells. With monthly geothermal well flows and logged temperatures the GHC estimated the geothermal energy use (and therefore fossil fuel savings) at the OIT campus. We also have ongoing discussion concerning both the low temperature and high temperature geothermal power generation plants proposed for campus.

Snow Melting System, Klamath Falls, OR: Geo-Heat Center staff designed a snow-melting system for an access ramp and stairs at the northeast corner of Cornett Hall at the Oregon Institute of Technology campus. The system will use existing geothermal water that is used to heat the campus.

Review of Technical Papers: The following technical papers were reviewed by GHC staff:

- Andrew Chiasson reviewed two papers for *Geothermics*: “Specification and Optimization of Pump Setting Depths in Geothermal Fields: A Case Study on the Balcova-Narlidere (Turkey) Geothermal Field”, and “Ground Source Performance Benchmarks.”
- John Lund reviewed a paper for *Geothermics*: “Distilled Water Production from Low Temperature Geothermal Shallow Seawater.”
- John Lund and Andrew Chiasson reviewed a Ph.D. thesis from the University of Auckland, New Zealand on: “Identification and Interpretation of Characteristic Periodic Variations of Near Surface Fluids in the Te Aroha, Rotorua, and Orakeikorako Geothermal Fields of New Zealand” by Jonathan David Leaver in Mechanical Engineering.

- "Numerical Modeling of a Geothermal Standing Column Well". Submitted to G*eothermics.* Reviewed by Andrew Chiasson.
- "Influence of Natural Convection in Water-Filled Boreholes for GCHP". Submitted to *ASHRAE Transactions.* Reviewed by Andrew Chiasson.
- "Simulation of District Heating in Tianjian, China." Submitted to *Geothermics.* Reviewed by Toni Boyd.
- "Heat and Cooling" International Energy Authority (IEA) publications – reviewed by John Lund
- "Analysis of the Geothermal Heating System at the Klamath Falls YMCA" – Oregon Institute of Technology student paper by Bobbie Hager – reviewed by John Lund
- "Accelerating the Market Penetration of the Geothermal Heat Pump System" a white paper prepared by Sandy Glatt and Curtis Framel of USDOE for presentation to the Deputy Undersecretary of EERE at USDOE, Andrew Karsner. It was heavily edited by Toni Boyd, Andrew Chiasson and John Lund and also sent to several others from review. Status unknown at this time.
- Toni Boyd, Andrew Chiasson, and John Lund attended the Geothermal Resources Council technical paper review sessions (to select papers for the 2007 GRC Annual Meeting) in Sparks, NV. We reviewed 10 papers on direct-use and geothermal heat pumps.

<u>In addition, samples of other technical assistance reports are attached to this document. These include:</u>

- Lassen Motor Parts Connection to the Susanville, CA district heating system.
- Oregon Institute of Technology/Geo-Heat Center Low-Temperature Power Generation Proposal
- Oregon Institute of Technology/Geo-Heat Center High-Temperature Power Generation Proposal
- Geothermal Greenhouse Facility, Oregon Institute of Technology/Geo-Heat Center
- Geothermal Aquaculture Facility, Oregon Institute of Technology/Geo-Heat Center
- Geothermal Energy at New Mexico State University in Las Cruces, NM
- Habitat for Humanity, Heat Pump Savings, Grand Junction, CO
- H&H Farms Greenhouses Investigation, Boise, ID
- "Chill Out!" – Campus Solutions to Global Warming, Oregon Institute of Technology
- Examples of Combined Heat and Power Plants Using Geothermal Energy – technical paper by John W. Lund and Andrew Chiasson. Presented at the Geothermal Resources Council Annual Meeting 2007 and at the PNOC Geothermal Conference, Philippines.
- Feasibility Study Walkway Snowmelt System, Steamboat Springs Ski Area, CO (revised)
- Feasibility Study for Geothermal Heat Pump System for Snow-Melting at the Fourth St. Heritage Corridor, Ketchum, ID
- Preliminary Feasibility Study for the Geothermal Heat Pump System at the College of Southern Idaho, Twin Falls, ID.

CASE STUDIES

Four case studies were published in the recent issue of our Quarterly Bulletin (Vol. 27, No. 4) prepared by Andrew Chiasson and Gordon Bloomquist. These are with their corresponding website links:

"From Creamery to Brewery with Geothermal Energy: Klamath Basin Brewing Company", http://geoheat.oit.edu/bulletin/bull27-4/art1.pdf.
"Bonnevile Hot Springs Resort", http://geoheat.oit.edu/bulletin/bull27-4/art2.pdf
"Ouray Hot Springs Motel, Lodges & Spas", http://geoheat.oit.edu/bulletin/bull27-4/art3.pdf,
"The Veterans Administration Hospital District Heat System."
http://geoheat.oit.edu/bulletin/bull27-4/art4.pdf

Two case studies were published in the recent issue of our Quarterly Bulletin (Vol. 28, No. 1) prepared by Andrew Chiasson and Claude Sapp. These are with their corresponding website links:

"Greenfuels of Oregon: Geothermal Energy Utilization in Biodiesel Production"
http://geoheat.oit.edu/bulletin/bull28-1/art3.pdf.
"Geothermal Power Generation and Biodiesel Production in Wabuska, Nevada"
http://geoheat.oit.edu/bulletin/bull28-1/art4.pdf

One case study was published in the recent issue of our Quarterly Bulletin (Vol. 28, No. 2) prepared by Brian Brown, a local consulting engineer. It is with the corresponding website link:

"Klamath Falls Geothermal District Heating System at 25 Years" by Brian Brown.
http://geoheat.oit.edu/bulletin/bull28-2/art2.pdf

PROVIDING EDUCATIONAL MATERIAL

The Geo-Heat Center receives approximately 1000 requests annually for assistance in developing and using geothermal resources. Many of these inquiries can be best addressed by providing a concise document on specific subject area with appropriate diagrams, graphs, photographs, etc., to the user. We presently have over 100 such documents, available either in hard copy or through our website as PDF files. During the grant period we mailed out 918 papers and Quarterly Bulletins; distributed 4,000 documents at energy fairs and professional conferences, in Anchorage and Chena Hot Springs Alaska, Portland, Salem, Bend and John Day, OR, Tucson, AZ, San Diego, CA, Tokyo, Japan, Addis Abba, Ethiopia, and Denver, CO. We also distributed 530 documents to students from local grade and junior high schools in "Girls in Science" and "I'm Going To College" workshops on the OIT campus, 26 publications to Mexican students and Korean Professor who visited campus. In addition we mailed out 16 of our 454-page "Geothermal Direct-Use Engineering and Design Guidebook."

QUARTERLY BULLETIN

The first issue of our Quarterly Bulletin (Vol. 27, No. 3 – September, 2006) was completed under this contract. This issue consists of 20 pages with a theme of "Hot Springs, Power and Ice" and included the following articles:

We are Back by The Editor (John W. Lund)

Chena Hot Springs by John W. Lund

Absorption Chiller for the Chena Hot Springs Aurora Ice Museum by Gwen Holdmann and Donald C. Erickson

Steamboat Springs, Colorado by John W. Lund

Strawberry Hot Springs by John W. Lund

Hot Sulphur Springs, Colorado by John W. Lund

Peninsula Hot Springs – A Developers Story by Charles Davidson

Approximately 2000 copies were mailed to subscribers free of charge, including 30 international ones. This issue is also available on our website at: http://geoheat.oit.edu/bulletin/bull27-3/bull27-3-all.pdf.

The second issue of our Quarterly Bulletin (Vol. 27, No. 4 – December, 2006) was completed under this contract. This issue consists of 20 pages with a theme of "Utilizing Geothermal" and consisted of the following articles

From Creamery to Brewery with Geothermal Energy: Klamath Basin Brewing Company by Andrew Chiasson

Bonneville Hot Springs Resort by R. Gordon Bloomquist

Ouray Hot Springs Motels, Lodges & Spas by R. Gordon Bloomquist

The Veterans Administration Hospital District Heating System by R. Gordon Bloomquist

Micro-Geothermal Devices for Low-Energy Air Conditioning in Desert Climates by John Abraham and Gamille George

Geothermal Projects Proposed for the Oregon Institute of Technology Campus by John W. Lund

Approximately 2000 copies were mailed to subscribers free of charge, including 30 international ones. This issue is also available on our website at: http://geoheat.oit.edu/bulletin/bull27-4/bull27-4-all.pdf.

The third issue of our Quarterly Bulletin (Vol. 28, No. 1 – March 2007) was completed under this contract. This issue consists of 20 pages with a theme of "BioFuels from Geothermal" and consisted of the following articles

Biofuels from Geothermal by The Editor (John Lund)

Geothermal Energy Utilization in Ethanol Production by Andrew Chiasson

Greenfuels of Oregon: Geothermal Energy Utilization in Biodiesel Production by Andrew Chiasson

Geothermal Power Generation and Biodiesel Production in Wabuska, Nevada by Claude Sapp

Design of a Geothermal Energy Dryer for Beans and Grains Drying in Kamojang Geothermal Field, Indonesia by Untung Sumotarto

Approximately 2000 copies were mailed to subscribers free of charge, including 30 international ones. This issue is also available on our website at: http://geoheat.oit.edu/bulletin/bull28-1/bull28-1-all.pdf.

The fourth issue of our Quarterly Bulletin (Vol. 28, No. 2– June 2007) was completed under this contract. This issue consists of 24 pages with a theme of "Geothermal Energy Use" and consists of the following articles

Characteristics, Development and Utilization of Geothermal Resources by John W. Lund

Klamath Falls Geothermal District Heating System at 25 Years by Brian Brown

"Chill Out" – Oregon Institute of Technology is a Winner by John W. Lund and Toni Boyd

Continuing Advances in PEX Downhole Exchangers for Direct-Use Heating Applications by Andrew Chiasson and Ron Swisher.

Approximately 2000 copies were mailed to subscribers free of charge, including 30 international ones. This issue is also available on our website at: http://geoheat.oit.edu/bulletin/bull28-1/bull28-1-all.pdf.

The fifth issue of our Quarterly Bulletin (Vol. 28, No. 3– September 2007) was completed under this contract. This issue consists of 28 pages with a theme of "Sustainability – World

Generation - Australia" and consists of the following articles

Comments from the Editor by John W. Lund

Geothermal Sustainability by Ladislaus Rybach

World Geothermal Generation in 2007 by Ruggero Bertaini

The Burgeoning Australian Geothermal Energy Industry by Graeme Beardsmore

Approximately 2000 copies were mailed to subscribers free of charge, including 30 international ones. This issue is also available on our website at: http://geoheat.oit.edu/bulletin/bull28-3/bull28-3-all.pdf.

SHORT COURSES, WORKSHOPS AND PROFESSIONAL CONFERENCES

The following is a list of the short courses, workshops and professional conference attended by the GHC staff. Many, especially the international ones, were either all or in-part funded by outside sources and, thus, not charged to this grant. Details of each of these meetings can be found in the quarterly reports. The main presentations are also listed below.

International Geothermal Association Board of Directors Meeting, Brussels, Belgium (April 3-4, 2006):

Utility Geothermal Working Group Webcast, GeoExchange Applications (April 18, 2006): Andrew Chiasson gave a presentation on "GeoExchange Technologies."

Renewable Energy Working Group meeting, Salem, Oregon (April 20, 2006):

Geothermal Resources Council paper review meeting, San Diego, CA (May 8-9, 2006):

Geothermal Resources Potential Workshop, NREL, Golden, CO (May 16, 2006), John Lund provided input on direct-use potential in the U.S.

Arizona Geothermal Direct Use Conference, Phoenix, AZ (May 18-19, 2006).

California Tribal Geothermal Workshop, Susanville, CA (June 8-9, 2006):

ASHRAE Annual Summer Meeting, Quebec City, Quebec, Canada (June 26-28, 2006):

Australian Earth Sciences Convention, Melbourne, Australia (July 2-7, 2006). John Lund presented a talk on "Direct Heat Utilization of Geothermal Resources Worldwide 2005".

American Society of Agricultural and Biological Engineers Annual International Meeting in Portland,OR (July 9-12, 2006). Toni Boyd presented talks on "Geothermal Heating of

Greenhouse and Aquaculture Facilities” and “Greenhouse Heating with Geothermal Heat Pump Systems.”

2nd Annual Alaska Renewable Energy Fair, Anchorage, AK (August 12, 2006).

2006 Alaska Renewable Energy Fair, Chena Hot Springs, AK (August 20, 2006). Toni Boyd gave a presentation on “Geothermal Heat Pumps.”

2006 Alaska Geothermal Conference, Chena Hot Springs, AK (August 21-22, 2006).

Sohn International Symposium on Advanced Processing of Metals and Materials; Principles, Technologies and Industrial Practices, San Diego, CA (August 30, 2006). John Lund gave a presentation on “Research on the Use of Waste Silica from the Cerro Prieto Geothermal Field, Mexico.”

Mineral Extraction from Geothermal Brines Workshop, Tucson, AZ (September 6-9, 2006). John Lund gave a presentation on “Research on the Use of Waste Silica from the Cerro Prieto Geothermal Field, Mexico.”

Geothermal Resources Council Annual Meeting, San Diego, CA (September 10-14, 2006). John Lund gave a presentation on “Research on the Use of Waste Silica from the Cerro Prieto Geothermal Field, Mexico.”

Girls in Science Workshop, Klamath Falls, OR (September 30, 2006). John Lund gave a presentation on “Introduction to Geothermal Energy” and Toni Boyd gave a tour to 12 science teachers.

World Geothermal Congress 2010 Planning Meeting, Jarkarta, Indonesia (October 3-5, 2006).

Oregon Environmental and Health Association Meeting, Klamath Falls, OR (October 6, 2006). Toni Boyd gave a presentation on “Geothermal Fluids in Oregon” and gave a tour to 12 attendees.

International Geothermal Association Board of Directors Meeting, Chiba, Japan (October 8-9, 2006).

New Perspective of Geothermal Energy Utilization in Japan, Chiba, Japan (October 10, 2006). John Lund and Gordon Bloomquist (Washington State Energy Program) gave a presentation on “Status of Goethermal Use and Development in the United States.”

Renewable Energy 2006, Chiba, Japan (October 11-13, 2006). John Lund gave a keynote presentation on “Present Utilization and Future Prospects of Geothermal Energy Worldwide – 2006.”

Leadership Klamath Meeting, Klamath Falls, OR (October 17, 2006). Toni Body gave a presentation on "Introduction to Geothermal Energy" and gave tour to 22 attendees.

President's Round Table Forum, Oregon Institute of Technology, Klamath Falls, OR (October 31, 2006). John Lund and Toni Boyd gave a presentation on the potential geothermal projects on the campus – as presented in the technical assistance papers that are attached.

Oregon State Geothermal Working Group Meeting, Bend, OR (November 7, 2006). John Lund and Toni Boyd gave a presentation on the potential geothermal projects on the campus – as presented in the technical assistance papers that are attached.

Cellulosic Ethanol Pre-Summit, Washington, D.C. (November 13, 2006).

Geothermal Development and Finance Workshop, Washington, D. C. (November 14, 2006).

The First International East African Rift Geothermal Conference, Addis Ababa, Ethiopia (November 26-29, 2006). John Lund gave a keynote presentation on the "History, Present Utilization and Future Prospects of Geothermal Energy Worldwide" and a 2nd paper on "Direct Utilization of Geothermal Energy."

Klamath Basin Renewable Energy Conference, Klamath Falls, OR (November 29, 2006).

Biotactics Meeting with Klamath County Economic Development Association, Klamath Falls, OR (December 15, 2006). .

Webinar, Klamath Falls, OR (January 10, 2007). Andrew Chiasson made a presentation to the Utility Geothermal Working Groups thru the Internet on "Direct Use Geothermal Options."

Rotary Luncheon, Klamath Falls, OR (January 18, 2007). John Lund gave an invited presentation on "Geothermal Utilization" which included a general overview of geothermal energy and on the proposed geothermal projects on the OIT campus.

Geothermal Resources Council Board of Directors meeting, Burlingame, CA (January 25, 2007).

ASHRAE Winter Meeting, Dallas, TX, (January 27-31, 2007).

Harvesting Clean Energy Conference, Boise, ID (January 28-31, 2007).

Colorado GeoPowering the West meeting, Denver, CO (January 31, 2007).

Oregon Institute of Technology Day at the Capital, Salem, OR (Februrary 8, 2007).

World Geothermal Congress 2010 organizational meeting, Bali, Indonesia (February 18-21, 2007). John Lund gave a presentation on the "History, Presentation Utilization and Future Prospects of Geothermal Energy Worldwide."

PowerGen Conference, Las Vegas, NV (March 7, 2007). Andrew Chiasson presented a paper on "Examples of Combined Heat and Power Plants Using Geothermal Energy."

Geoexchange BC 2007 meeting, British Columbia, Canada (March 9, 2007). Andrew Chiasson presented a paper on "Overview and Design of Hybrid Geoexchange Systems with Solar Collectors."

International Geothermal Association, Board of Directors Meeting, Manila, Philippines (March 5-6, 2007).

National Geothermal Association of the Philippines, 5th General Assembly Meeting, Manila, Philippines (March 6, 2007). John Lund presented an invited paper on "Utilization of Geothermal Energy Worldwide – Its Contribution to Energy Security."

The 28th Philippines National Oil Company Energy Development Corporation (PNOC EDC) Geothermal Conference, Manila, Philippines (March 7-8, 2007). John Lund presented a paper on "Examples of Combined Heat and Power Plants Using Geothermal Energy."

International Energy Agency – Geothermal Implementing Agreement meeting, Nice, France (March 21-23, 2007).

Chill Out: Campus Solutions to Global Warming, National Wildlife Federation (March 13, 2007).

Renewable Energy in Oregon: Opportunities, Obstacles and Outlook, Portland, OR (April 2, 2007).

Desalination of Brackish Waters, University of Mexico, Mexico City, (April16-18, 2007).

Seminar on Geothermal Energy, Institute of Electrical Investigations, Cuernavaca, Mexico (April 18, 2007). John Lund gave an invited paper on "Geothermal Heat Pump Technology and Utilization."

Chill Out: Campus Solutions to Global Warming, National Wildlife Federation, Washington, D. C. (April 16-19, 2007). Toni Boyd made a presentation on the use of geothermal energy on the OIT campus – see the attached material in the technical assistance section for more details.

International Ground Source Heat Pump Association, Oklahoma State University (April 23-27, 2007).

XIII National Congress of Geologists, Matera, Italy (May 10-12, 2007). John Lund presented an invited paper on "Characteristics, Development and Utilization of Geothermal Resources."

2007 Joint Engineering Conference, Bend, OR (May 17, 2007). Andrew Chiasson gave a presentation on "Geothermal Heat Pump Design."

Geothermal Resources Council, Technical Paper Review, Sparks, NV (May 21-22, 2007).

European Geothermal Congress 2007, Unterhaching, Germany, (May 29- June 2, 2007). John Lund gave a paper on “Examples of Combined Heat and Power Plants Using Geothermal Energy.”

Central Oregon Energy Fair, Bend, OR, (July 14-15, 2007).

Northwest Section of Geothermal Resources Council and GeoPowering the West Meeting in Portland , OR, (July 23, 2007).

Sol West 2007, Energy Fair, John Day, OR, (July 27-29, 2007).

Pavement Snow Melting Project, Steamboat Springs, CO, (August 1-3, 2007).

International Solar Energy Society Conference 2007, Beijing China, (September 18-21, 2007). John Lund gave a keynote paper on “Development and Utilization of Geothermal Resources.”

Geothermal Resources Council Annual Meeting, Sparks, NV, 30 September, (October 1-3, 2007). John Lund gave a paper on “Examples of Combined Heat and Power Plants Using Geothermal Energy.”

COMPREHENSIVE DATA BASES

The Geo-Heat Center has developed and maintained comprehensive databases of geothermal resources locations (over 12,000 wells and springs) in 16 western states, and information on specific geothermal developments in the United States (over 450 entries), including location, energy use, and contact person. In addition, a number of existing software programs, developed by staff members at the Geo-Heat Center have been formatted for Microsoft Excel with accompanying documentation in pdf format. The well and spring database is available on CD-ROM either for the entire 16 states or by individual states. Over this grant period we have distribution 24 copies of the databases CD-ROMs. The software programs are also available on CD-ROM. During this period we have distributed 71 copies of these software programs.

APPLIED RESEARCH AND DEVELOPMENT

Equipment for soil/rock thermal conductivity testing has been purchased for use with designing geothermal heat pump closed loop piping systems. This equipment will provide assistance to contractors and users of geothermal heat pump systems to optimize the loop lengths. This device was used in Hawaii to test a downhole heat exchanger application in a well near Puna on the island of Hawaii.

Two years ago we installed a PEX (cross-linked polyethylene) pipe system as a downhole heat exchanger in a well. The purpose was to test this material as an alternate to the typical black iron pipe used in most installations in Klamath Falls. A well at a second home in Klamath Falls was outfitted with this system in October, 2006 in order to verify the data from the first well. We also installed and tested this system in Hawaii near Hilo under another grant.

The third well with PEX (cross-linked polyethylene) pipe was installed on 1965 Leroy Street. Five loops were place in the well – 220 feet long to the bottom of the well. It will be used to heat a residence, garage and snow melt system for the patio and driveway. An example of this system appear under the technical assistance section above and as a technical article in Vol. 28, No. 2 of the Quarterly Bulletin – the link is http://geoheat.oit.edu/bulletin/bull28-2/bull28-2/art.4.pdf.

COMPREHENSIVE GEOTHERMAL LIBRARY

Approximately 5,700 books, journals, maps and monographs are available for use at the Geo-Heat Center Library. We also have an extensive library of CD-ROM with presentations and proceedings from various conference and workshops, from which we can download papers as requested. A number of journals and magazine, mainly related to biofuels, were added to the library along with news reports from the International Geothermal Association, the Geothermal Energy Association, Geothermal Resources Council, and Geothermal biz.com. Approximately 10 publications along with various journals and newsletter have been added to our library over the period of this grant.

COMPREHENSIVE INTERNET WEBSITE

The Geo-Heat Center website, maintained by Toni Boyd and consisting of approximately 1,900 files, provides a variety of technical information to potential developers and users that is also consider technical assistance. The following website activity occurred during the 18-month period of this grant:

Total Users:	1,365,258	Average user per day:	2,491
Total hits	6,008,500	Average hits per day:	10,964
Total downloaded files	1,889,323	Average per day:	3,448

Top downloaded files (Session Downloads)

1-Geothermal Direct-Use Case Studies	84,408
2-Heat Exchangers, Chapter 11*	74,779
3-Ground-Coupling with WSHP	71,335
4-Cost Containment for GSHP	47,817
5-Drilling and Well Construction, Chapter 6*	45,747
6- Piping - Chapter 10*	38,283
7-Scaling in GHP Systems	37,780
8-Absorption Refrigeration, Chapter 13*	28,159
**9-Engineering Cost, Chapter 17*	26,461+

10-Specs of Water Wells	24,879
**11-GHP Owner Info. Survivial Kit	
**12-Ground-Source Heat Pump Case Studies	23,586+
**13-Geothermal (Ground-Source) Heat Pumps A World Overview, Bulletin 25/3	22,232+
**14-Residential Swimming Pool with GHP	16,546+

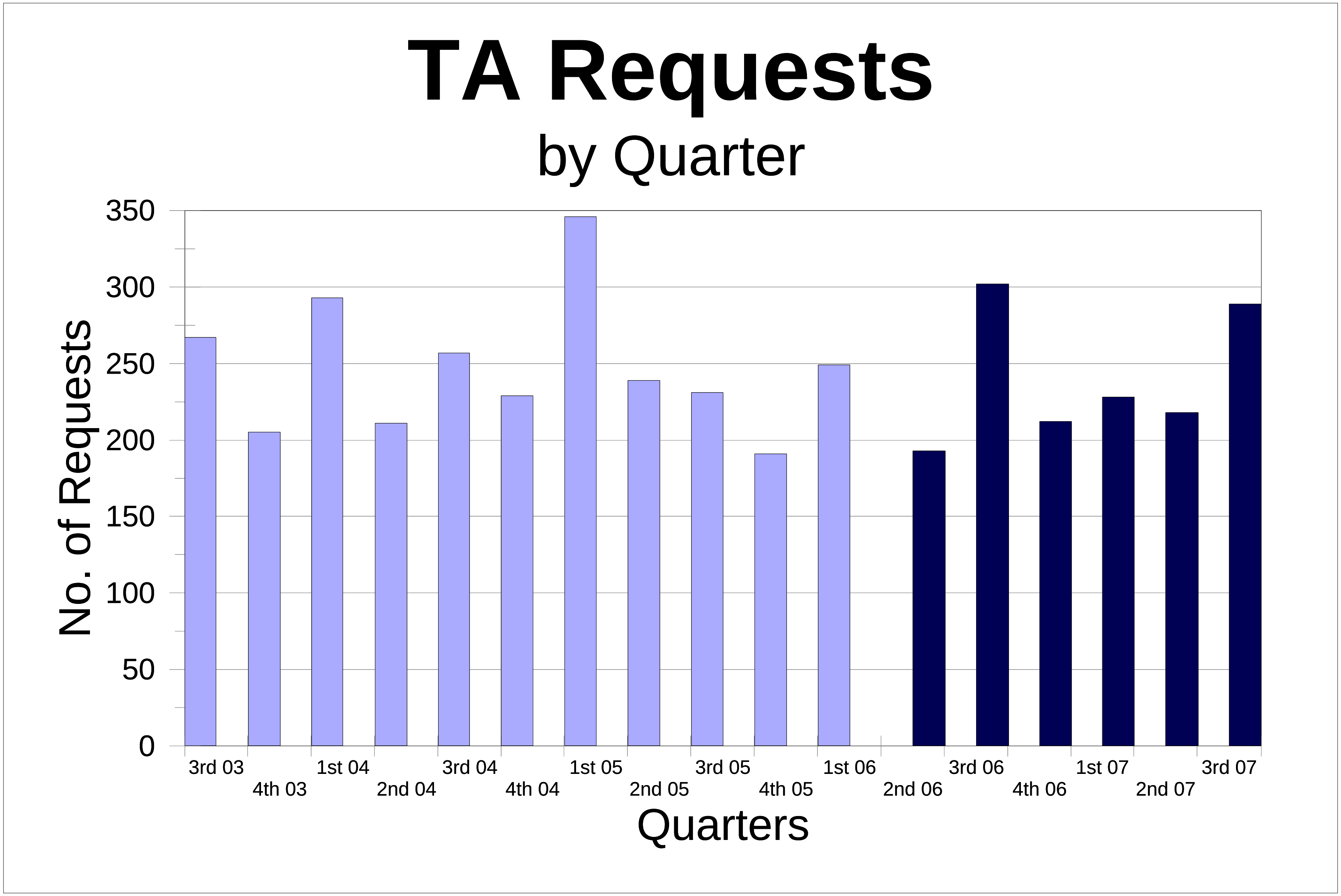
WSHP = water source heat pumps; GSHP = ground source heat pumps; GHP = geothermal heat pumps
*indicates chapters from our 454-page publication: "Geothermal Direct-Use Engineering and Design Guidebook."
**indicates that the ranking and values for these five items is in question due to insufficient data.

Based on limited data, the top users by International Countries (approximately 10% of total):

Canada, United Kingdom, Australia, India, Germany, Italy, New Zealand, Netherlands and Turkey.

MARKET OPPORTUNITIES

The Geo-Heat Center staff has discussed market opportunities to potential developers through our technical support activities and at professional meetings. Recent interest has been in low-temperature geothermal power generation, and in these cases we have provided contacts for several manufactures of these units in the United States. We are also promoting the use of PEX (cross-linked polyethylene) pipe for downhole heat exchangers and pavement snow melting systems which is manufactured in the United States. Finally, we are also promoting the low temperature power plant developed by United Technologies Corporation, similar to the one installed at Chena Hot Springs in Alaska (see the Quarterly Bulletin article – http://geoheat.oit/bulletin/bull27-3/bull27-3/art.2.pdf). We have been working with Halley Dickey of UTC and Dan Schochet of ORMAT International of Reno, NV to develop a potential project for the Oregon Institute of Technology campus. We have talked to the City of Klamath Falls about installing such a power plant in the upstream side of their district heating system which provides up tot 220^{o}F water from a well.



TA Requests
by Quarter
No. of Requests
350
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250
200
150
100
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0
3rd 03
4th 03
1st 04
2nd 04
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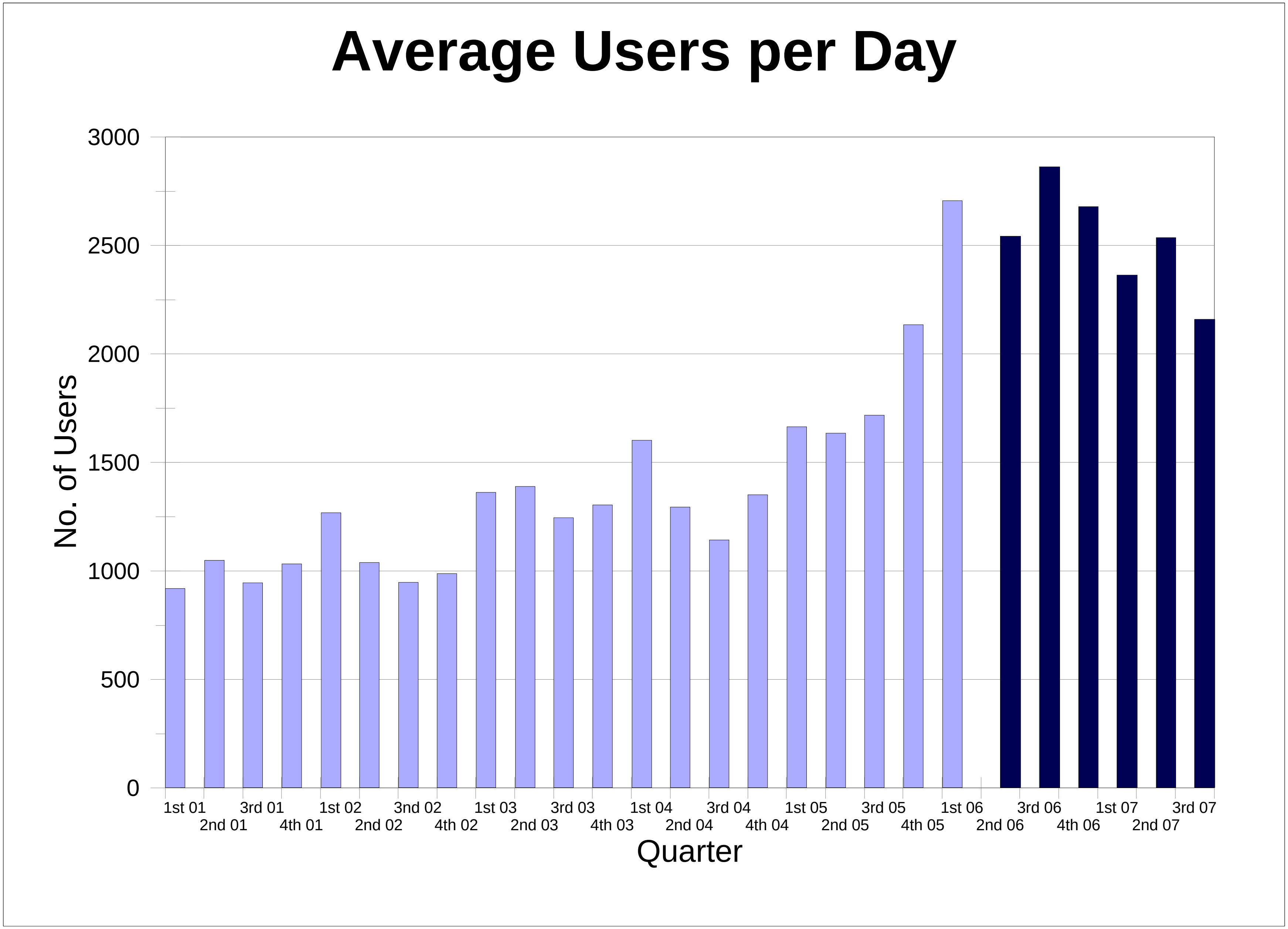
Quarters


Average Users per Day
No. of Users
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2500
2000
1500
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500
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1st 01
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3rd 01
4th 01
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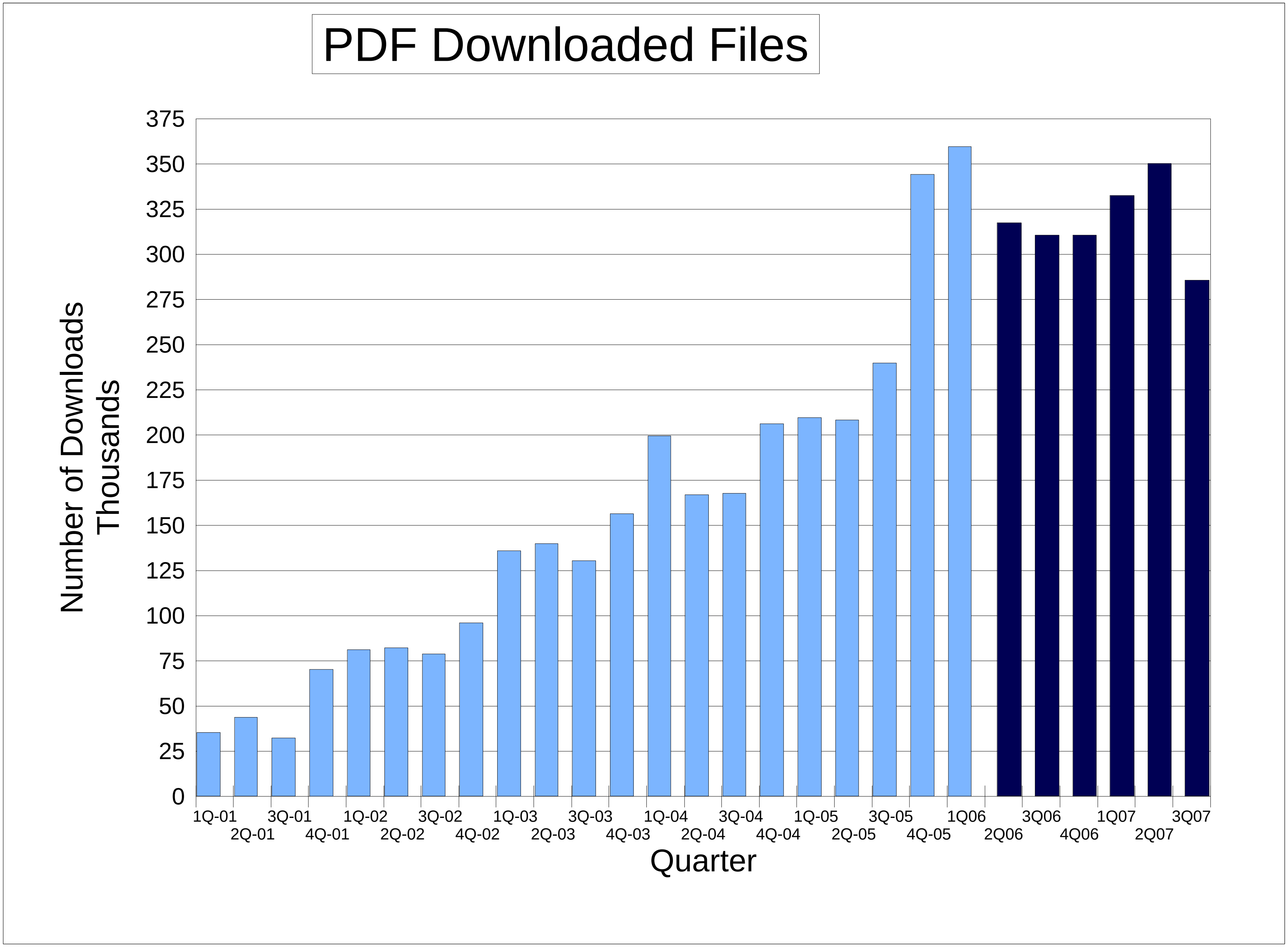
PDF Downloaded Files
Number of Downloads
Thousands
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325
300
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250
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200
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150
125
100
75
50
25
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1Q-01
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3Q-01
4Q-01
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Quarter

GEO-HEAT CENTER

Oregon Institute of Technology, Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

John W. Lund, Director
Andrew Chiasson
Tonya "Toni" Boyd

TO: Kyle Porter
Lassen Motor Parts
1289 Main St.
Susanville, CA 96130-4422

June 16, 2006

RE: Connecting to the Susanville Geothermal District Heating System

Dear Kyle,

We completed our estimate of costs and savings for you to connect to the Susanville geothermal district heating system based on the information we have. When we visited on June 8, Mike Namo of the Susanville Water Department told us that your geothermal fee would be $0.38/ sq. ft, based on 8,800 sq. ft of floor space. When we asked over what time period this would apply to, he was unsure and said that Craig Platt would have to confirm this. As we've been unable to get in touch with Craig, we assumed that this charge would be for one year, which would amount to $3,344 per year. If this was the cost per month, the geothermal fee would be $40,128 per year, which obviously wouldn't make any sense. The actual fee would need to be verified and quoted in writing before doing anything.

Based on the last two years of natural gas usage at your facility, the economics of pursuing connecting to the geothermal system are:

Estimated future annual natural gas costs at (2006 rates):	*$9,800*
Annual geothermal fees (@ $0.38/ sq. ft, 8,800 sq. ft):	*$3,344*
Annual Savings:	***$6,456***
Estimated cost to connect to the geothermal main and retrofit existing furnaces to hot water:	*$13,530*
Payback period on energy savings:	***2 to 3 years***

The payback period looks very good. The next step would be to get actual price quotes on the work. The following describes more details of the retrofit, a breakdown of our cost estimate, and some possible retrofit equipment.

Connecting to the Susanville Geothermal System and Retrofitting Existing Equipment

Figure 1 shows a sketch of our proposed geothermal retrofit design. A brazed plate heat exchanger is included to isolate the geothermal water from and prevent corrosion of the heating equipment. Software printouts and example equipment components are included at the end of this letter report.

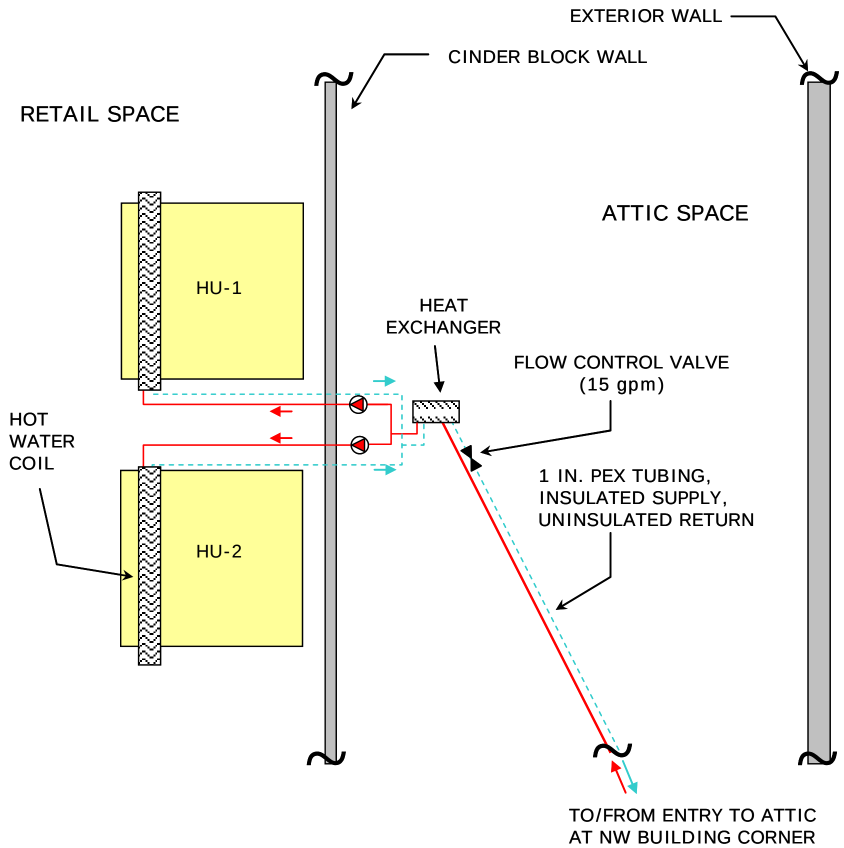


Figure 1. Sketch of retrofit equipment

To tap into the geothermal mains (supply and return), all that is needed is a weldolet, fittings, and shutoff valves. On the geothermal supply side we sized the system for 1-inch cross-linked polyethylene (PEX) pipe from the mains to the heat exchanger, which we propose to be located in the attic. PEX pipe has a high durability, high temperature and pressure rating (200°F @ 80 psi), and is flexible and easy to install. From our site visit, it appears easiest to run the PEX pipe up the back exterior wall (in a protective covering), penetrate the building wall near the NW corner, and run the PEX pipe across the attic space to where the furnaces are located. We recommend purchasing insulation separately and insulating the supply line only. The heat exchanger was sized for 15 gpm flow through the geothermal side, which amounts to less than 10 psi drop across the city supply and return mains.

The retrofit hot water coils need to be located upstream of all flex ducts exiting the discharge plenum. Hot water coils were sized using manufacturer's software, and no practical coils exist in a size that would fit into the existing plenum. Although the contractor you select may have access to a different brand of coils, USA Coil manufactures one with an overall width (including casing) of just over 26 inches (see attached details). The existing discharge plenum is 19 in. wide, so the plenum will need to be re-fabricated to accommodate the coils.

Supply (and return) water to the coils will be "clean" water circulated by small Grundfos (or similar) pumps of 1/12 horsepower. These should be wired into thermostats so that they are only activated when the building calls for heat. Operated in this manner, annual electrical costs for the pumps are on the order of $50 to $100. At the design conditions, pump "5" or "7" on the attached sheets would be a good pump selection.

Cost Estimate

A breakdown of our cost estimate is as follows:

Item	Unit	Quant.	Unit Cost	Amount	Totals
OUTDOOR WORK					
City fee for geothermal water main tap	lump	1	$200	$200	
Geothermal water main taps, fittings, valves	lump	1	$500	$500	
Cut, remove, haul asphalt, repave	ft	80	$20	$1,600	
Trench excavation, pipe bedding, backfill	ft	80	$10	$800	
PEX pipe installation (insulated supply, uninsulated return)	ft	90	$10	$900	
Wall cut, water-tight sealing	lump	1	$200	$200	
					$4,200
INDOOR WORK					
PEX pipe installation in attic (insulated supply, uninsulated return)	ft	80	$10	$800	
Fittings, valves, pressure & temperature gauges	lump	1	$500	$500	
Hot water coils, sheet metal fabrication, retrofit work on furnaces	lump	1	$3,800	$3,800	
Circulating pumps + installation	lump	2	$250	$500	
Heat exchanger (brazed) + installation	lump	1	$1,500	$1,500	
Thermostat controls + wiring	lump	1	$1,000	$1,000	
					$8,100
TOTAL (+10% contingency)					**$13,530**

Sincerely,

Andrew Chiasson, Toni Boyd

HEAT EXCHANGER SELECTION DETAILS

v.1.3.0

SWEP International AB
P.O. Box 105
Hjalmar Brantingsväg 5
261 22 Landskrona
Sweden

SWEP SSP CBE

HEAT EXCHANGER: B10Tx50H/1P

SINGLE PHASE - Design

Customer: Date: 6/15/2006
Reference: Our Ref.:

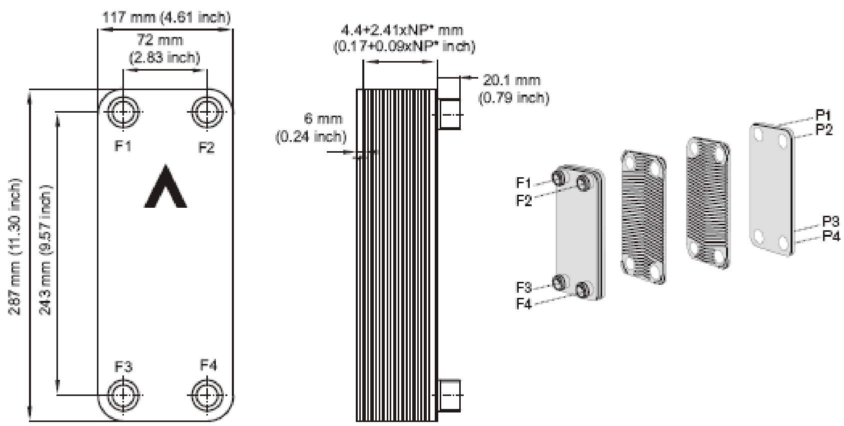
DUTY REQUIREMENTS			**SIDE 1**		**SIDE 2**
Fluid Side 1	Water				
Fluid Side 2	Water				
Inlet temperature	°F	:	165.00		127.36
Outlet temperature	°F	:	137.71		150.00
Flow rate	US gpm	:	15.00		18.00
Max. pressure drop	psi	:	20.0		7.25
Thermal length	NTU	:	2.18		1.81
PHYSICAL PROPERTIES					
Reference temperature	°F	:	151.36		138.68
Dynamic viscosity	cP	:	0.426		0.472
Dynamic viscosity - wall	cP	:	0.447		0.450
Density	lb/cuft	:	61.17		61.40
Specific heat capacity	Btu/lb,°F	:	1.001		0.9998
Thermal conductivity	Btu/ft,h,°F	:	0.3814		0.3776
PLATE HEAT EXCHANGER					
Heat load	Btu/h	:		200000	
Total heat transfer area	sqrft	:		16.0	
Heat flux	Btu/h/sqrft	:		12500	
Log mean temperature difference	°F	:		12.53	
Overall H.T.C. (available/required)	Btu/sqrft,h,°F	:		992/996	
Pressure drops - total	psi	:	1.10		1.49
- in ports	psi	:	0.299		0.434
Port diameter	in	:	0.945		0.945
Number of channels		:	24		25
Number of plates		:		50	
Oversurfacing	%	:		0	
Fouling factor	sqrft,h,°F/Btu	:		0	

Note:

Disclaimer: Data used in this calculation is subject to change without notice. "SWEP may have patents, trademarks, copyrights or other intellectual property rights covering subject matter in this document." "Except as expressly provided in any written license agreement from SWEP," "the furnishing of this document does not give you any license to these patents, trademarks, copyrights, or other intellectual property."

SWEP A DOVER COMPANY

B10 All-stainless



STANDARD CONNECTIONS

For specific dimensions, or information about other types of connections, please contact your SWEP sales representative.

TECHNICAL DATA

Max flow rate	12 m³/h (53 usg/min.)
Max working pressure at 225°C (437°F)	13 bar (189 psi)
Max working pressure at 350°C (662°F)	10 bar (145 psi)
Min working temperature	-196°C (-321°F)
Test pressure	22 bar (319 psi)
Max. Number of plates	120
CBE weight dry (approx.)	1.5+0.126×NP* kg (3.31+0.278×NP* lb)
Hold-up volume: inner circuit	0.061×(NP*/2-1) litre (0.016x(NP*/2-1) gal.)
Hold-up volume: outer circuit	0.061×NP*/2 litre (0.016x(NP*/2) gal.)
Standard connection size	1"
Connection height	20.1 mm (0.79 inch) or 45.1 mm (1.78 inch)

*NP = Number of plates

MATERIAL

Plate material:	EN 10028/7-1.4401 (AISI 316)
Brazing material:	Nickel-based alloy
Connection material:	EN 10272-1.4401 (AISI 316)

THIRD-PARTY APPROVALS (selection)
Europe, Pressure Equipment Directive (PED 97/23/EC)
USA, Underwriters Laboratories (UL)
Canada, Canadian Standard Association (CSA)
Japan, The High Pressure Gas Safety Institute of Japan (KHK)

For additional information please contact your local SWEP representative.
SWEP reserves the right to make changes without prior notice

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THE A LINE – OUR ALL-STAINLESS CBEs

SWEP's all-stainless range has been developed for highly demanding environments with high-temperature and/or high-pressure requirements. The products contain no copper whatsoever, so they can be used in applications where copper-ion free media are essential, e.g. in electronics or ammonia applications. In particular, all-stainless CBEs have increased resistance to aggressive media. They can also withstand higher working temperatures than normal copper-brazed CBEs. Some products also have a unique frame in stainless steel, making it possible to use working pressures up to 31 bar (450 psi).

Easy to choose the right product solution

With SWEP's unique SSP CBE, the SWEP Software Package, you can do advanced heat transfer calculations yourself, and choose the product solution that suits your application best. It's also easy to choose connections and generate drawings of the complete product. If you would like advice, or you would like to discuss different product solutions, SWEP offers all the service and support you need.

If you would like more information about B10 All-Stainless or our other products, please contact your local SWEP representative.

SWEP
A DOVER COMPANY

SWEP INTERNATIONAL AB
Box 105, SE-261 22 Landskrona, Sweden
Phone +46 418 540 00
Fax +46 418 292 95
Internet: www.swep.se
E-mail: info@swep.se

HOT WATER COIL SELECTION DETAILS

Fluid Selection Program
Version 2.1.0

General Information

Project Name	:	Napa Auto Parts - Susanville, CA
Coil Item No.	:	
Coil Tag	:	
Date	:	06/15/2006 09:28:47
Model No	:	HW12CN01802375005R

Coil Construction

Fin Type	:	12 1.25 x 1.08 Waffle	
Fin Height	:	23.75	inch
Fin'd Length	:	18	inch
Rows Deep	:	Auto-Select	
Fins/Inch	:	Auto-Select	
Circuiting	:	Auto-Select	
Tube Material	:	Copper	
Tube Thick	:	0.016	inch
Fin Material	:	Aluminum	
Fin Thick	:	0.0060	inch
Allow OppEnd	:	No	

Airside

Airflow	:	1900	SCFM
Altitude	:	4000	Feet
Ent. DB/WB	:	70.0 /	°F
Cap Req'd	:		Btu/Hr
LDB/LWB Req'd	:	120.0 /	°F

Fluid Side

Fluid	:	Water	
Ent Fluid Temp	:	150	°F
Lvg FLuid Temp	:	130	°F
Fluid Flow Rate	:		GPM

Coil Performance

Model No.	:	HW12CN01802375005R	
Rows / FPI	:	3 / 13	
Circuiting	:	Quarter	
Total Cap	:	106,532	Btu/Hr
Sens Cap	:	106,532	Btu/Hr
Lvg DB/WB	:	121.3	°F
Face Velocity	:	640.0	SFPM
Standard APD	:	0.36	in. w.c.
Lvg Fluid	:	125.4	°F
Fluid Flow	:	8.8	GPM
Fluid PD	:	3.06	ft H2O
Conn Size	:	1.00"	
Dry Weight	:	38	Lbs

Additional Construction Notes

Coil Coating	:	None
Casing Mat'l	:	Galvanized Steel
Casing Type	:	Flanged
Conn. Mat'l	:	Copper
Conn. Type	:	MPT

Special Notes:

Fluid Selection Program
Version 2.1.0

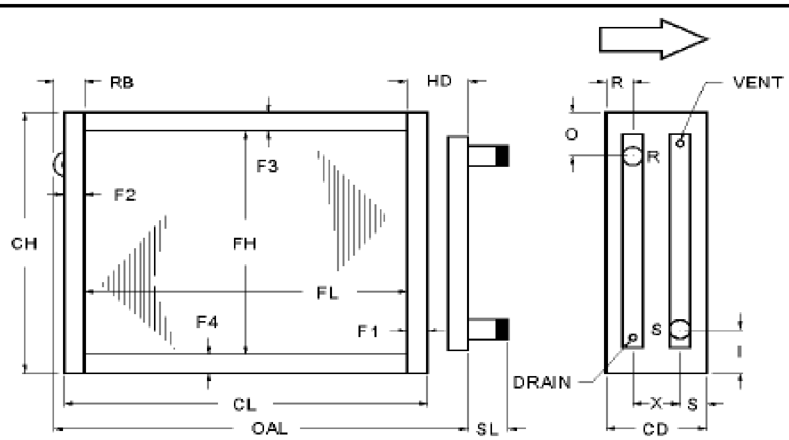
General Information

Project Name	:	Napa Auto Parts - Susanville, CA
Coil Item No.	:	
Coil Tag	:	
Date	:	06/15/2006 09:29:35
Model No	:	HW12CN01802375005R

Coil Construction

Fin Type	:	12 1.25 x 1.08 Waffle		Coil Coating	:	None
Rows	:	3		Casing Mat'l	:	Galvanized Steel
FPI	:	13		Casing Type	:	Flanged
Tube Material	:	Copper		Connections	:	1.00" Copper MPT
Tube Thick	:	0.016	inch	Circuiting	:	Quarter
Fin Material	:	Aluminum				
Fin Thick	:	0.0060	inch			

Coil Dimensions



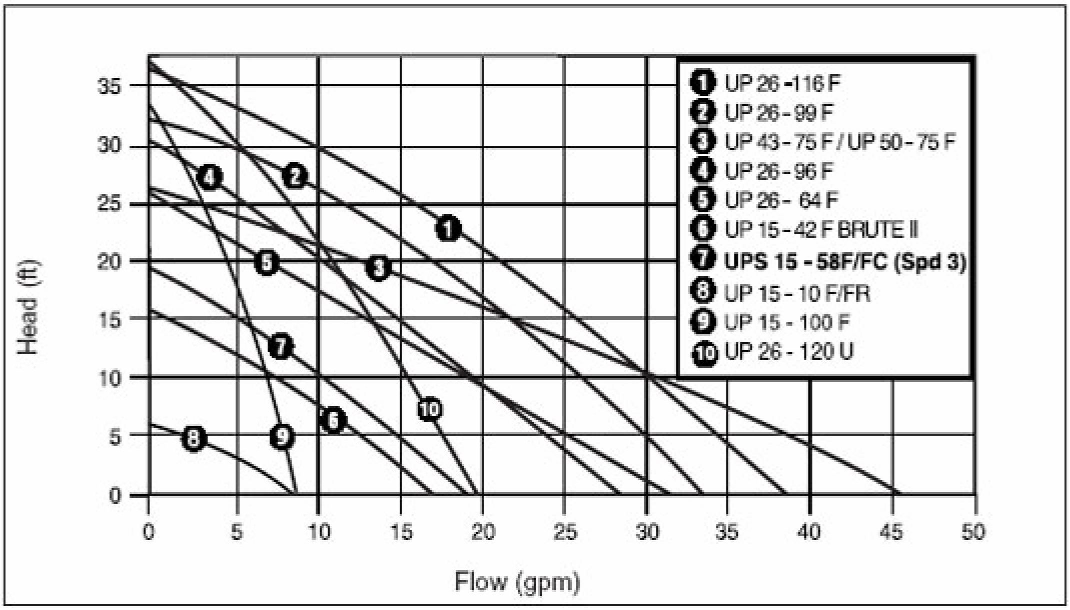
FH	FL	CH	CL	CD	HD	OAL	SL	I	S
23.75	18.00	26.75	21.00	6.50	4.13	26.25	2.00	2.25	2.17

O	R	F1	F2	F3	F4	HD1	RB	Drawing
2.25	2.17	1.50	1.50	1.50	1.50	4.13	1.75	WTRRHSTD

Special Notes:

PO Box 578 * Devault, PA 19432 * PH:(800)USA-COIL
PH:(610)296-9668 * Fax:(610)296-9763 * Email: sales@usacoil.com * www.usacoil.com

CIRCULATING PUMP SELECTION DETAILS



Approx. 9 in.

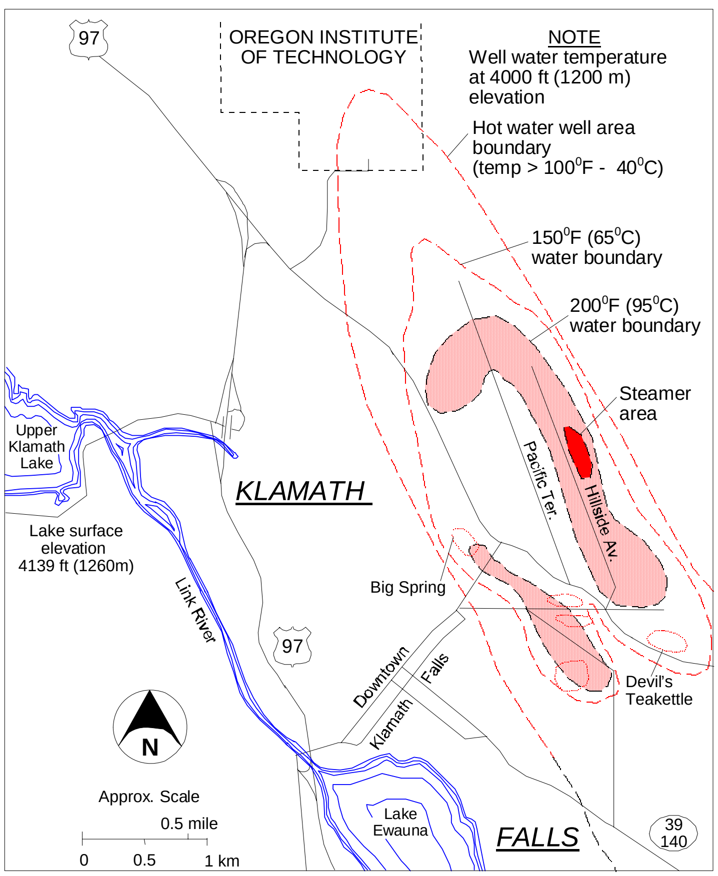
Source: www.grundfos.com

OREGON INSITUTE OF TECHNOLOGY/GEO-HEAT CENTER HIGH-TEMPERATURE POWER GENERATION PROPOSAL

THE PROPOSAL

We propose to install a high-temperature geothermal power plant on the Oregon Institute of Technology campus. Technical support would be provided by the Geo-Heat Center. The power plant would be approximately one megawatt (MW) in generating capacity and most likely be a flash steam type. This plant would use high-temperature geothermal water/steam from a proposed 5,000 to 6,000 feet deep geothermal well to be drilled into the fault along the east side of campus. The plant would be housed adjacent to the existing heat exchange building on the south east corner of campus near the geothermal production wells. Cooling water would be supplied from the nearby cold water wells to a cooling tower. The plant would provide 100% of the electricity demand on campus saving approximately $500,000 annually, with any excess electricity sold into the grid through a net metering system. This would be the first flash steam geothermal power plant in Oregon and would serve as a demonstration site and as an educational training facility. If sufficient temperature and flows were obtained from the deep well, not only could energy be generated from a flash power plant, but the "waste" water could also be run through a low-temperature binary power plant in what is called a "bottoming cycle" to produce additional energy. And, finally this "waste" water would be used for space heating on campus or sold for a fee to adjacent land owners, as the flow would supplement are existing wells used for space heating.

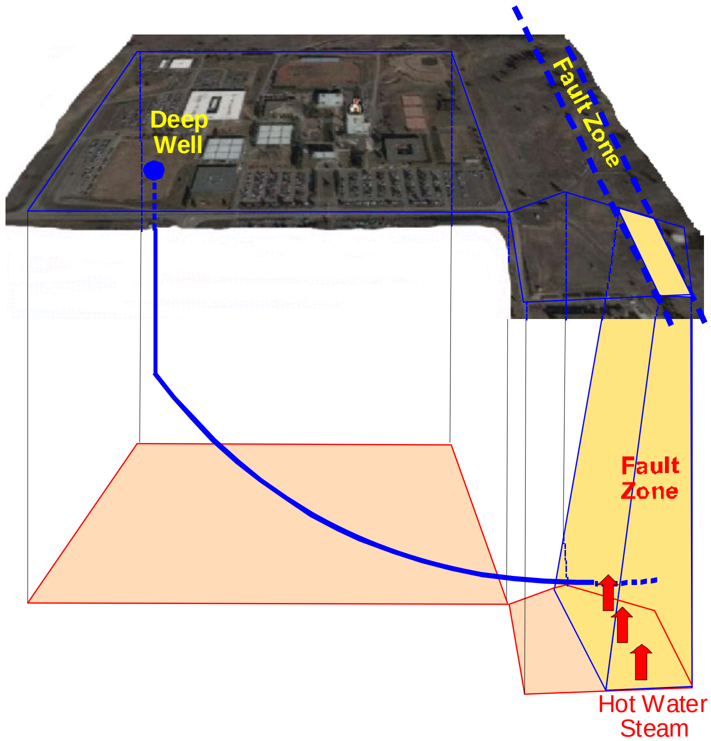
THE GEOLOGIC SETTING



The geothermal resources in Klamath Falls were used by the Indians and early settlers. Today more than 600 wells are used to heat homes, businesses, churches, public and governmental facilities, including swimming pools and for sidewalk snow melting. A greenhouse facility is also heated that grows tree seedlings. The OIT campus has been heated entirely with geothermal energy since the early 1960s from three wells drilled on the south east corner of campus. The hot water is gravity feed to all the buildings on campus, and provides heating and domestic hot water to the entire campus. Geologically, the geothermal water is heated through deep circulation within the earth and then upwells along the fault on the east side of campus where the OIT wells tap into this water as shown in the figure. This geothermal water has been used for over 45 years with no change in temperature or flow rate. Based on investigations from geothermal geologists there is a high probability of a higher temperature geothermal resource at depth in excess of 300°F. Temperatures above 300°F are suitable for flash steam power generation, whereas those below this temperature are best suited for binary (organic Rankine cycle) power generation.

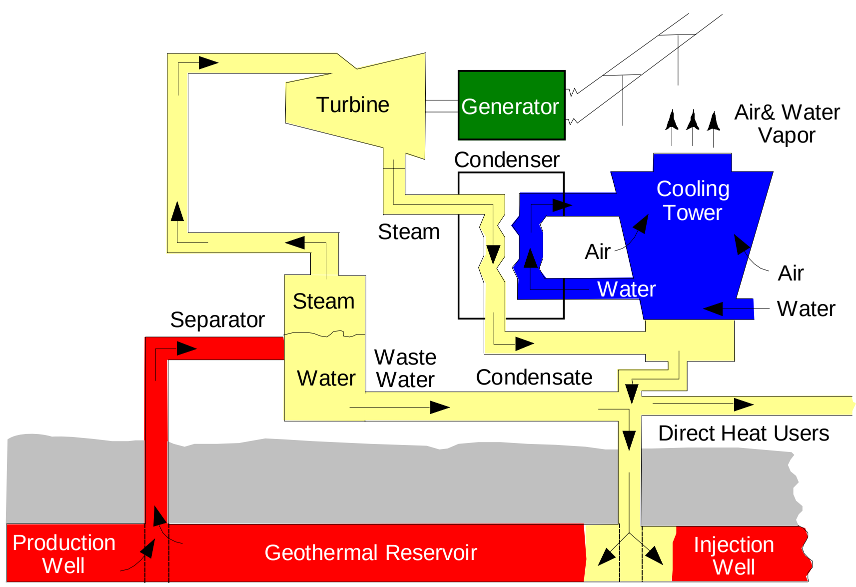
THE WELL

A deep, 5,000 to 6,000 foot, geothermal well would be drilled on campus to tap the expected high temperature (above 300°F) geothermal water that is estimated to be available upwelling along the fault system on the east side of campus. This well would be deviated from vertical in order to intersection the fault close to right angles as illustrated in the figure below. The high-temperature geothermal fluids would then be pumped from the well, run through a separator where the pressure is reduced to approximately 100 psi producing steam. The steam is sent to the power plant and the "waste" water (approximately 85%) is then used in a bottoming cycle power plant and/or for space heating. This is illustrated in the power plant diagram below. The exact location of the well has yet to be determined, but would be on campus property.



THE PLANT

The proposed one megawatt (MW) flash steam plant uses proven technology that has been used with geothermal fluids in many parts of the world. Geothermal fluid, under pressure, would be pumped from depth; the pressure is then reduced producing steam at 100 psi which would be used to turn the turbine-generator set. The steam is finally condensed by cold water from the cooling tower to improve the efficiency of the energy output by causing



a “driving force” across the turbine. Only a small part of the fluid, around 15%, would be consumed in the process, thus the remainder could be used for a bottoming cycle power plant, and/or to supplement the campus heating system, or provide heat to adjacent users for a fee. The plant would most likely be located near the existing well field adjacent to the present heat exchanger building.

THE BENEFITS

The installation of this power plant would provide a number to benefits:

- A showcase for interested developers in conjunction with tours of campus.
- A realistic laboratory for our engineering students to study, gather data and report their findings, and making this information available to other potential users
- Monitoring the operation of the plant through a web-based controls such as SCADA (Supervisory Control & Data Acquisition System) where anyone could log on to a computer and see how the plant is operating – temperatures, flow rates, energy produced, etc. This could be done anywhere in the world, by grade schools, high schools, universities and other interested persons.
- Saving the campus approximately $500,000 annually in our electricity costs
- Making the campus a “**Net Zero**” energy user.
- Making OIT and Oregon a leader in developing and using renewable, green energy.
- Providing additional income to the campus by selling the excess hot water to adjacent users for an income of approximately $200,000.
- Generating additional electricity with a bottoming cycle power plant (binary cycle) using the “waste” water after flashing.

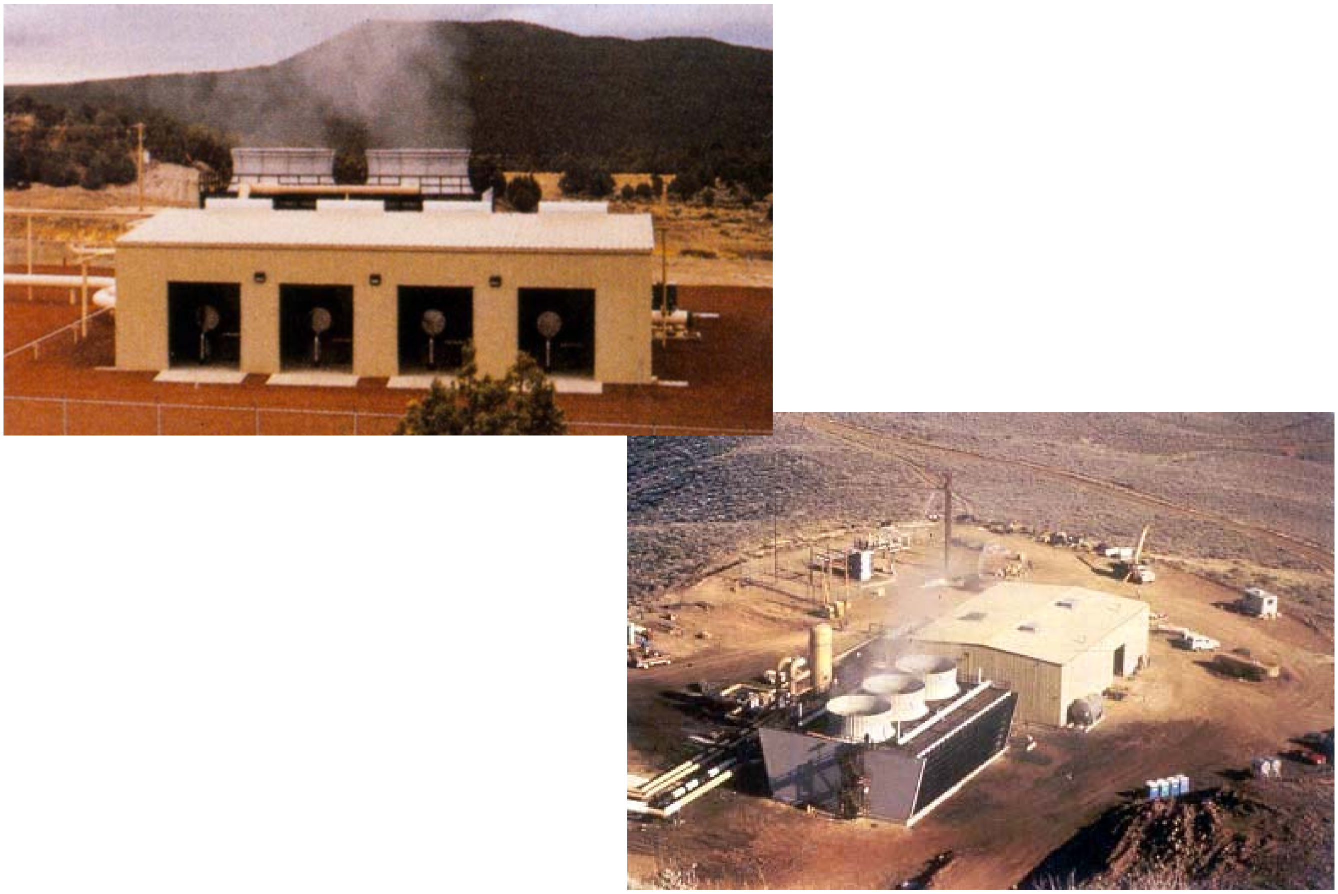
THE COSTS

The well would cost approximately $2,200,000; the plant would cost approximately $1,500,000; and the cooling tower; piping and installation expense would add approximately $300,000 for a total cost of $4,000,000. The gross saving would be approximately $600,000 annually in the campus electricity cost. The plant itself would have approximately $100,000 annual operation and maintenance cost, for a net savings of $500,000 annually. Additional income from the selling of hot water to adjacent users could provide $200,000 annually for a total income of $700,000. These costs and incomes would provide a simple payback of under six years.

THE CONCLUSIONS

The design installation of this plant is dependent upon the temperature of the fluid produced from the deep production well. The entire process from start of drilling to plant completion would take approximately one to two years. We have had interest expressed by several plant manufacturers, thus, providing a power plant should not be a problem, and the suppliers may help with some of the expenses as their product will be “on display”. The lead time on obtaining a drilling rig is unknown at this point.

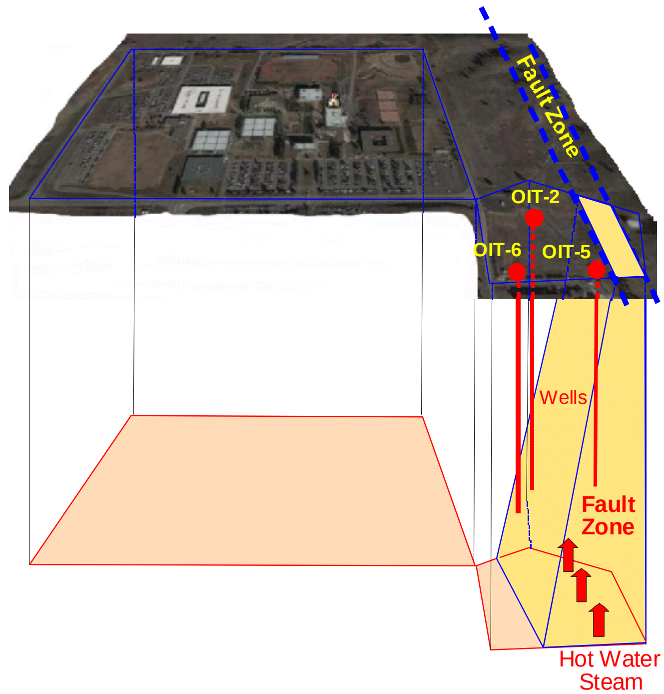
Geothermal exploration is generally associated with high-risk ventures. While this may be true, the proposed well has some “fall-back” options to reduce risk. These options include using the well, if actual temperatures are lower than expected, for binary power plant and/or direct-use heating or cooling of the campus.



Examples of existing flash steam geothermal power plants.
These are larger than the one MW plant proposed for OIT campus.

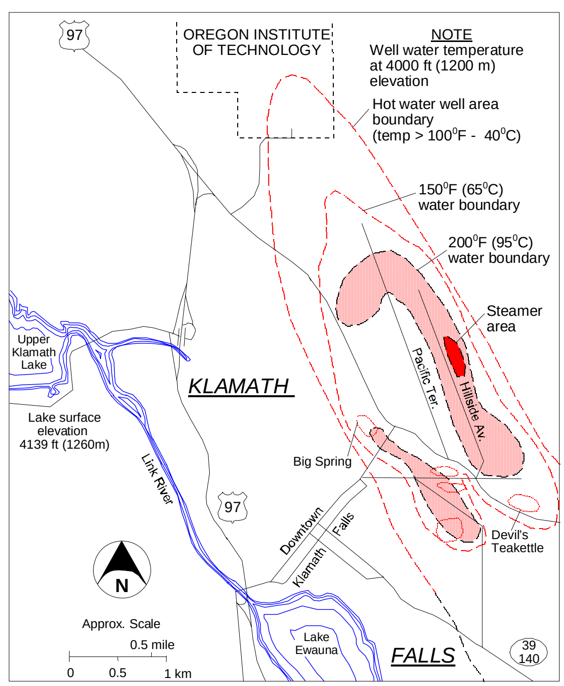
OREGON INSITUTE OF TECHNOLOGY/GEO-HEAT CENTER LOW-TEMPERATURE POWER GENERATION PROPOSAL

THE PROPOSAL



We propose to install a geothermal power plant using a low-temperature resource on the Oregon Institute of Technology campus. Technical support would be provided by the Geo-Heat Center. The power plant would be a binary or organic Rankine cycle (ORC) type in the 200 kW generating capacity range. This plant would use the existing geothermal water that is presently supplied from wells for heating the campus. The process would take approximately 15 degrees off the top of our 192^{o}F geothermal water, and the remaining 177^{o}F is then sufficient to heat the campus by “cascading” the hotter water to lower temperature uses. The plant would be housed in the existing heat exchange building on the south east corner of campus near the geothermal production wells. Cooling water would be supplied from the nearby cold water wells to a cooling tower. The plant would provide approximately 25% of the electricity demand on campus saving approximately $100,000 annually. This would be the first geothermal power plant in Oregon and would serve as a demonstration site and as an educational training facility.

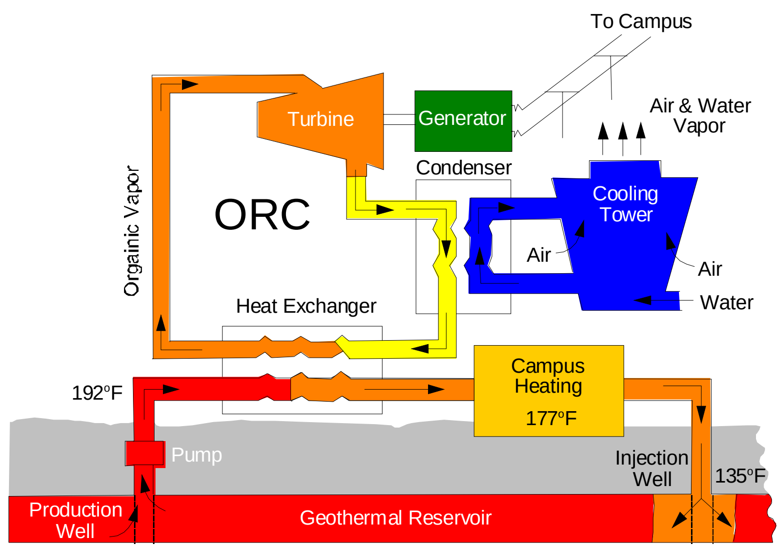
THE GEOLOGIC SETTING



The geothermal resources in Klamath Falls were used by the Indians and early settlers. Today more than 600 wells are used to heat homes, businesses, churches, public and governmental facilities, including swimming pools and for sidewalk snow melting. A greenhouse facility is also heated from the City district heating system that grows tree seedlings. The OIT campus has been heated entirely with geothermal energy since the early 1960s from three wells drilled on the south east corner of campus. The hot water is gravity feed to all the buildings on campus, and provides heating and domestic hot water to the entire campus. Geologically, the geothermal water is heated through deep circulation within the earth and then up wells along the fault on the east side of campus where the OIT wells tap into this water as shown in the figure. This geothermal water has been used for over 45 years with no change in temperature or flow rate. The capacities of the existing well pumps are adequate to supply the needs of the power plant and to heat campus.

THE PLANT

The proposed 200 kW binary or ORC plant uses proven technology that has been used with geothermal fluids in many parts of the world. A recent installation of a plant of this type at Chena Hot Springs, Alaska using 165°F water, has stimulated interest in using low-temperature fluids. Since geothermal water below the boiling point does not produce steam to turn a turbine-generator set, a binary cycle plant uses a low boiling point hydrocarbon (organic fluid) in a close loop that is boiled by the geothermal water to produce a vapor to run the turbine. Since the geothermal fluid is not consumed, but only supplies heat, it can be further used (cascaded) for space heating of the campus. The operation of the binary power plant or ORC is illustrated below.



THE BENEFITS

The installation of this power plant would provide a number of benefits:

- A showcase for interested developers in conjunction with tours of campus.
- A realistic laboratory for our engineering students to study, gather data and report their findings, and making this information available to other potential users
- Monitoring the operation of the plant through a web-based controls such as SCADA (Supervisory Control & Data Acquisition System) where anyone could log on to a computer and see how the plant is operating – temperatures, flow rates, energy produced, etc. This could be done anywhere in the world, by grade schools, high schools, universities and other interested persons.
- Saving the campus approximately $100,000 annually in their electricity costs
- Moving the campus closer to becoming a "**Net Zero**" energy user.
- Making OIT and the State of Oregon a leader in developing and using renewable, green energy.
- Proving that this technology is a viable means to reduce fossil fuel consumption.

THE COSTS

The plant would cost approximately $300,000 and the cooling tower, piping and installation expense would add approximately $100,000 for a total cost of $400,000. The gross saving would be approximately $150,000 annually in the campus electricity cost. The plant itself would have approximately $50,000 annual operation and maintenance cost, for a net savings of $100,000 annually. This would provide a simple payback on the capital cost of four years.

THE CONCLUSIONS

The installation of this plant would require minimal time and disruption of the hot water use on campus. It is possible that it could be installed in the spring of 2007. We have already had a number of inquiries from manufacturers/installers of small-scale and low- temperature power plant, thus, we would most likely receive a favorable price and rapid service by these businesses, as we would become a showcase for their product. The most likely supplier would be United Technologies Corporation (UTC) out of the Los Angeles area. The successful completion of this project would be a milestone for OIT, Klamath Falls, and the State of Oregon in promoting clean renewable energy.

UTC 200 kW ORC at Chena Hot Springs, Alaska

GEOTHERMAL GREENHOUSE FACILITY
OREGON INSTITUTE OF TECHNOLOGY/GEO-HEAT CENTER

Proposal

Oregon Institute of Technology with technical support from the Geo-Heat Center proposes to construct two geothermally heated greenhouses on campus. These greenhouses would each be 100 feet long and 60 feet wide (6,000 square feet). Different heating and cooling systems would be provided to each greenhouse as a research and demonstration project. Bench-top heating system would also be provided for soil heating of potted plants. All heating and cooling in the greenhouses would be monitored and controlled by computer.

The greenhouses would be utilized in conjunction with the Klamath-Lake County Economic Development Association as an incubator facility for interested investors/developers to test the feasibility of growing their crop in a controlled environment utilizing geothermal energy. This would result in spin-off full size commercial development that would contribute to the employment and economy of the region. This project would be similar to the one developed on the New Mexico State University campus at Las Cruces. The abbreviated article from the Geo-Heat Center Quarterly Bulletin (Vol. 23, No. 4 – December, 2002) describing the project is attached.

The facility would also provide research and demonstration projects for students in mechanical, electrical and computer engineering on campus. Agricultural students from the Klamath Community College could be involved in testing various crops for commercial production in the area. The local Oregon State University Extension office could also utilize the facility in cooperation with the local high schools.

Geology and Background

Geothermal resources are available in both Klamath and Lake Countries, many of which are already developed and utilized for space heating and agri-business application. There are several geothermally heated greenhouses in the Klamath Falls area for growing tree seedlings and potted plants. There are also several geothermally heated greenhouses just north of Lakeview growing potted plants and vegetables. All of these have been operated successfully over a number of years and provide products to the local market. An experimental greenhouse was built and operated on campus in the 1980s; however, it was removed due to lack of funding.

Costs

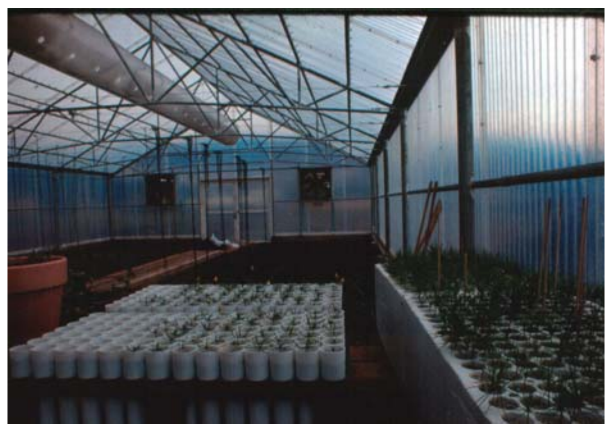
To construct two 6000 ft^2 greenhouses would cost approximately $20/$ft^2$ for a total of $240,000. This would include the structure and all of the heating and cooling equipment. In addition, a warehouse and heat exchanger room would be required for storage costing about $60,000; however, this could be shared with the proposed aquaculture project. A part time maintenance person would be required costing $40,000 per year; also shared with the aquaculture project. “Waste” water from the geothermal system at around 150°F and 60 gpm would be required, that could easily be met from our existing geothermal wells, mainly by cascading from the campus heating system.

Benefits

- A similar facility has been constructed on the New Mexico State University campus at Las Cruces, which has been very successful in attracting potential investors to experiment with their products in a geothermal environment. At least five clients have gone on to build successful commercial operation.
- This facility would provide an incubator site for potential spin-offs for large commercial facilities in Oregon similar to that experienced in New Mexico; however, the OIT project would provide a different climate for projects.
- The heating and cooling systems would provide a laboratory for students from Mechanical, Electrical and Computer Engineering programs to test various heating and cooling systems, controls, etc.
- The facility would provide a showcase for potential developers/investors in Oregon.
- The facility could also be used to raise vegetables and plants for use of campus, making the campus a sustainable and green facility.

Conclusions

An experimental greenhouse located on campus would serve three important clients: 1) potential developers to test their product and eventually spin-off in a commercial operation, 2) a student laboratory for renewable energy and agricultural applications, and 3) a showcase for a "green" and self-sustainable campus.



OIT Greenhouse Project

GEOTHERMAL AQUACULTURE FACILITY
OREGON INSTITUTE OF TECHNOLOGY/GEO-HEAT CENTER

Proposal

Oregon Institute of Technology with technical support from the Geo-Heat Center proposes to construct two geothermally heated outdoor aquaculture ponds and a covered grow out tank facility on campus. The outdoor ponds would each be 100 feet long and 30 feet wide (3,000 square feet) and the indoor covered facility would be of greenhouse construction 100 by 60 feet (6,000 square feet). Different heating systems would be provided to each pond as a research and demonstration project. The covered facility would consist of a series of fiberglass tanks, heated by the geothermal water and supplement with overall space heating. All heating systems would be monitored and controlled by computer. Various fish species, hard-shell aquatic species and even various algae could be tested.

The aquaculture facility would be utilized in conjunction with the Klamath-Lake County Economic Development Association as an incubator facility for interested investors/developers to test the feasibility of growing their specie in a controlled environment utilizing geothermal energy. This would result in spin-off full size commercial development that would contribute to the employment and economy of the region. This project would be similar to the one developed on the New Mexico State University campus at Las Cruces. The abbreviated article from the Geo-Heat Center Quarterly Bulletin (Vol. 23, No. 4 – December, 2002) describing the project is attached.

The facility would also provide research and demonstration projects for students in mechanical, electrical and computer engineering on campus. Agricultural students from the Klamath Community College could be involved in testing various aquatic species for commercial production in the area. The local Oregon State University Extension office could also utilize the facility in cooperation with the local high schools.

Geology and Background

Geothermal resources are available in both Klamath and Lake Countries, many of which are already developed and utilized for space heating and agri-business application. There are several geothermally heated aquaculture ponds in the Klamath Falls area for growing tropical fish. These have been operated successfully over a number of years and provide products to the west coast market. An experimental aquaculture facility was built and operated on campus in the 1980s to grow prawns, and mosquito fish, and rainbow trout; however, it was removed due to lack of funding.

Costs

To construct two 3000 ft^2 ponds (lined) would cost approximately $\$10/ft^2$ for a total of $60,000. This would include the excavation and all of the heating equipment. The covered building, with concrete floor and tanks would cost approximately $\$40/ft^2$ for a total of $240,000. In addition, a warehouse and heat exchanger room would be required for storage costing about

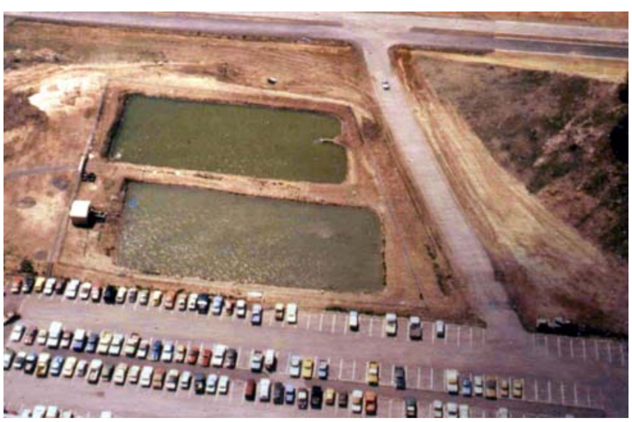
$60,000; however, this could be shared with the proposed greenhouse project. A part time maintenance person would be required costing $40,000 per year; also shared with the greenhouse project. "Waste" water from the geothermal system at around 120^{o}F and 150 gpm would be required, that could easily be met from our existing geothermal wells, mainly be cascading from the greenhouse project.

Benefits

- A similar facility has been constructed on the New Mexico State University campus at Las Cruces, which has been very successful in attracting potential investors to experiment with their products in a geothermal environment. Several clients have gone on to build successful commercial operation.
- This facility would provide an incubator site for potential spin-offs for large commercial facilities in Oregon similar to that experienced in New Mexico; however, the OIT project would provide a different climate for projects.
- The heating systems would provide a laboratory for students from Mechanical, Electrical and Computer Engineering programs to test various heating systems, controls, etc.
- The facility would provide a showcase for potential developers/investors in Oregon.
- The facility could also be used to raise fish for consumption of campus, making the campus a sustainable and green facility.

Conclusions

An experimental aquaculture facility located on campus would serve three important clients: 1) potential developers to test their product and eventually spin-off in a commercial operation, 2) a student laboratory for renewable energy and agricultural applications, and 3) a showcase for a "green" and self-sustainable campus.



OIT Aquaculture Project

GEOTHERMAL ENERGY AT NEW MEXICO STATE UNIVERSITY IN LAS CRUCES

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SWTDI GREENHOUSE FACILITY (GGF)

Two 6,000-ft^2 greenhouses and a 2,400-ft^2 metal storage space, office and work shop comprise the Geothermal Greenhouse Facility (GGF), which has been heated continuously with geothermal since December 1986 (Figure 5) (Photo 3) (Schoenmackers, 1988). A propane boiler provides back up heat in case of geothermal well pump failure. The GGF is of Dutch design and all structural members are made of galvanized steel that is mounted on 10-inch concrete piers set 24 inches into the ground. A variety of glazing films are used in the doubled glazed panels that contain central dead air spaces. Also, different cooling and ventilation schemes are applied in the two greenhouses that are laid out with the long axes oriented east to west. The south greenhouse has a traditional fan and pad evaporative air cooling system installed with a typical 75 percent wet bulb depression and a complete air exchange capability of once every minute. GGF temperature increases from the west end pad to the east end fan are about 10 to 12^{o}F when in a cooling mode. The north greenhouse has a fog cooling system that uses 90 fog nozzles that create 10-micron droplets or fine mist to create a distributed evaporative cooling effect without significant lateral temperature gradients. Side and roof vents are used to provide natural ventilation.

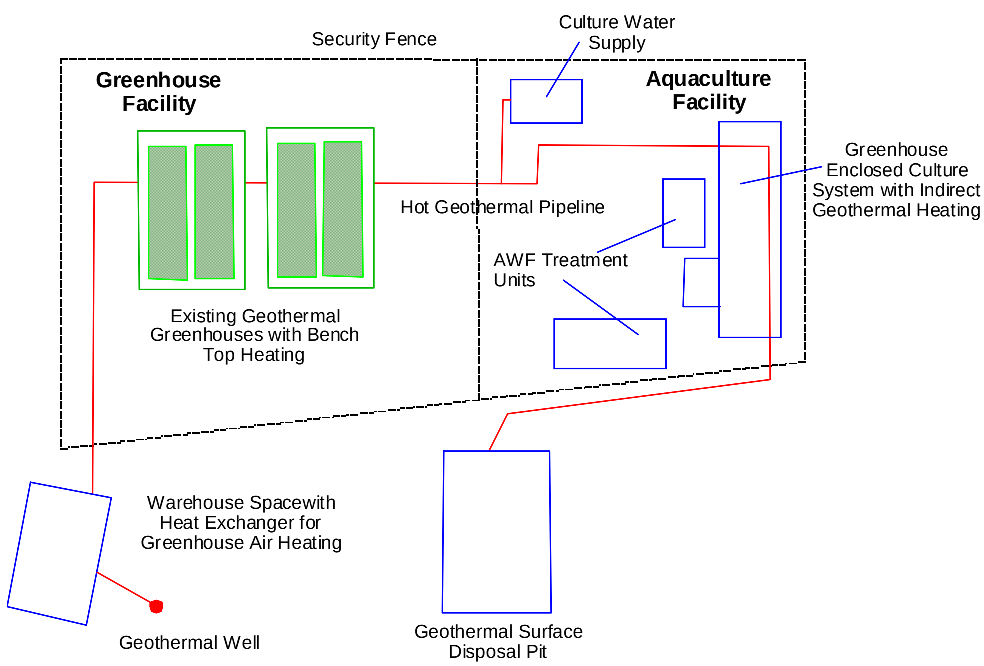


Figure 5. ***Generalized layout of the NMSU/SWTDI Geothermal Greenhouse (GGF) and Geothermal Aquaculture (GAF) Facilities (Zachritz, et al., 1996).***

The GGF uses between 25 and 60 gpm of 148^{o}F water from well PG-4 for geothermal heating. The maximum flow represents about 25 percent of the currently installed discharge from PG-4. The geothermal water is feed into a Trantor stainless steel (type 316) plate and frame heat exchanger with a designed maximum flow of 80 gpm and an approach temperature of 10^{o}F. The heated freshwater is feed into a closed-loop, hydronic geothermal heating system by 3- inch black iron pipe. Four modine high-efficiency, fan-coil units are outfitted with inflatable 24-inch poly tube with 1-inch holes on 1-ft centers to provide 3,850 cfm of evenly distributed warm air flow (Photo 4). Typical hot water inflow to the four heaters is at 131°F with an exit temperature of 110°F for an installed geothermal heating capacity of about 525 x 10^3 Btu/hr in the closed-loop hydronic system.

Photo 3. Interior of SWTDI greenhouse facility.

An additional bench top heating system taps geothermal water directly with motorized ball valves before passing through the heat exchanger. The bench top system provides soil heating for horticultural cultivation with a 50,000-ft long series of 5/32 inch ID rubber tubing (Photo 5). The bench top heating system uses about 25 gpm and typically shows a temperature loss of 15 to 30°F for an installed geothermal heating capacity of about 375 x 10^3 Btu/hr.

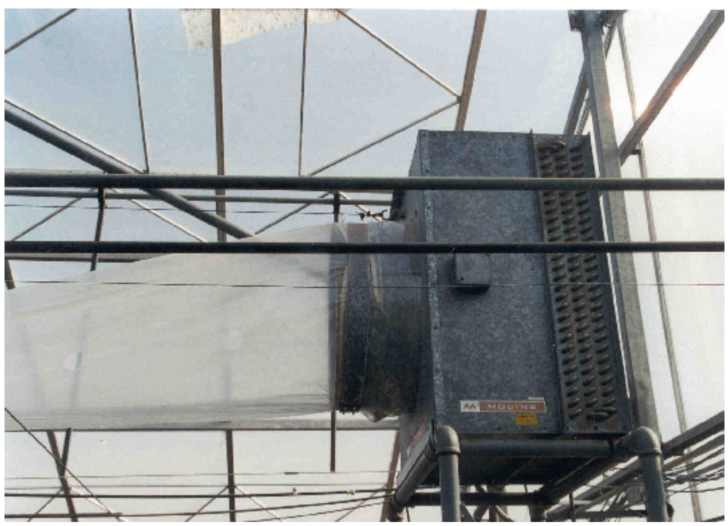


Photo 4. Modine heater with poly tube.

All heating and cooling in the geothermal greenhouse is monitored and controlled by computer. After exiting the heat exchanger and the bench top heating system, the cooled geothermal water is allowed to flow into a 46-ft by 46-ft by 15-ft permitted disposal pond or is cascaded to the SWTDI Geothermal Aquaculture Facility (GAF).

SWTDI GEOTHERMAL AQUACULTURE FACILITY (GAF)

The SWTDI Geothermal Aquaculture Facility (GAF) was funded in 1993 by the USDOE with the purpose of demonstrating energy use and energy savings and value enhancement of a cascaded direct-use geothermal aquaculture operation that is coupled to geothermal greenhouse heating (Zachritz, et al., 1996). In addition, the facility also demonstrates the application of several wastewater treatment approaches for aquaculture that include an artificial wet land for denitrification and two different approaches of solids removal. The facility was designed for both research and as a business incubator for lease to potential aquaculturalists. Tilapia and stripped bass have been grown in the facility.

The layout of the geothermal aquaculture facility is shown in Figure 6. Two large 6,000-gallon capacity intensive culture systems simulate commercial level production while a number of smaller tanks provide for brood stock maintenance and fry production (Photo 6). The culture systems can use freshwater, cooled geothermal water, or custom mixes for marine applications. Each of the two large culture systems uses different wastewater treatment. Flow through or recirculation flows can also be accommodated by the GAF.

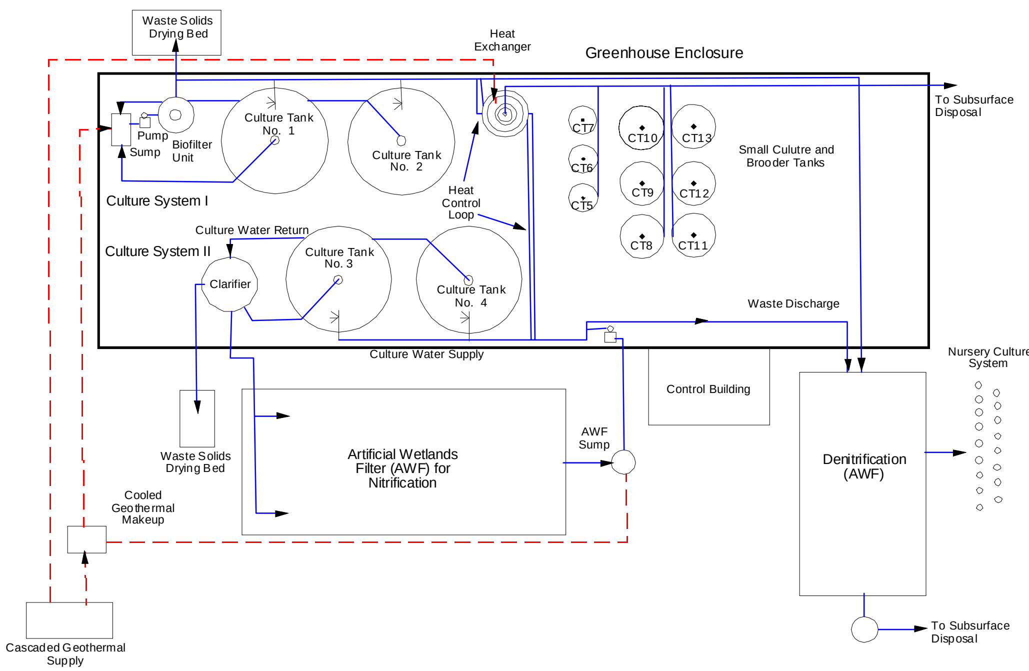


Figure 6. Process flow diagram of the Geothermal Aquaculture Facility (GAF)(Zachritz, et al., 1996).

Photo 5. Greenhouse bench heating system..

Geothermal heating is done by cascading a maximum 25 gpm of geothermal water from the GGF bench top heating system to the aquaculture facility. Cascaded hot water arrives at the heat exchanger at 90 to 135^{o}F for heating culture water in a closed loop fashion. The GAF is contained in a 3,000-ft^2 double-walled arched greenhouse (Photo 7). Cooling and ventilation is done with cooling pad at one end of the greenhouse and fans at the opposite end of the greenhouse. All heating and cooling is monitored and controlled by computer. The GAF system at 16 to 17 gpm geothermal flow typically shows a temperature loss of 6 to 9^{o}F across the heat exchanger for an installed geothermal heating capacity of about 76 x 10^3 Btu/hr.

Photo 6. Large aquaculture tanks.

Photo 7. SWTDI aquaculture building.

BENEFITS

Geothermal use at NMSU has benefited New Mexico in several ways. First, the campus geothermal system has an annual energy savings compared to natural gas up to several hundred thousand dollars annually depending upon annual climate, the cost of fossil fuel and maintenance costs for the geothermal system. Since 1986, six clients have leased the GGF and one client has leased the GAF. The GGF has resulted in important rural economic development as five clients have gone on to build successful geothermal and non-geothermal greenhouse business in the state.

GEO-HEAT CENTER

Oregon Institute of Technology, Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

John W. Lund, Director
Andrew Chiasson
Tonya "Toni" Boyd
Debi Carr

June 26, 2007

TO: A.J. Johnson
SUBJECT: Ground-Source Heat Pump Potential Energy Savings
Habitat for Humanity
Grand Junction, CO

Dear A.J.,

Based on a 28,000 ft^2 mixed office/retail building in Grand Junction, CO, I've estimated the following annual energy costs. The electricity and natural gas rates were extracted from the utility bills you provided, and are taken as $0.1026/kWh for electricity and $1.05/therm for natural gas.

Annual Heating and Cooling Costs
Habitat for Humanity Building
Grand Junction, CO

Item	*Heating*	*Cooling*	*Total*
Conventional	$ 13,256	$ 7,300	$ 20,556
Ground-Source Heat Pump	$ 7,400	$ 3,982	$ 11,382
Annual Ground-Source Energy Savings	$ 5,856	$ 3,318	$ 9,174

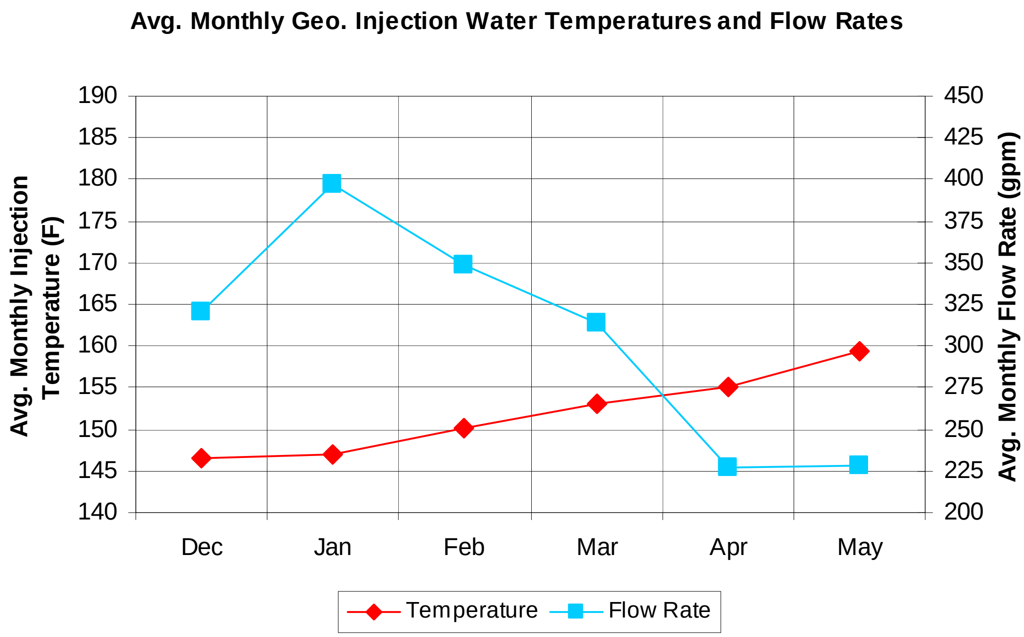
From recent case studies of ground-source heat pump systems, the installed cost including all mechanical work and the closed-loop ground heat exchanger is on the order of $14/$ft^2$. Typical installed costs of conventional rooftop units range from $10/$ft^2$ to $12/$ft^2$ of floor space. This translates to an incremental cost of the ground-source system of $56,000 to $112,000.

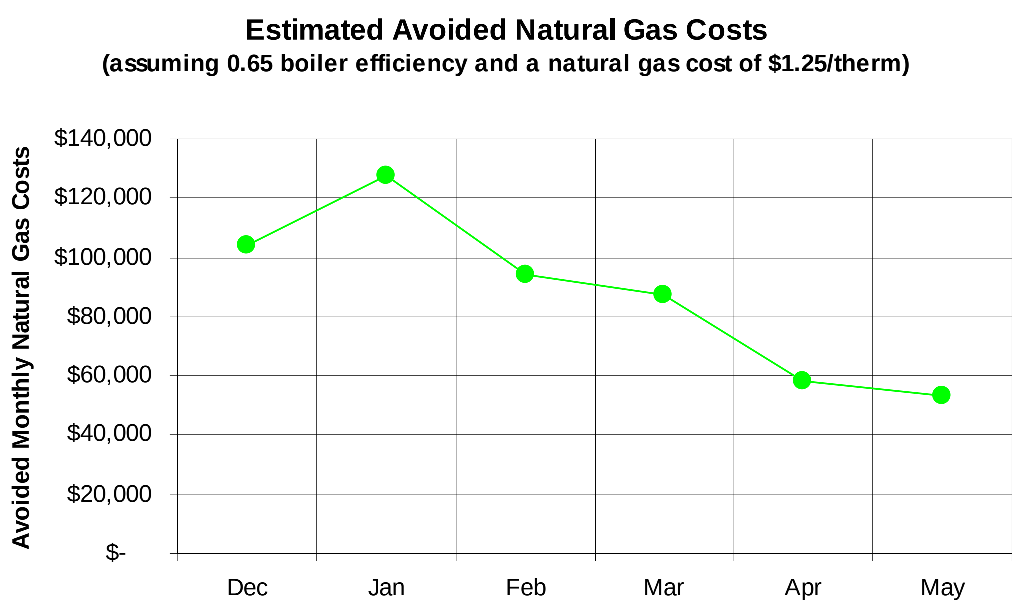
With an annual energy savings of $9,174 as estimated in the above table, the simple payback on the incremental cost (based on energy savings alone) ranges from 6.1 to 12.2 years.

Hope this information has been helpful,

Andrew Chiasson, P.E.

Estimated OIT Avoided Natural Gas Costs





The total estimated avoided natural gas cost for Dec. 2006 through May 2007 is $525,000. Assuming that November is similar to March, October is similar to April, and May is similar to September, the total estimated avoided natural gas cost from September through May is on the order of **$725,000**.

GEO-HEAT CENTER

Oregon Institute of Technology, Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

John W. Lund, Director
Andrew Chiasson
Tonya "Toni" Boyd
Debi Carr

September 22, 2006

TO: Gerry Galinato, P.E.
Idaho Energy Division
Idaho Department of Water Resources
Boise, ID

RE: H&H Farms
4995 N Brookside Ln.
Boise, ID

This letter report is a follow-up to IDWR's August 2006 analysis of options to reduce energy costs at H&H Farms Greenhouses. It appears that the proprietors of H&H Farms are seeking a "quick-fix" to their increased energy costs due to the recent sharp rises in natural gas prices.

Supplemental Geothermal Analysis of Options

The H&H Farms site does not have a known hydrothermal resource of elevated groundwater temperature with adequate flow rate. There are, however, reports of wells on the adjacent property with groundwater at temperatures of about 110-118°F. These wells are reported to be about 800 to 1600 ft deep with low well yields. Consequently, a closed-loop geothermal heat pump system was considered in the August IDWR analysis by Gerald Fleischman, and the payback period was estimated at about 17 years.

It is generally not economical to heat a greenhouse with geothermal heat pumps handling 100% of the peak load. This is for two main reasons: (1) the peak load is a function of outdoor air temperature, and the peak load is approached only about 1% of the time, and (2) loads on the geothermal loop are highly imbalanced over the annual cycle (i.e. heating only with cooling provided by evaporative methods), requiring much greater loop lengths than if the loads were balanced. Typical heating load profiles over the year are such that a system sized as a base-load heating system at 50% of the peak load can handle over 90% of the annual load as shown in Figure 1.

Open-loop or "well-to-well" systems are much more economically feasible, since the well depths are not dependent on the annual load imbalance as with closed-loop systems. However, groundwater availability at the site is in limited supply. Therefore, the more logical geothermal scenario might be a "standing column well". The standing column well configuration consists of deep wells (i.e. 1000 to 1500 ft) where groundwater is pumped to a heat pump and returned to the same well, therefore giving them characteristics of both closed- and open-loop systems. If elevated temperatures are encountered, the system performance will be enhanced, and possibly could allow the heat pumps to be by-passed during low demand hours.

A typical rule of thumb for standing column well design is 50 ft/ton, and at 50% of the peak load, approximately 100 tons would be required. Three standing column wells at 1500 ft depth would provide about 90 tons or 45% of the peak load and about 87% of the annual load (see Figure 1). If the drilling could be done for $50/ft, the total drilling cost would be $225,000 and the heat pump cost would be $112,500 at $1250/ton. Adding the cost of submersible pumps, a central heat exchanger, pump house, and horizontal transfer piping, the total project cost would be about $400,000.

Taking 87% of Gerald's annual savings (to account for the natural gas usage during peak times), the simple payback would be about 12.7 years. Ideally, the heat pumps could be coupled to a radiant floor/soil heating system to take advantage of soil heat storage effects, and the existing air forced air heating system could be used for peaking only.

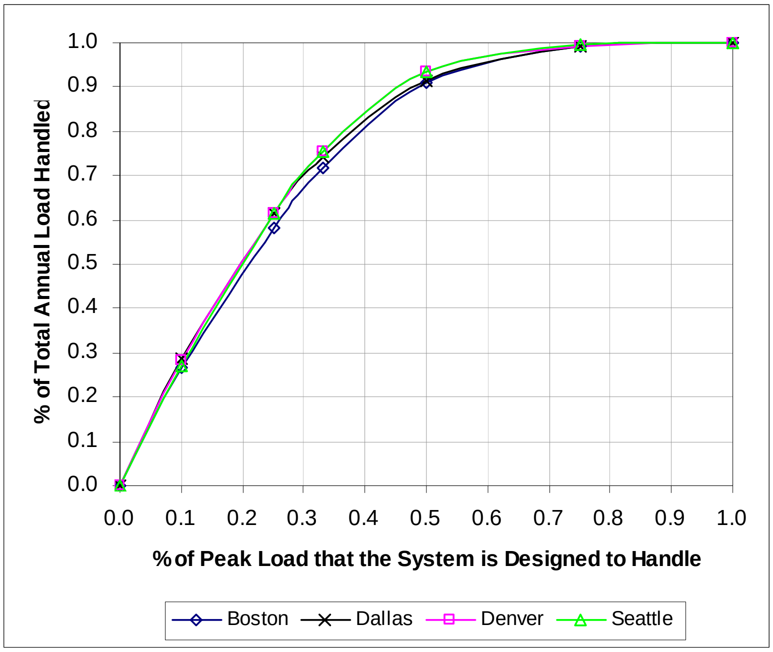


Figure 1. *Fraction of total annual heating load actually handled versus design fraction of peak load for a base-load system.*

One challenge of a geothermal heat pump retrofit is the available space for equipment in the greenhouses. The H&H greenhouses were constructed for wall-mounted, forced-air units. From Gerald's calculations, each greenhouse would have a peak load of about 300,000 Btu/hr or 25 tons. Currently, heat pumps above 5 to 6 tons are either unavailable or must be custom built at higher cost, so multiple 5-ton units would be required. Further, multiple units are easier to control and more manageable to install. Therefore, a significant modification to the greenhouse structure would be necessary to fit these into the space, so a more practical design would be to house multiple water-to-water heat pumps in a mechanical building and pipe hot water to radiant soil tubing (or fan coil units if that is the owner's preference).

<u>Supplemental Analysis of Other Options</u>
Of the other options presented in IDWR's analysis, the most viable one with a reasonable payback is a heat pipe type ventilation air heat recovery system. This will considerably reduce energy consumption.

Air-source heat pumps sound like a good idea, but they face the same challenge as water-to-air geothermal heat pumps. It is difficult to find these with capacities above 5 tons, and therefore multiple units would be required. Significant greenhouse modification would be necessary to fit these into the space. Also, multiple outdoor condensing units would take up land area.

<u>Greenhouse Envelope Improvements</u>
The obvious advantage of an improved greenhouse envelope is that energy demands are reduced. H&H is

using a double-poly film which is generally quite efficient. During the next phase of poly replacement, H&H might consider the addition of operable thermal screens (essentially a third layer) to reduce heat losses at night. These could be installed on a roller, and either manually or automatically controlled to roll down at night, based on a set point temperature.

Recommendations

In this case, geothermal energy does not provide a "quick fix" without an economic incentive. H&H may be eligible for funds through the USDA Farm Bill Section 9006, and we recommend that this option be pursued for next year's solicitation.

Some short term solutions to energy costs are energy conservation through ventilation air heat recovery and greenhouse envelope improvements. These investments will also complement a geothermal heat pump system should grant funding be realized.

“CHILL OUT”
OREGON INSTITUTE OF TECHNOLOGY IS A WINNER

John W. Lund and Toni Boyd
Geo-Heat Center

In March 2007, the National Wildlife Federation hosted a national competition called "Chill Out! Campus Solutions to Global Warming" with their partners, the Earth Day Network, Campus Climate Challenge and the Society for College and University Planning. The purpose of the contest was to spotlight solutions to global warming on campuses and to share these with a national audience. In addition to grants and other prizes, winning campuses were featured in a national broadcast on the week of Earth Day (on April 18, 2007 at 3:00 eastern). Students, faculty or staff could either submit a short written blurb on the contest entry website or a short video segment on the linked YouTube site. Details on the contest and the winners can be found at www.nwf.org/chillout (you can also access the contest through NWF's Campus Ecology website at www.nwf.org/campusecology.)

Chill Out seeks to advance and celebrate the innovators of global warming solutions on college and university campuses all across the country. The first annual nationwide contest was held throughout the fall and winter of the 2006-2007 school year. Winners received grant money and a feature in the Chill Out Broadcast on April 18, 2007.

The live Chill Out broadcast brought together thousands of college students, faculty and staff to celebrate real and practical solutions to global warming taking places on colleges today. It features a special message from Al Gore to colleges and universities, the winning campuses and an interactive panel of sustainability heroes.

The following is what John Lund submitted to the contest:

‘CHILL OUT!
CAMPUS SOLUTIONS TO GLOBAL WARMING”

OREGON INSTITUTE OF TECHNOLOGY
3201 CAMPUS DR.
KLAMATH FALLS, OR 97601

Oregon Institute of Technology, a state college of the Oregon University System, was founded in 1947. Due to high energy costs on the original campus, a new campus was constructed to take advantage of geothermal energy that was known to exist in the community. In the early 1960s, three deep wells were drilled taping geothermal hot water at 192°F (89°C). This hot water now heats the entire campus of about 650,000 sq. ft. (60,000 sq. m) saving about $1,000,000 annually in heating and domestic hot water costs. No other source of energy is available for heating thus; the campus is entirely energy independent of fossil fuel sources. The campus also uses the geothermal energy *for melting snow on stairs and handicap ramps. The installed capacity of this system is 6.2 MWt and the annual energy use is about 47 billion Btus (14 GWh), saving 10,000 tonnes of* CO_2 *emissions annually (compared to producing it from petroleum).*

This year, the campus administration is proposing to drill a well (5,000 to 6,000 ft – 1,500 to 1,800 m) deep into a fault that is known to have a geothermal resource around 300^oF *(*150^oC*), to generate electricity. If this is successful, a one megawatt (MWe) geothermal power plant of either a flash steam or binary type will be installed to provide all the electricity needs on campus. This will provide an additional savings of around $500,000 and reduce* CO_2 *emissions by about 16,000 tonnes annually (compared to producing it from petroleum). The campus would then be 100% "green" by producing all of its energy needs from geothermal resources.*

In addition, the campus will construct a geothermally heated greenhouse and aquaculture facility to train interested students and potential developers in the use of geothermal energy for agricultural purposes.

The Geo-Heat Center was established on campus in 1974 to provided information dissemination and technical assistance for persons and organizations nation-wide and internationally to develop and utilization geothermal energy (website: http://geoheat.oit.edu). The Center staff also provides tours of the campus and community geothermal uses to educate students and interested investors in the benefits of geothermal energy, as well as assisting in the development of the geothermal uses. The proposed power plants, greenhouse and aquaculture facilities will also be used as a training facility and showcase to help transfer geothermal use to other locations throughout the country. Even though, high temperature geothermal energy is generally only available in the western states, the Geo-Heat Center also provides information and training in geothermal (ground-source) heat pumps that can be installed anywhere in the country as they only require normal ground and ground-water temperature to be utilized for both heating and cooling. Our staff of four people has provided technical assistance on geothermal energy use to every state in the Union and well as over 50 countries.

Oregon Institute of Technology was one of the eight winners, and was requested to participate in a live webcast in Washington, D.C. on April 18, 2007. The eight winners are list below.

California State University—Chico
Mount Wachusett Community College
Monmouth University
Richard Stockton College
Oregon Institute of Technology
University of California, Santa Barbara
Oberlin College
The Lawrenceville School (High School)

The National Wildlife Federation video team visited campus in March and filmed an interview with President Martha Anne Dow, Geo-Heat Center Director, John Lund, and OIT graduate Toni Boyd. They also filmed various geothermal uses on campus. This short video can be viewed on the National Wildlife Federation website: www.nsf.org/chillout.

Toni Boyd, of the Geo-Heat Center, then represented the campus at the live webcast in Washington, D.C. on April 18. She was part of a panel discussion during the live webcast with the other seven winner.

The event and award is certainly an honor for our campus, and was the only submittal featuring geothermal energy.

EXAMPLES OF COMBINED HEAT AND POWER PLANTS USING GEOTHERMAL ENERGY

John W. Lund and Andrew Chiasson

Geo-Heat Center
Oregon Institute of Technology
Klamath Falls, OR 97601

ABSTRACT

Examples of combined heat and power plants (CHP) using both high temperature (above 200^{o}C) and low temperature (around 100^{o}C) geothermal resources are described. These installations, some of which have been in operation for over 30 years, make more efficient use of the geothermal resources by cascading the geothermal fluid to successively lower temperature applications, thereby improving the economics of the entire system dramatically. The cascaded use, after being used for power generation, can include space or district heating, greenhouse heating, and aquaculture pond and swimming pool heating. The high temperature geothermal power plants normally use flash steam technology, whereas the low temperature operation use binary or Organic Rankine Cycle (ORC) power units. High temperature power generation with geothermal energy is usually economic as stand-alone plants, but low-temperature power generation is often not economic, with net plant efficiencies normally below 10% due to the low source temperature and relatively high parasitic loads from pumps. Examples of high temperature CHP installation described in this paper include the Sudurnes Regional Heating Corporation plant at Svatsengi, Iceland, and the Nesjavellir Geothermal plant near Reykjavik, Iceland. Low temperature installations described in this paper include ones at Bad Blumau and Altheim, Austria, Neustadt-Glewe, Germany, and at Egat, Thailand.

1.0 INTRODUCTION AND BACKGROUND

Combined heat and power (CHP) plants are not a new use of energy, whether it be from conventional fossil fuels or geothermal energy. In combining uses of heat with power generation, the power plant becomes increasingly more net efficient, which in turn improves power plant economics. This is particularly true in geothermal power plants, where thermodynamic efficiencies are typically much lower than conventional power plants, due to the lower working fluid temperatures in geothermal power plants. For example, conventional fossil fuel-fired power plants produce steam on the order of 550^{o}C, while most geothermal power plants operate with source temperatures in the range 90^{o}C-200^{o}C.

To illustrate the advantages of CHP with a geothermal power plant, consider a 10 MWe plant with a resource temperature of 150^{o}C. According to Rafferty (2000), at this resource temperature, a geothermal power plant would have a net efficiency of about 10%. This means that 100 MWt of energy is the combined amount of geothermal energy supplied to the plant plus parasitic equipment requirements (pumps, cooling tower, etc.) plus waste heat rejected to or lost to the environment. With incremental recovery of waste heat for beneficial uses, the efficiency of the whole CHP operation increases dramatically.

More specifically, consider the following examples of using a high temperature resource (150^{o} C) and a low temperature resource (100^{o} C) in a cascaded situation with a volumetric flow rate of 76 L/s. The high temperature resource could sustain a 2.0 MWe geothermal power plant with three employees generating around $1.0 million USD annually, resulting in a simple payback period of five years. Adding a two-line onion dehydration plant producing 13,600 tonnes of dried onions per year with a load factor of

0.83 (the load factor expresses the equivalent fraction of a year that a system operates at full load) would reduce the simple payback of the combined operation to one year and add 75 employees.

The low temperature resource could sustain a 250 kWe binary geothermal power plant with one employee generating around $140,000 USD annually, resulting in a simple payback period of five years. Adding a district heating system serving 100,000 m^2 of floor space with a load factor of 0.25 would reduce the simple payback to four years, but only add about two more employees. If a greenhouse operation of 24 ha with a load factor of 0.25 were added instead, the combined simple payback would be reduced to three years and add 144 employees.

As can be seen from the above examples, applications with a higher load factor result in a more efficient operation and shorter payback period; the higher the load factor, the lower the cost of the delivered heat. Rafferty (2003) examined the cost of delivered heat as a function of load factor for U.S. climates. For example, the cost of energy (including capital, maintenance, and operating costs) is approximately 4 times greater for a small space heating application with a load factor of 0.15 than for an industrial application with a load factor of 0.4, while the cost of energy of a greenhouse with a load factor of 0.22 is about double that of an industrial application with a load factor of 0.4.

Another important factor to consider in adding a cascaded direct-use application is the distance from the source water, as the pipeline cost strongly impacts the capital cost of the project. Installed costs of pre-insulated hot water pipelines range from about $500,000 USD per km for a 100-mm diameter pipeline to about $1,000,000 USD per km for a 300-mm diameter pipeline (NRC, 2005). Adding a direct-use application, in most cases, provides substantial additional employment opportunities, which is an economic benefit to the community that is difficult to quantify. The remainder of this paper describes actual examples of geothermal CHP cases.

2.0 EXAMPLES OF COMBINED GEOTHERMAL HEAT AND POWER PLANTS

2.1 Sudurnes Regional Heating Corporation, Svartsengi, Iceland

The Svartsengi plant (Figure 1) supplies hot water to a district heating system (hitaveita) serving about 20,000 people on the Reykjanes Peninsula (Thorolfsson, 2005, Ragnarsson, 2005). In addition it also serves about 25,000 inhabitants in Hafnarfjordur and other communities with electricity. The total installed generating capacity of the combined plant is 46.4 MWe providing about 370 GWh/yr, and 200 MWth providing about 2,700 TJ/yr in the form of hot water for district heating. The plant is located closed to the town of Grindavik about 50 km to the south west of the capital Reykjavik. It is located on an active mid-Atlantic spreading center with active fissure earthquake swarms, volcanic craters and open fissures and faults. The plant is built on a lava field which dates from a volcanic eruption in the year 1226. The first well was drilled in 1972, with the number of drilled wells currently at 20. Of these, 12 are production wells and one well is used for reinjection. The reservoir fluid is a brine at 240^{o}C. Most of the waste water flows into the adjacent lava field, which due to silica precipitation sealing the disposal pond, the famous “Blue Lagoon” bathing area was formed, visited by almost 200,000 tourists annually.

A flow diagram of the Svartsengi Power Plant is shown in Figure 2. The first heat exchanger experiments started in 1974 in a small-scale pilot plant. Based on the results of this research, a second pilot plant was built in 1976 which supplied the town of Grindavik with 20 L/s of hot water. The first electric plant, Power Plant I, was built in 1976-78. At the time, it was the first of its kind in the World, providing both geothermal electric energy and space heating for a district heating system simultaneously. This provided 150 L/s for the district heating system, which amount to 50 MJ/s (MWth) thermal power and two 1-MWe back-pressure steam turbine generators. Subsequently, 75 MWth of thermal energy and 6 MWe back-pressure turbines were installed in 1981. This was followed by three 1.2 MWe binary power units in 1989 with water-cooled condensers and four 1.2 MWe binary power units in 1993 with air-cooled condensers. Finally in 1999 a 30-MWe condensing steam turbine was commissioned and in 2000 a district heating increase of 75 MJ/s (MWth) was commissioned. With retirements and improvements of existing equipment, the electrical generating system now consists of 12 turbines, five of which are steam units and seven are binary (organic Rankine cycle).

The plant maintenance and operating staff consists of 22 persons, who also operate 20 geothermal wells and wellheads, 70 control valves, 100 pumps, 20 km of pipelines and thousands of valves. Two 50-MWe power plants are scheduled for installation in 2006.

2.2 Nesjavellir Power Plant, Reykjavik Energy, Iceland

The Nesjavellir Power plant (Figure 3) , located just to the west of Lake Thingvalla, provides electricity and district heating energy to the city of Reykjavik 27 km away (Lund, 2005; Ragnarsson, 2005). This high temperature field as high as 380^{o}C, has been operating a co-generation power plant since 1990.

The primary purpose of the plant is to provide hot water for the Reykjavik area. The plant capacity is 210 MWe generating 2,100 GWh/yr of electric energy, and provides 1,100 L/s of 83^{o}C hot water for district heating with a capacity of 290 MWt which provides about 4,500 TJ/yr. Freshwater from nearby wells is heated by steam and water in a heat exchanger for the district heating system. In 1998 the power plant came on-line with two 30 MWe steam turbines. In 2001 the plant was enlarged to 90 MWe with the installation of a third turbine. In 2005, a fourth turbine came on line bring the capacity to 290 MWe.

A flow diagram of the plant is shown in Figure 4. A total of 22 wells have been drilled to depths ranging from 1,000 to 2,200 m. The steam-water mixture from the wells is separated and the steam piped to the turbines at 12 bars at 190^{o}C. The separated hot water is passed through shell-and-tube heat exchangers to heat the incoming cold water. This cold water at 4^{o}C for the district heating system is obtained from five wells near Lake Thingvalla, which is then heated through condensers and heat exchanger to 85 to 90 ^{o}C. Since the freshwater is saturated with dissolved oxygen that would cause corrosion after being heated, it is passed through deaerators; where, it is boiled at low pressure to remove the dissolved oxygen and other gases, cooling it to 82-85^{o}C. Finally, a small amount of geothermal steam containing acidic gases is injected into the water to rid it of any remaining oxygen and lowers its pH, thereby preventing corrosion and scaling.

Water for the district heating system is pumped through an 800-mm diameter pipeline to storage tanks overlooking Reykjavik. From the storage tanks, the water is fed through pipelines to the communities which are served by the district heating system (Orkuveita Reykjavikur). The pipeline, 27 km in length, has fixed and expansion points every 200 m, and is designed to carry water at 96^{o}C at a rate if 1,870 L/s. At 560 L/s, the water takes about seven hours to cover the distance, losing only 2^{o}C. At the higher rates of flow, the loss is only 1^{o}C. The 8-to-10 mm thick steel pipe is insulated with 100 mm of rock wool and cover with aluminum sheets where it lies above ground, and insulated with polyethylene and covered with PEH plastic where it lies underground.

2.3 Bad Blumau, Austria

Bad Blumau, a resort community, is located in east Austria in the Styrian Basin which is a sub-basin of the Pannonian Basin (Goldbrunner, 2005). The Basin has heat flow values up to 95 mW/m^2 and temperatures of more than 100^{o}C at depths of 2,000 m. The geothermal projects at Bad Blumau have its origins in drilling for hydrocarbons. This exploration, with drilling to 3,046 m in well Bad Blumau 1a, encountered fluids of 100^{o}C at 17 L/s. Two wells were then drilled for geothermal fluids, Bad Blumau 3 to 1,200 m producing 1.5 L/s at 47^{o}C and Bad Blumau 2,360 m producing 80 L/s at 110^{o}C. The geothermal fluids of the deeper wells are sodium-bicarbonate-chloride type with a total dissolved solids (TDS) of 17.9 g/L. Due to the potential for carbonate precipitation, polyphosphate is added at the well.

A process schematic of the Blumau geothermal project is shown in Figure 5. A 250 kW geothermal binary (organic Rankine) cycle power plant was installed in 2001. The plant used brine at

110^{o}C to generate a net 180 kW. The existing water at 85^{o}C is fed into the district heating system, providing heat for the Rogner Bad Blumau Hotel and Spa (Figure 6). The spent water is then returned to a 3,000-m deep injection well. The spa with pools of 2,500 m^{2} is provided geothermal water at 1.5 L/s. The heating of the spa complex and hotels (1,000 beds) is established by a geothermal doublet of using well 1a and 2. Since the water is high in CO_2, 1.5 t/h of liquid gas is being extracted. The total capacity of the space heating is 3.5 MWth and the pools at 1.6 MWth for a total of 5.1 MWth. The electric power plant produces around 1.56 million kWh over three months in 2003.

The spa was built entirely with private investments of €55 million with the local government providing €20 million for the drilling of wells and improving the local infrastructure. The overnight stays are around 40,000 annually, with 340 jobs in the thermal resort hotel and 170 jobs in regional services being created.

2.4 Altheim, Austria

Altheim is a municipality in the Upper Austrian "Inn-region" with 5,000 inhabitants. A well for the district heating system was drilled in 1989. The well produced geothermal fluids flowing from an aquifer about 2,300 m deep. The artesian flow from the well was 46 L/s at 104^{o}C, but, with downhole pumps can produce 85-100 L/s at 106^{o}C. The district heating system capacity is 10 MWth supplying heat to 650 consumers, or about 40% of the inhabitants of Altheim. About 80% of the thermal energy is used for these homes, and the remainder is used for heating a school and swimming pool. A schematic of the power plant and district heating system is shown in Figure 7.

A second well was drilled in 1994 was deviated for a total length of 3,100 m at a vertical depth of 2,200 m (Figure 8). This well produced 100 L/s at 93^{o}C. This well is now used as the injection well receiving the spent water at 65^{o}C. About half of the water from the original production well goes to the district heating system. The other half of the flow is used to power a 2.5 MWe binary (organic Rankine) cycle generator installed in 2000 with the highest output capacity of 1.027 MWe. Presently only about 500 kWe producing around 100,000 kWh/month is supplied to the grid, with the remaining power used for the various pumps and other auxiliaries.

The district heating system, operating about 1,200 hours/year charges about €0.04/kWh ($0.05 USD/kWh) based on a 30^{o}C temperature drop in the water. However, the customers usually achieve a greater temperature drop, thus paying less per kWh. There is of course, a significant reduction in air pollution, based on using fossil fuel prior to 1989. These amount to between 58 and 72% reduction in greenhouses gases for the community, saving about 2,500 t/year of equivalent fossil fuel.

2.5 Neustadt-Glewe, Germany

The Neustadt-Glewe geothermal heating plant, located in northern Germany, was commissioned in 1995, supplying exclusively the base load for a district heating system. The total output of the system is 11 MWth of which geothermal supplies 6 MWth; the remainder provided by a gas-fired boiler unit that covers the peak load. In 2003, a 210 kWe gross geothermal electric power unit was added to the system. A schematic of the CHP system is shown in Figure 9.

The geothermal electric power unit, a binary (organic Rankine) cycle, uses 98^{o}C water from a 2,300-m deep well. The plant uses n-perfluorpentane as a working fluid, and the parasitic loads are due to pumps and fans amounting to 31 kW. The production pump in the well is not included in the parasitic load. The production pump is a speed-controlled electric submersible set at 260 m.

The plant supplies heat and power using a parallel-series connection of power plant and heating station. The heating station takes priority over the power plant. The incoming flow rate of the brine at 110 m^{3}/h, is split and a part is fed to the power plant. The brine leaves the power plant at a constant outlet temperature where it joins the upstream flow to the heating station. The minimum mixing temperature required in the summer is 73 ^{o}C, and to meet the heating demand in wintertime 98^{o}C is required. Thus, the power plant is fed with variable mass flow rate of brine at constant temperature;

while, the heating station is provided with a constant mass flow rate at variable temperature. After use, the fluid is returned to an injection well around 50^oC.

The total district heating project cost was €9.45 million ($12.3 million USD) of which €6.44 million ($8.37 million USD) was for the geothermal side of the system. The electrical generation plant cost €950,000 ($1.24 million USD). As of 1998 1,300 households, 20 trade consumers and one industrial enterprise are supplied with heat from the plant. During this time, 15,900 MWh of heat of which 15,042 MWh was geothermal (95%) was supplied to the customers. The system saved about 1.7 million m^3 of natural gas/yr and reduced the emission of CO_2 by 2,700 tonnes.

2.6 Fang Geothermal Plant, Egat, Thailand

This combined operation was commissioned in 1989 and consists of a single-module 300 kWe binary power plant that has a water cooled condenser with once-through flow (Ramingwong, et al., 2005). A photograph of the geothermal power plant is shown in Figure 10.

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The net power output varies with the season from 150 to 250 kWe (175 kWe average) producing 1.2 GWh/yr. This multipurpose project (Figure 11) then cascades the water from the power plant for refrigeration (cold storage) crop drying and a spa, with an installed capacity of 480 kWt producing 0.92 TJ/yr. The artesian well provides approximately 8.3 L/s of 116^oC water. The well requires chemical cleaning to remove scale about every two weeks. Plant availability is 94% and the estimated power cost is from $0.063 to $0.086 USD per kWh. This is very competitive with diesel generated electricity which runs $0.22 USD to $0.25 USD per kWh.

3.0 CONCLUDING SUMMARY

This paper has described examples of combined heat and power plants utilizing geothermal energy. Examples of high temperature CHP installation described included the Sudurnes Regional Heating Corporation plant at Svatsengi, Iceland, and the Nesjavellir Geothermal plant near Reykjavik, Iceland. Low temperature installations described included ones at Bad Blumau and Altheim, Austria, at Neustadt-Glewe, Germany, and at Egat, Thailand.

The installations described, some of which have been in operation for over 30 years, make more efficient use of the geothermal resources by cascading the geothermal fluid to successively lower temperature applications, thereby improving the economics of the entire system dramatically. The cascaded use, after being used for power generation, can include space or district heating, greenhouse heating, aquaculture pond heating, swimming pool heating, space cooling, and refrigeration.

From a simple economic analysis, it was shown that the greater the load factor for the direct-use application, the more efficient the operation and the shorter the payback period of the combined heat and power project. A higher load factor essentially spreads the capital cost over a greater quantity of heat over the annual cycle, and thus results in a lower cost of delivered heat. This implies that in cold climates, district heating applications are more economically favorable than in warmer climates. Higher load factors are usually achieved with industrial operations using high temperature resources that are not entirely dependent on weather factors, and thus operate more frequently during the year. Another benefit of some direct-use applications is job creation.

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Figure 1. Aerial view of the Svartsengi Power Plant and "Blue Lagoon".

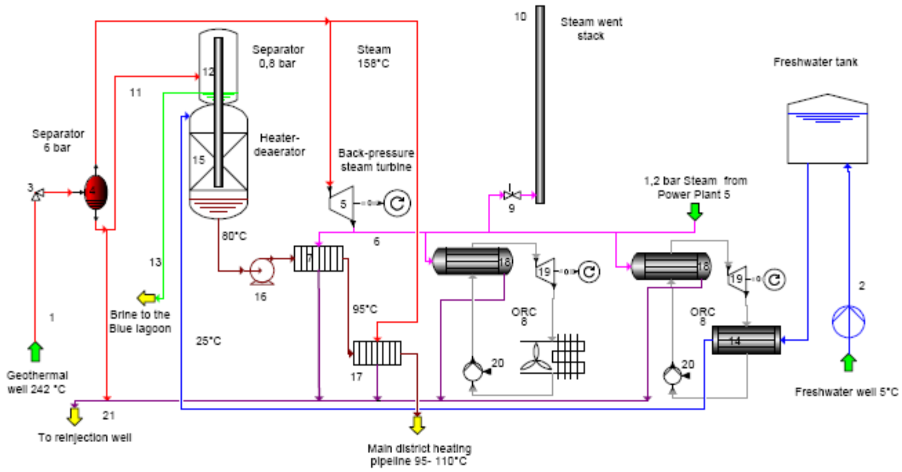

Figure 2. Flow diagram of the Svartsengi Power Plant.

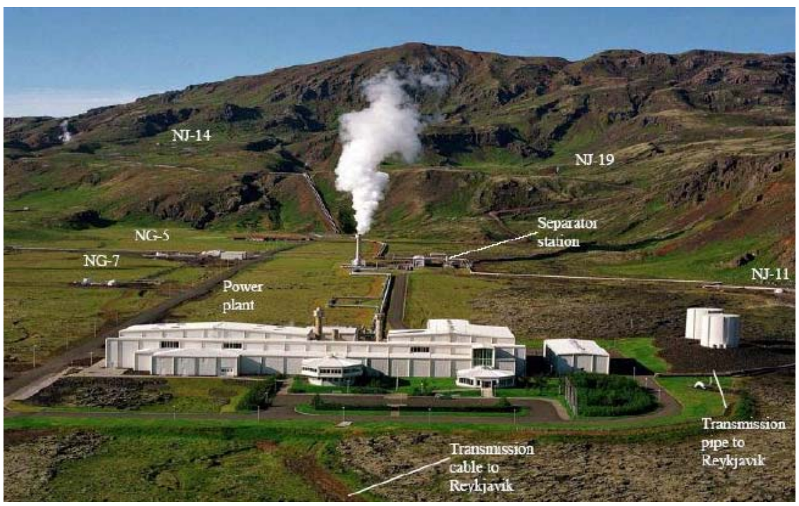

Figure 3. Overview of the Nesjavellir Power Plant.

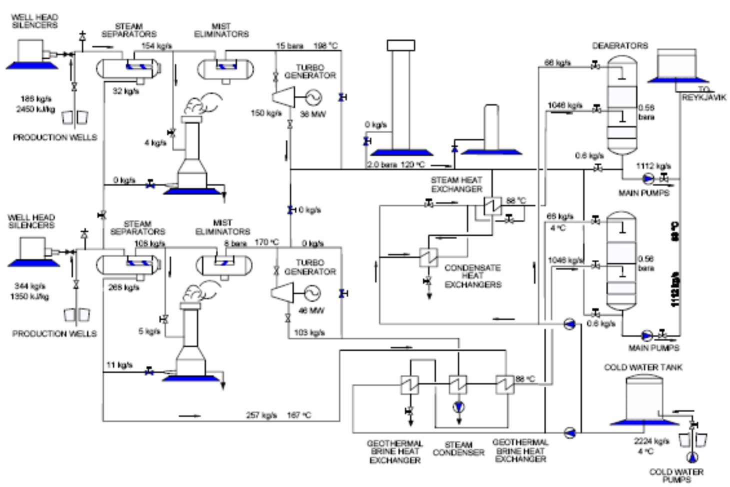

Figure 4. Flow diagram of the Nesjavellir Power Plant.

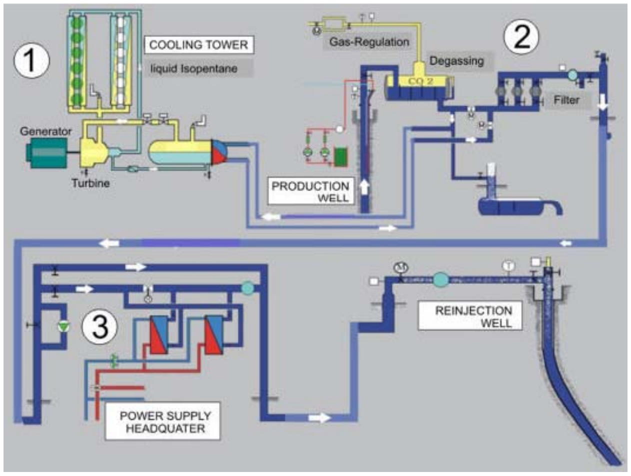

Figure 5. Blumau geothermal project. (1) ORC, (2) CO_2-gas, and (3) district heating.

Figure 6. Rogner Bad Blumau spa and outdoor pools.

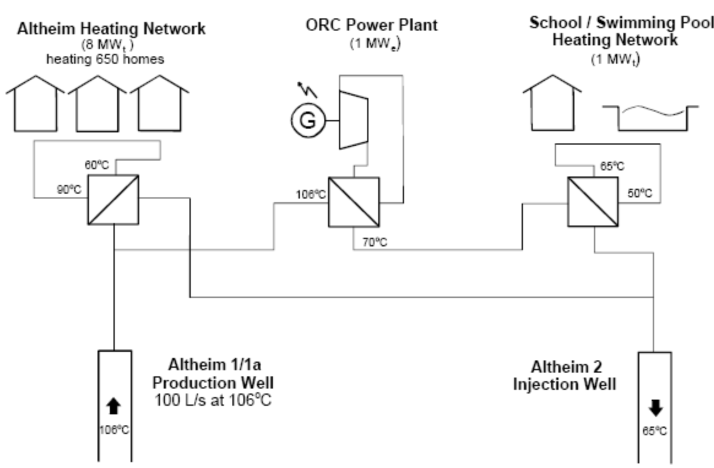

Figure 7. Schematic of the Altheim Power Plant and district heating system.

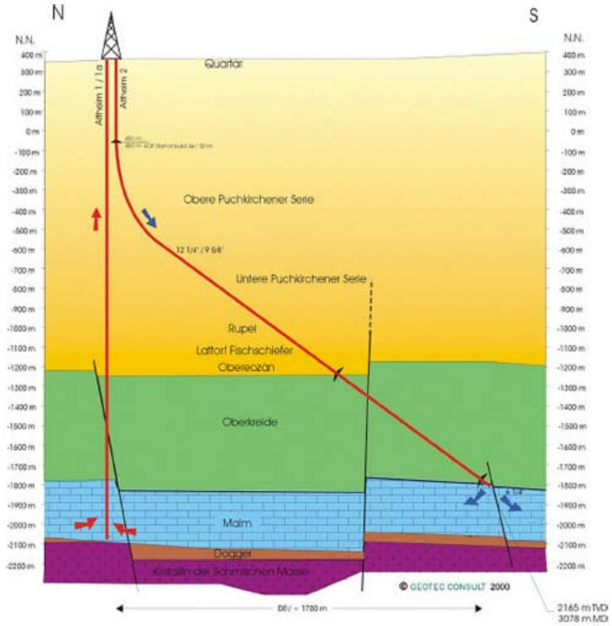

Figure 8. Geologic cross-section showing production and injection wells at Altheim.

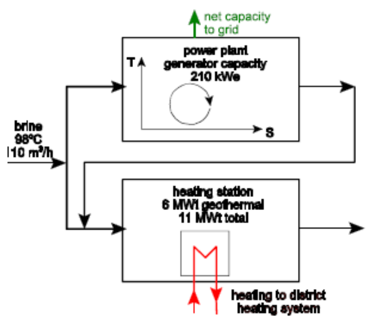

Figure 9. Process schematic of the CHP project in Neustdat-Glewe.

Figure 10. Fang binary geothermal power plant in Egat, Thailand.

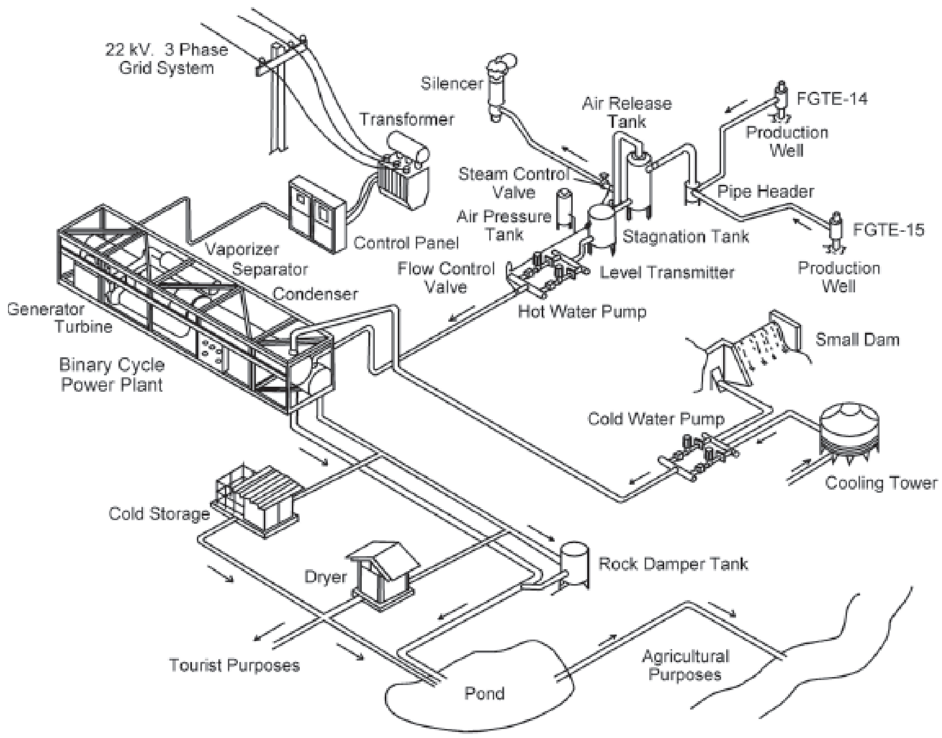

Figure 11. Process schematic of the Fang Geothermal CHP project in Egat, Thailand.

FEASIBILITY STUDY
WALKWAY SNOWMELT SYSTEM
STEAMBOAT SPRINGS SKI AREA, COLORADO
REVISED

Based on a meeting with City and Ski Area representatives during a visit to Steamboat Springs on August 9th, 2007, the following revised alternatives and recommendations are presented for implementing a geothermal walkway snowmelt system for the ski area.

The following alternatives are based on the outcome of a geologic investigation and subsequent results of the current drilling of temperature gradient holes to define a possible geothermal reservoir. This is based on recommendations made in a letter to the city on June 9, 2006 and a feasibility study prepared later in June of 2006. The following alternatives are based on the revised assumptions that 100,000 square feet of walkway area will be served by the system at 125 Btu/hr/ft^2 peak load requiring 12.5 million Btu/hr total peak load (based on experience with the Vale, CO snowmelt system). The PEX (cross-linked polyethylene) pipe under the walkway is assumed constant for all alternatives at about \$7/ft^2 = \$700,000 for the 100,000 ft^2.

Drilling cost can vary depending upon the depth and diameter of the hole and the availability of drilling rigs. For deep holes (1,000 feet in depth) with large diameter (above 12-in), the cost is around \$100 per foot. For shallow wells (up to 300 feet deep) and intermediate diameter 8 to 10-inch, the cost is around \$40 per foot. For closed loop heat pumps the holes are 150 to 200 feet deep and would cost from \$5 to \$10 per foot.

Alternative 1. Assumes that a geothermal resource of over 140°F is found and can be developed with sufficient flow (300 to 500 gpm per well) at 1000 feet deep. This temperature water can be used directly in the snow melt system. However, as an additional benefit, the water could first be used for space heating of nearby buildings and then cascaded at around 110 to 120°F for snow melting. Assuming a 30°F temperature drop in the snowmelt system, 2 to 3 production wells and 1 to 2 injection wells would be required. The following costs are estimated.

3 to 5 wells at \$100/ft at 1000 feet each:	\$300,000 to	\$500,000
Pumps for the production wells @ \$30,000 each	\$ 60,000 to	\$ 90,000
Heat exchangers, storage tank and controls	\$ 50,000 to	\$ 60,000
Total incremental cost	\$410,000 to	\$650,000

Plus the annual operating cost of the 75 hp pumps at \$24,000 to \$40,000 annually, minus income from space heating of buildings at 10 million Btu/hr selling for \$7.5 per million Btus for 2,000 heating hours per year = \$150,000 annual income.

Alternative 2. Same assumptions as Alternative 1, except that downhole heat exchangers (DHE) are used (good above 140°F), thus eliminating the need for injection wells, as no water is pumped from the wells – only heat. The costs would be:

8 to 9 production wells @ $100/ft at 1,000 ft. each	$800,000 to $900,000
Downhole heat exchangers and circulations pumps	$100,000 to $110,000
Controls	$ 50,000 to $ 55,000
Total incremental cost	$950,000 to$1,065,000

Plus the annual operating cost of the 10 hp circulation pumps at $10,000 to $11,000 annually. Since, DHE are less efficient compared to pumping, the energy output would probably not be sufficient to providing additional heat for buildings.

Alternative 3. Assuming a geothermal resource of around 110°F is found and can be developed with sufficient flows of 300 to 500 gpm per well. This is just adequate for snow melting, but not adequate for space heating, as the water could not be cascaded and still meet the snow melt requirement. The estimated cost for this use is the same as alternative #1, except there would be no income from selling energy for space heating. This temperature could not be used with downhole heat exchangers.

Total incremental cost: $410,000 to 650,000

Plus the annual cost of operating the well pumps at $24,000 to $40,000.

Alternative 4. Assuming that no geothermal resource (above 100°F) is found, and only normally ground water (or ground temperature) exists in the area at economic depths. This would require the use of geothermal heat pumps, either open loop (using well water) or closed loop (ground-coupled). For 100% snow melt, a total of about 1,000 tons of heat pump capacity would be required. This would require pumping about 3 gpm/tons of capacity for the open loop system or 3,000 gpm at peak load. This would require 6 to 10 wells that would probably been fairly shallow – say around 300 feet each. The closed loop system would require one 150 to 200 foot deep, 4-inch diameter vertical holes with a closed loop of pipe per ton of capacity or 1,000 holes. The cost would be:

a. Open loop:

6 to 10 wells @ $40/ft at 300 feet each	$ 72,000 to	$120,000
3 to 5 injections wells @$40/ft x 300	$ 36,000 to	$ 60,000
Pumps and controls	$ 50,000 to	$ 85,000
Heat pumps @ $700/ton	$ 700,000 to	$ 700,000
Total incremental cost	$ 858,000 to	$ 965,000

Plus the annual cost of electricity for the heat pump compressors at $70,000, minus potential income from summer residents for space cooling of around $150,000 annually.

b. Closed loops:

1,000 holes at $5/ft -$10/ft for 200 feet each	$1,000,000 to $2,000,000
Pumps and controls	$ 25,000 to $ 40,000

Heat pumps @ $700/ton	$ 700,000 to $ 700,000
Total incremental cost	$1,725,000 to $2,740,000

Plus the annual cost of electricity for the heat pump compressors at $70,000, minus potential income from summer residents for space cooling of around $150,000 annually.

With the closed loop system, heat would be continually removed from the ground and, thus, some means of injecting heat into the ground during the summer months must be considered. This would include a passive solar system or providing cooling to adjacent buildings, both which would reject heat to the ground. This is necessary to maintain a constant ground temperature in the vicinity of the vertical heat exchange holes.

Alternative 5. Since geothermal heat pumps alone have a very high capital cost, using them only to maintain the system in a warm condition (idling), and using gas to peak the system when snow falls, would reduce the investment cost. Designing the heat pumps to meet 50% of the peak load, would probably provide 90% of the total season heating demand. Thus, the gas-fired heating system for peaking would only be required about 10% of the time based on ASHRAE weather data. Either an open loop or closed loop heat pump system could be used. The costs would be as follows:

a. Open loop: 50% of alternative 4a = $429,000 to $482,500

   Plus the annual cost of electricity for the heat pumps compressors at $35,000, minus potential income from summer residents for space cooling of around $75,000 annually.

   Cost of boiler, piping, tanks for 1.25 million Btu capacity = $50,000
   Plus the annual cost of gas at $12 per million Btu = $22,500

b. Closed loop: 50% of alternative 4b = $862,500 to $1,370,000

   Plus the annual cost of electricity for the heat pump compressors at $35,000, minus potential income from summer residents for space cooling of around $75,000 annually.

   Boiler and gas costs would be the same as in 5a above.

Alternative 6. Using a conventional gas fired boiler systems, such as used at Vale:

Cost of boiler, piping, tanks, etc. for 12.5 million Btu capacity $250,000

Plus the annual cost of gas at $12 per million Btu = $225,000
This cost would most likely increase in future years, but is not considered in this study.

COST COMPARISONS

There are several ways to compare the various alternative, and with the natural gas option. Two methods are used here: (1) equivalent annual cost at 7% interest, and (2) simple payback time comparing the additional capital cost divided by the annual savings relative to natural gas.

1. Equivalent Annual Cost

The costs of the various geothermal systems are compared with the natural gas alternative (Alternative 6) with the following assumptions. Cost of money is 7%/year; life of geothermal wells, including heat pump wells at 50 years (CRF = 0.07246); and cost of all other equipment is 30 years (CRF = 0.08059). All costs are converted to equivalent annual costs for ease of comparison and to determine the payback period for geothermal over natural gas.

Alternative 6. Natural gas:

Capital investments:	250,000 x 0.08059 =	$20,150/yr
Annual cost of gas:		$225,000/yr
Total equivalent annual cost =		**$245,150**

Alternative 1. Resource >140°F and water used directly:

Capital investments:	$300,000 x. 0.07246 =	$21,740	
	$500,000 x 0.07246 =		$36,230
	$110,000 x 0.08059 =	$ 8,865	
	$150,000 x 0.08059 =		$12,090
Annual operating costs:		$24,000	$40,000
Total equivalent annual cost =		$54,605	$88,320
Total annual savings over gas =		**$190,545**	**$156,830**
Savings with $150,000/yr income =		$340,545	$306,830

Alternative 2. Resource >140°F using DHE

Capital investments:	$800,000 x 0.07246 =	$57,970	
	$900,000 x 0.07246 =		$65,215
	$150,000 x 0.08059 =	$12,090	
	$165,000 x 0.08059 =		$13,300
Annual costs:		$10,000	$11,000
Total equivalent annual cost =		$ 80,060	$ 89,515

Total annual savings over gas =	**$ 165,020**	**$ 164,075**

Alternative 3. Resource at 110°F and water used directly (same as Alternative 1 without the $300,000 annual income).

Total equivalent annual cost =	$ 54,605	$ 88,320
Total annual savings over gas =	**$190,545**	**$156,830**

Alternative 4. Geothermal heat pumps – open and closed loop

a. Open loop

Capital investments: $108,000 x 0.07246 =	$ 7,825	
$180,000 x 0.07246 =		$13,045
$ 750,000 x 0.08059 =	$ 60,440	
$ 785,000 x 0.08059 =		$63,265
Annual costs:	$ 70,000	$ 70,000
Total equivalent annual cost =	$138,265	$146,310
Total annual savings over gas =	**$106,885**	**$ 98,840**
Savings with $150,000/yr income =	$256,885	$248,840

b. Closed loop:

Capital investments: $1,000,000 x 0.07246 =	$ 72,460	
$2,000,000 x 0.07246 =		$144,920
$ 725,000 x 0.08059 =	$ 58,430	
$ 740,000 x 0.08059 =		$ 59,640
Annual costs:	$ 70,000	$ 70,000
Total equivalent annual cost =	$200,890	$274,560
Total annual savings over gas =	**$ 44,260**	**(no savings)**
Savings with $150,000/yr income =	$194,260	$120,590

Alternative 5. 50% of peak load by geothermal, remaining by natural gas

a. Open loop

Capital investments:		
50% of alternative 4a. =	$ 34,130	$ 38,155
Capital cost of gas = $50,000 x 0.08059 =	$ 4,030	$ 4,030
Annual costs:		
Annual cost of geothermal =	$ 35,000	$ 35,000
Annual cost of gas =	$ 22,500	$ 22,500

Total equivalent annual cost =	$ 95,660	$ 99,685
Total annual savings over 100% gas =	**$149,490**	**$145,465**
Saving with $75,000/yr income =	$224,490	$220,465

b.Closed loop

Capital investments		
50% of alternative 4b. =	$ 65,445	$102,280
Capital cost of gas = $50,000 x 0.08059 =	$ 4,030	$ 4,030
Annual costs:		
Annual cost of geothermal =	$ 35,000	$ 35,000
Annual cost of gas =	$ 22,500	$ 22,500
Total equivalent annual cost =	$126,975	$163,810
Total annual savings over 100% gas =	**$118,175**	**$81,340**
Savings with $75,000/yr income =	$193,175	$156.340

2.Simple payback period

This method compares the incremental capital cost over the gas option (alternate 6) divided by the annual savings compared to 100% gas.

	Additional capital cost	Annual savings
Alternate 1:	$160,000 to $400,000	$201,000 to $185,000
	Payback = 0.80 to 2.16 years	
	With $150,000/yr income	$351,000 to $335,000
	Payback = 0.46 to 1.19 years	
Alternate 2:	$700,000 to $815,000	$215,000 to $214,000
	Payback = 3.26 to 3.81 years	
Alternate 3:	$160,000 to $400,000	$201,000 to $185,000
	Payback = 0.80 to 2.16 years	
Alternate 4a.	$608,000 to $715,000	$155,000 to $155,000
	Payback = 3.92 to 4.61 years	

	With $150,000/yr income	$305,000 to $305,000
	Payback = 1.99 to 2.34 years	
Alternate 4b.	$1,475,000 to $2,490,000	$155,000 to $155,000
	Payback = 9.52 to 16.06	
	With $150,000/yr income	$305,000 to $305,000
	Payback = 4.84to 8.16 years	
Alternate 5a.	$229,000 to $282,500	$167,500 to $167,500
	Payback =1.37 to 1.69 years	
	With $75,000/yr income	$242,500 to $242,500
	Payback = 0.94 to 1.16 years	
Alternate 5b.	$662,500 to $1,170,000	$167,500 to $167,500
	Payback = 3.96 to 6.99 years	
	With $75,000/yr income	$242,500 to $242,500
	Payback = 2.73 to 4.82 years	

CONCLUSIONS

The economic aspects of the project can be viewed from four different perspectives: lowest risk, lowest initial investment cost, lowest annual cost, and shortest payback time .

Lowest risk

The project that has the lowest risk is the closed loop geothermal heat pump – alternative 4b. This installation is essential risk free, as you can drill the 200-foot deep holes anywhere and be guaranteed that you get ground temperatures in the range of 40 to 90°F temperature – the ideal range for geothermal heat pumps. However, this alternative has the highest costs and in the extreme case (high drilling cost) is not economical unless the $150,000/year income potential is considered. Choices with increasing risk are alternative 4a (open loop GHP), alternative 3 (low temperature geothermal), 2 (DHE) and alternative 1 (direct use).

Lowest initial investment cost

The project with the lowest initial investment cost is the high temperature direct-use – alternative 1 or low temperature direct-use – alternative 3. However, these alternatives has one of the highest risks, that of obtaining geothermal water >140°F or at least 110°F. The next lowest cost alternatives are 5a and 4.

Lowest annual cost

The project with the lowest annual cost is the direct use – alternative 1 or 3 without the savings from supplying heat to adjacent buildings, and alternative 1 if the income from the heating district is realized.

Shortest payback time.

Most of the alternatives have payback times of less than 10 years. Alternatives 1 (direct-use), 3 (low temperature direct-use) and 5a (open loop GHP supplemented with natural gas) have almost immediate payback, especially if the income from selling the heat is considered. .

In summary, it appears that alternative 2 with the DHE is the most economical if a high temperature (>140°F) resources is encountered, and alternative 5a (open loop GHP with gas peaking) if no geothermal resource is encountered, but normal temperature ground water is available. Otherwise alterative 4b or 5b should be considered.

GEO-HEAT CENTER

Oregon Institute of Technology, Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

John W. Lund, Director
Andrew Chiasson
Tonya "Toni" Boyd
Debi Carr

FEASIBILITY STUDY FOR A GEOTHERMAL HEAT PUMP SYSTEM FOR SNOW-MELTING AT THE FOURTH STREET HERITAGE CORRIDOR, PHASE 1 – LEADVILLE AVE. TO WALNUT AVE., KETCHUM, ID

Introduction

With the coordinated efforts of the Idaho Energy Division of the Idaho Department of Water Resources (IDWR), the Geo-Heat Center conducted an assessment of the feasibility of a geothermal heat pump system for snow melting of sidewalks along the Fourth Street Heritage Corridor in Ketchum, ID. This feasibility study addresses Phase I of construction, from Leadville Ave. to Walnut, Ave.

The snow melting system is a hydronic type that has been designed by Forsgren Associates, Inc. of Boise, ID, and the tubing installation was completed in the spring of 2007. The tubing spacing is 12-inches, and the heat source is planned to be from two boilers, each installed in an underground vault in two alleys.

Several options for the geothermal energy source were considered, but these options were reduced to one after a site meeting on August 21, 2007. Conveying geothermal water from Guyer Hot Springs was considered, but the availability of the water is questionable and piping costs through city streets would be cost prohibitive. A closed-loop earth coupling for water source heat pumps was considered, but due to the large heating load, there is not nearly enough land area to accommodate the several hundred vertical boreholes that would be required. Other sources of flowing water (i.e. sewers and water mains) were considered as heat sources for water-source heat pumps, but flow rates are questionable during peak snow melting demand times. Use of cold-climate air-source heat pumps was brought up at the site meeting, but currently available units are of small capacity, designed for the residential sector, and thus for snow melting loads, several tens of outdoor condensers would be required. Cold-climate air-source heat pumps may be a viable option if larger units come to the market. Thus, the most viable geothermal option, and the focus of this feasibility study, is water-source heat pumps, with the source being groundwater pumped from a well(s) and injected into a receiving well(s).

Overview of Snow Melting Systems

Snow melting systems are unique in that the peak load may occur under a number of weather conditions. That is, the quantity of energy necessary from a snow melting system depends on the outdoor air temperature, the wind speed, the snowfall rate, and the density of the snow. Most large snow falls occur under milder air temperatures, not at the coldest outdoor design condition.

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE, 2003) describes a study that compiled and analyzed 30-years of weather data for several cities to determine design snow melting loads. For Boise, ID (the closest data set to Ketchum), a heat flux of 146 Btu/hr/ft^2 is necessary to keep an area snow free 99% of the time, while only 62 Btu/hr/ft^2 is necessary to melt snow after a certain period of time after accumulating.

Figure 1 is a contour map of snow melting design data taken from the Wirsbo Snow & Ice Melting Manual. A review of these data shows that a supply temperature of 167^{o}F and 100^{o}F would be required in order to keep the sidewalk surface at 35^{o}F under a design heat flux of 146 Btu/hr/ft^2 and 62 Btu/hr/ft^2, respectively. These temperatures could easily be supplied by a boiler, but 130^{o}F is the upper limit of fluid temperatures capable of being supplied by water-source heat pumps available today. Therefore, with a supply temperature of 130^{o}F, the available heat output from a water-source heat pump would be unlikely able to keep the area snow free 99% of the time with tubing at 12-inch spacing. However, this situation is still acceptable; it would simply mean that during heavy storms, some snow accumulation would occur on some areas of the sidewalk, while other areas would be kept snow free. After the storm, the system would eventually catch up and melt all the snow.

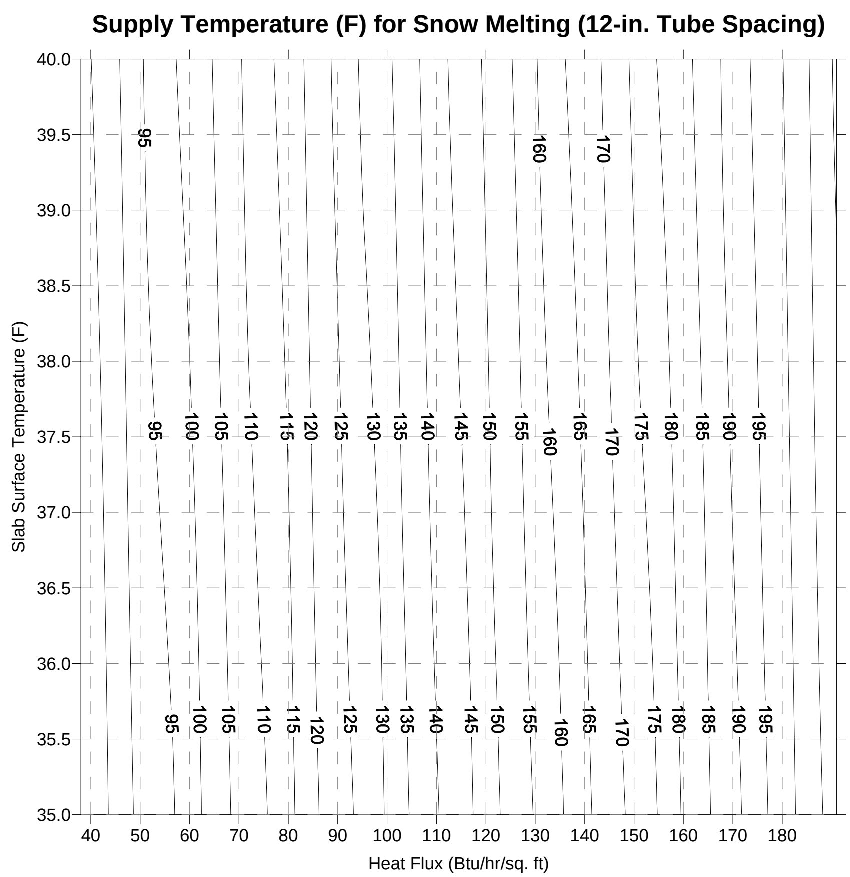

Figure 1. Contour map of fluid supply temperature as a function of slab surface temperature and design heat flux.

Based on an expected heat flux of 100 Btu/hr/ft^2 on a total snow melting area of 18,000 ft^2, the peak heating load that water-source heat pumps would be capable of supplying for Phase I is approximately 1.8 million Btu/hr.

Geological Conditions

The geological conditions for an open-loop (well to well) heat source have been evaluated by Kenneth Neely, Technical Hydrogeologist of the Idaho Department of Water Resources. In general the site geology consists of alluvial valley deposits overlying granite basement rocks. Therefore, the alluvial deposits would be the most likely target for the producing aquifer. From well driller's reports, it appears that the alluvial aquifer is less than 200 feet in total thickness in the City Hall/Fourth Street area.

Most wells in the area have yields of less than 50 gallons per minute (gpm), but a couple of wells have yields over 300 gpm. They were drilled for Sun Valley Sewer and Water, and are located northeast of City Hall, according to the well driller's reports. The actual yield of the proposed geothermal heat pump well will be controlled by two factors: the aquifer characteristics at that location and the well construction.

Groundwater temperature is likely in the range of 45-48^{o}F, with no evidence of thermal waters present. Ground water flow is most probably from the northeast to the southwest in the City Hall/ Fourth Street area, so an injection well should be sited in the downgradient direction if possible.

Based on the projected heating load of 1.8 million Btu/hr and the expected groundwater temperature, wells would have to supply groundwater at a total of approximately 275 gallons per minute.

Estimation of Annual Heating Energy Costs

The ASHRAE (2003) handbook (referenced above) also compiled the number of annual snow melting energy per city and the idling energy. Snow melting systems must be "idled" to keep the slab near 32^{o}F prior to a snowfall event. Otherwise, due to the transient nature of these systems, it may require an unacceptable amount of time for the slab to warm up and begin melting snow.

As mentioned above, for a heat pump system supplying 130^{o}F fluid, it is estimated for design purposes that this system will keep the sidewalks 50% snow-free during a peak design snow storm. According to ASHRAE (2003), 2,449 Btu/ft^2 and 73,015 Btu/ft^2 are the annual energy fluxes required for snow melting and idling, respectively, for Boise, ID. Thus, the following annual heating costs for snow melting are given below based on the following assumptions: $1.10/therm for natural gas, $0.05/kWh for electricity, a boiler efficiency of 0.85, a heat pump coefficient of performance of 2.75 (accounting for well pump electrical energy consumption), and a snow melting area of 18,000 ft^2. To keep the comparison on equal terms, both the boiler and heat pump systems were assumed to be designed for a snow-free area of 50% during a peak design storm. Slab edge heat losses were not considered.

Heating System	Annual Heating Cost
Geothermal heat pump	$7,240
Boiler (natural gas)	$17,600

Estimation of Simple Payback Period Based on Annual Heating Energy Savings

The all-inclusive capital cost of the boiler installation in underground vaults has been roughly estimated by Forsgren Associates, Inc. at $150,000. This estimated cost is comparable to the installation of water-source heat pumps. Therefore, the incremental cost of a geothermal heat pump system would be the cost of well drilling and testing, well pumps, and horizontal piping from wells to the heat pump vaults.

For cost estimating purposes, it is assumed that one supply and one injection well will be viable in the given space constraints, giving a total of four wells. Each of these wells are assumed to be drilled to 200 ft deep and finished in a concrete, below-grade well pit. Each of the two supply wells will contain variable-speed submersible pumps. The all-inclusive well installation cost is roughly estimated at $100,000.

Based on the estimated incremental capital cost of an open-loop geothermal heat pump system, the simple payback on energy savings over a natural gas boiler is on the order of 10 years.

Concluding Summary

The Geo-Heat Center has conducted an assessment of the feasibility of a geothermal heat pump system for snow melting of sidewalks along the Fourth Street Heritage Corridor (from Leadville Ave. to Walnut, Ave.) in Ketchum, ID. This feasibility study has been completed with the coordinated efforts of the Idaho Energy Division of the Idaho Department of Water Resources (IDWR).

The snow melting system is a hydronic type and has been designed by Forsgren Associates, Inc. of Boise, ID. The tubing installation was completed in the spring of 2007, and the heat source was planned to be from two boilers, each installed in an underground vault in each of two alleys.

Some specific conclusions from this study are summarized below:

- The most viable geothermal option was identified to be water-source heat pumps with the source being groundwater pumped from wells and injected into receiving wells. The heat pumps can be placed in underground vaults that are planned for the boiler installation.
- With 12-inch snow-melting tube spacing, it is expected that water source heat pumps can supply a heat flux of about 100 Btu/hr/ft^2 of snow melt area. Based on Boise, ID weather data, some snow accumulation will occur during a peak design storm, but then the system will eventually catch up and melt all the snow.
- The estimated peak heating load that water-source heat pumps would be capable of supplying for Phase I is approximately 1.8 million Btu/hr.
- A review of water well logs in the downtown Ketchum area by IDWR staff reveals that well yields of up to 300 gallons per minute are possible. Groundwater producing zones are generally less than 200 ft deep, and groundwater temperatures are likely in the range of 45-48^{o}F.
- To meet the projected heating load with the expected groundwater temperatures, wells would have to supply groundwater at a total of approximately 275 gallons per minute. Since two wells are considered for this study, each well would have to supply about 138 gallons per minute.
- Annual heating energy savings with a geothermal heat pump system over a natural gas boiler system is estimated at $10,360.
- Based on the estimated incremental capital cost of an open-loop geothermal heat pump system, the simple payback on energy savings over a natural gas boiler is on the order of 10 years.
- Before a geothermal heat pump design can proceed, test wells would need to be drilled in the alleys near the proposed locations of the heat pump vaults to insure that adequate groundwater flow rates are available.
- For future snow melting systems, closer tube spacing should be considered, as this allows lower fluid temperatures to be used. In this case for Phase I, 130^{o}F supply water transfers 100 Btu/hr/ft^2 at 12-inch tubing spacing. At 9-inch tubing spacing and 6-inch tubing spacing, a fluid supply temperature of 112^{o}F and 97^{o}F, respectively, provides the same heat flux.

Sincerely,

Andrew Chiasson, P.E.

GEO-HEAT CENTER

Oregon Institute of Technology, Klamath Falls, Oregon 97601 541/885-1750 FAX 541/885-1754

John W. Lund, Director
Andrew Chiasson
Tonya "Toni" Boyd
Debi Carr

PRELIMINARY FEASIBILITY STUDY FOR A GEOTHERMAL HEAT PUMP SYSTEM AT THE COLLEGE OF SOUTHERN IDAHO, TWIN FALLS, IDAHO

Introduction

With the coordinated efforts of the Idaho Energy Division of the Idaho Department of Water Resources (IDWR), the Geo-Heat Center conducted a preliminary assessment of the feasibility of a geothermal heat pump system for space heating of the planned Human Services and Health Sciences (HSHS) building at the College of Southern Idaho (CSI), located in Twin Falls, ID.

The geothermal heat pump system for the HSHS building is proposed to be connected to the existing district geothermal heating system that currently serves the other buildings on the CSI campus. The proposed use of the geothermal water calls for extracting additional heat from the return water from the existing buildings, and therefore the proposed use would not increase pumping of the geothermal wells. It is the Geo-Heat Center's understanding that this diversionary use of geothermal water alters CSI's water right slightly, and the water right was under legal review at the time of this pre-feasibility study.

For the economic analysis, two alternate heating systems were considered: (i) hot water heating coils supplied by a boiler and (ii) electric resistance heating.

Estimation of Annual Heating Costs

To estimate the annual heating energy use of the planned HSHS building, a computer model of the building was created using *eQuest* software. The following annual heating energy costs are based on a 67,500 sq. ft, two story educational building. Utility rates were obtained from CSI utility bills, and are approximated at $1.10/therm for natural gas and $0.051/kWh for electricity.

Heating System	Annual Heating Cost
Geothermal heat pump	$9,954
Boiler (natural gas)	$22,891
Electric resistance	$24,884

Estimation of Simple Payback Period Based on Annual Heating Energy Savings

As the new HSHS building has not yet been designed, capital costs of potential heating systems can only be roughly estimated. The heat distribution system for a natural gas boiler and a geothermal heat pump system would have many similarities, with the main difference being the heating plant (i.e. boiler vs. water-source heat pumps). However, an electric resistance heating system would essentially be a terminal system, with electric duct heating elements near terminal air diffusers, and would therefore be the lowest capital cost system.

Based on construction cost data from Means (2007), the estimated payback period on energy savings from a geothermal heat pump system is on the order of <u>10 years</u> and <u>17 years</u> when compared to a natural gas boiler and an electric resistance heating system, respectively.

<u>Some Water-Source Heat Pump Manufacturers</u>

Up to 35 ton (*rated cooling capacity*): WaterFurnace, FHP, Northern Heat Pump

Greater than 30 ton (*rated cooling capacity*): York

Sincerely,

Andrew Chiasson, P.E.