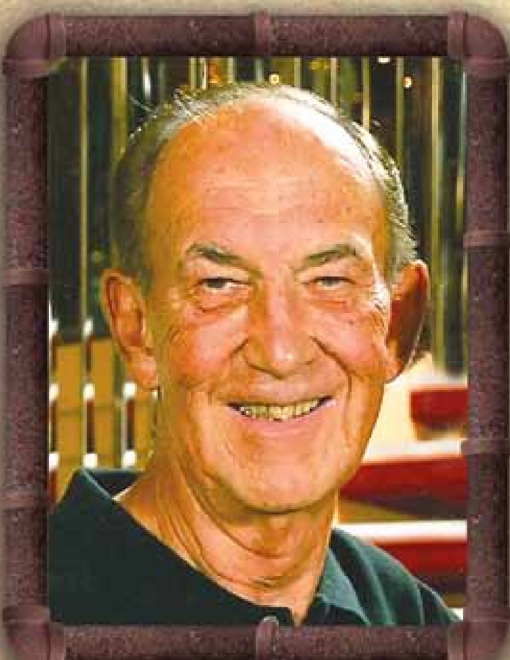
ISSN 0276-1084

VOL. 29 NO. 3 NOVEMBER 2010

GEO-HEAT CENTER QUARTERLY BULLETIN

IN MEMORIAM

Paul J. Lienau
1937 - 2008



Derek Freeston
1929 - 2010

Kiril Popovski
1943 - 2010

GEOTHERMAL DIRECT USE PIONEERS

OREGON INSTITUTE OF TECHNOLOGY • KLAMATH FALLS, OREGON 97601-8801 • (541) 885-1750

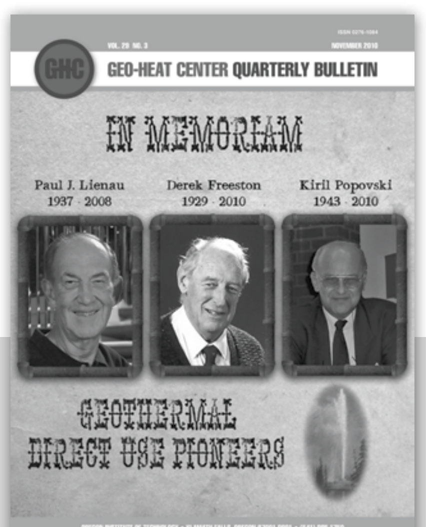
Vol. 29 No. 3 NOVEMBER 2010

GEO-HEAT CENTER QUARTERLY BULLETIN

ISSN 0276-1084

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

CONTENTS



Cover - Remembering the pioneers of Direct Use Geothermal Energy

PUBLISHED BY

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

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

EDITOR

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

WEBSITE:

http://geoheat.oit.edu

ACKNOWLEDGEMENT

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

SUBSCRIPTIONS

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

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

Name ____

Address ____

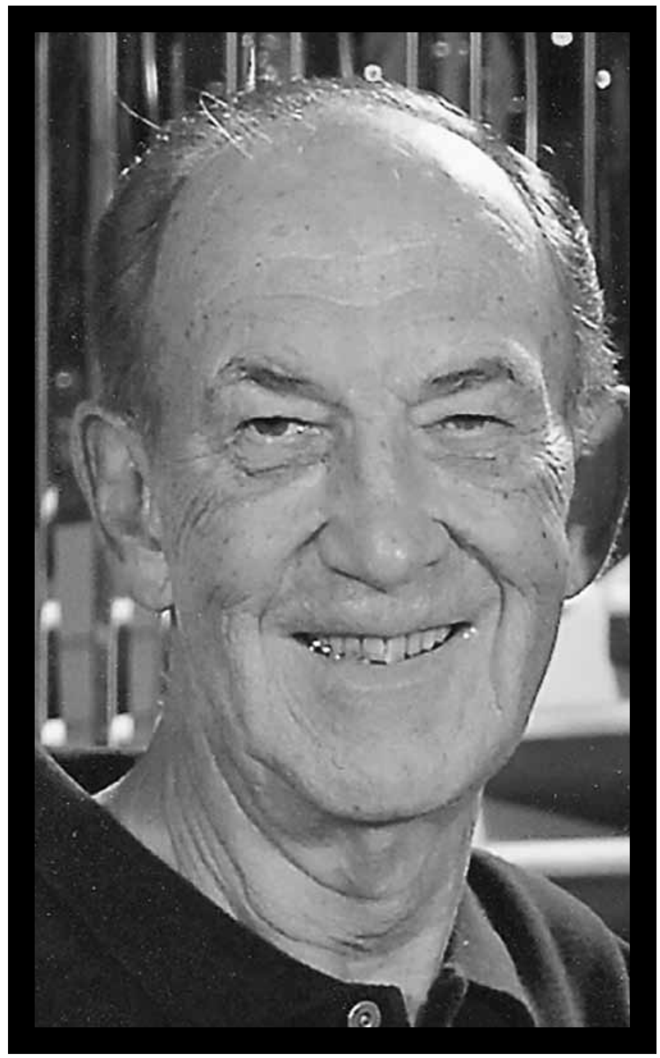
City, State, Zip _______________________________________

Country____

IN MEMORIAM
PAUL J. LIENAU, 1937 - 2008

Paul was born in Mitchell, South Dakota on January 20th, 1937 and moved to Rapid City, South Dakota where he graduated from high school. He received a B.S. degree in Physical Science from Black Hills State University in 1959,and a M.S. degree in Physics from Temple University in 1963. He taught physics at Oregon Institute of Technology from 1968 to 1974 as an Assistant and Associate Professor in the Math/Physics Department. In 1974, Paul and others hosted an International Geothermal Conference on the OIT campus. He and John Lund edited the Proceedings from the conference, and due to their interest in geothermal energy, along with Gene Culver and Lars Svanevik formed the Geo-Heat Utilization Center in 1975. Paul became the first Director of the Center, which later became the Geo-Heat Center. The directorship started as a part-time position, but with financial support from various contracts and grants, became a full-time position which he held until he retired in 1996.

During his tenure as Director of the Geo-Heat Center, Paul wrote many grants and participated in various professional organizations that help to fund the Center's work and promoted its reputation, both nationally and internationally. He was a member of the Geothermal Resources Council (GRC), the International Geothermal Association (IGA), and the Klamath County Economic Development Association (KCEDA). In 1982 he and Collen travelled to New Zealand where he lectured and did research at the Geothermal Institute, University of Auckland for three months. In 1988, he and his wife Colleen spent three months in China at Tianjin University lecturing at the Geothermal Resources and Training Center. He also visited Iceland, France, Italy and Japan in connection with his geothermal work. He developed the Geo-Heat Center into a nationally and internationally recognized center of excellence, specializing in the direct-use applications of geothermal energy. He, along with Ben Lunis, assembled and edited the Geothermal Direct-Use Engineering and Design Guidebook in 1991, which become the main reference for direct-use of geothermal energy worldwide, and has now gone through three editions. This publication was later translated into Turkish and Polish. He also started the Geo-Heat Center Quarterly Bulletin devoted to practical applications of geothermal energy, and this journal continues to be published today. As Director he also started the technical assistant program that provide information and help to developers and operators of geothermal direct-use project in the U.S. and throughout the world. As many as 1,000 technical assistance inquiries were handled each year. With Toni Boyd he started the Center's website that has made available many geothermal publications and the location of geothermal resources to the public. Under his leadership, the Center received a Geothermal Special Achievement Award from the Geothermal Resources Council (GRC) in 1993. He also received the Geothermal Pioneer Award from GRC in 1997. He wrote numerous papers on geothermal energy, along with performing research mainly funded by US Department of Energy contracts and grants. After retiring from the Center in 1997, he and Colleen moved to Camano Island, Washington. In Washington he was involved in many local activities, and visiting his sons and grandchildren. He passed away on September 27, 2008.

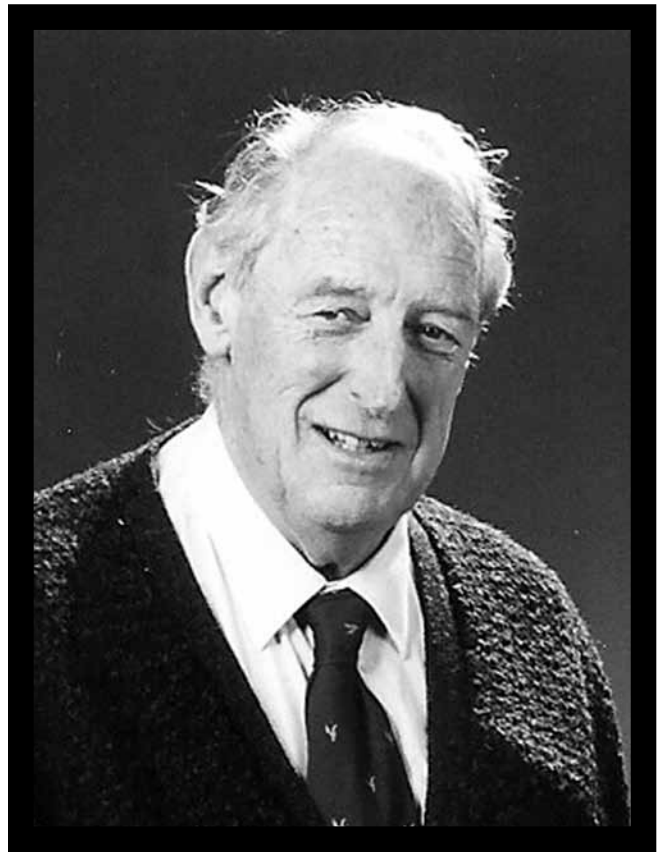


DEREK FREESTON, 1929 - 2010

Derek was born in Leicester, England on May 16th, 1929. He completed his trade qualifications as an aeronautical fitter on a government training award at the Royal Aircraft Establishment in 1947, and a degree in engineering from the University of London in 1952. He then took a three-year commission in the Royal Air Force Transport Command where he was the engineering officer in charge of the maintenance of a squadron of aircraft. In 1958 he started a teaching and research career at Rugby College of Engineering Technology. He worked on ventilation systems for large engines and ran a course on diesel design that attracted students from around the world. Seeking new challenges he immigrated with his family to New Zealand in 1969. In New Zealand he took up a post in the new Engineering School of Auckland University in the Department of Mechanical Engineering. He was initially interested in wind engineering where he carried out wind tunnel studies of models of major tower blocks proposed for downtown Auckland and Wellington as well as work on shelter belts for the developing New Zealand horticultural industry.

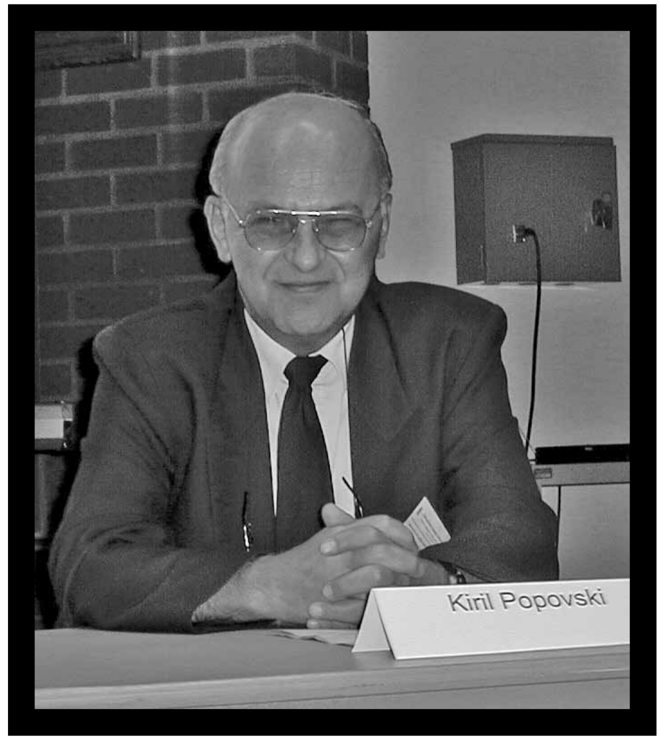
He then became interested in geothermal energy and worked with a series of postgraduate students on two-phase flow. In 1979 he was involved in setting up the Geothermal Institute at the University of Auckland under the United National Development Program. He took a sabbatical leave in 1981 and visited programs in China, Iceland and the USA, which include three months working at the Geo-Heat Center on the Oregon Institute of Technology campus as a visiting scholar. In 1985 and 1989 he spent three months in the Geothermal Department of Tianjin University in PR of China, and visited other geothermal sites in Europe, the Americas, Africa and Asia. He was one of the main lecturers in the Geothermal Institute, and was known for his expertise in the direct-use of geothermal energy. He retired from the University in 1992, but continued to give guest lectures and provide consulting around the world. He wrote the world update on direct-use for the 1995 World Geothermal Congress (WGC 1995) held in Florence, Italy, and co-authored the direct-use update for WGC 2000 (with John Lund), and WGC 2005 and WGC 2010 (with John Lund and Toni Boyd). He participated in all the World Geothermal Congress and presented several papers at these venues, but due to ill health he was unable to attend WGC 2010. Derek was also a member of the International Geothermal Association Board of Directors. He received a Special Achievement Award from the Geothermal Resources Council in 1993, recognizing his contribution to geothermal energy development throughout the world.

His professional contribution has left a lasting legacy through the hundreds of engineering students he has taught and his work with a host of professional engineers in many levels of government and private practice in New Zealand and many counties abroad. He was truly a Geothermal Pioneer.



He died peacefully in New Zealand on October 9th, 2010. Derek is survived by his wife Yvonne, his three children Marion, Mark and Janet, and their families comprising nine grandchildren and one great grandchild.

KIRIL POPOVSKI, 1943-2010



Kiril was born in Macedonia on July 17, 1943. He attended the University of Edvard Kardelj, in Ljubjana Slovenia and received a BSc in Mechanical Engineering in 1967, a MSc in Mechanical Engineering – Energetics in 1975, and a PhD in Technical Sciences in 1984. His major work at the university was in the design of district heating systems and the heating of greenhouses with geothermal energy. He did two post PhD studies, one in Italy and the other in New Zealand. He became a lecturer at St. Kliment Ohrid University in 1989 and later became the chair of the Thermoenergetics & Thermotechnics department and dean of the Faculty of Technical Sciences.

In 1989 he started the International Summer School on Direct Application of Geothermal Energy under the International Geothermal Association (IGA). He organized all the annual conferences which were held in many European countries with invited lecturer teaching students from local universities. The Summer School was held in Klamath Falls, Oregon in 1999, the only time it was held outside of Europe. He was the president of the Macedonian Geothermal Association, a member of the International Geothermal Board of Directors and Chairman of the European Forum under IGA. He was also the Manager of the Central Organization for Development and Investments in the Agriculture of Macedonia, and Technical Manager of the District Heating Company of Skopje, Macedonia. He was responsible for editing and publishing many proceedings from geothermal conferences. He wrote the geothermal country update paper on Macedonia for the World Geothermal Congresses along with many other papers on geothermal energy. He was best known for his expertise on the design of geothermally heated greenhouses.

He was working on geothermal projects, often late into the night, right up until he died on October 22, 2010. He was truly one of the geothermal pioneers.

MEASURING THE COSTS AND BENEFITS OF NATIONWIDE GEOTHERMAL HEAT PUMP DEPLOYMENT

Elizabeth C. Battocletti, Bob Lawrence & Associates, Inc.

William E. Glassley, California Geothermal Energy Collaborative

ABSTRACT

While the technology has existed since the late 1940s, geothermal heat pumps, also known as ground-source heat pumps and GeoExchange®, currently account for less than two percent of the total North American heating and cooling market. With support from the United States Department of Energy Geothermal Technologies Program through the American Recovery and Reinvestment Act of 2009, Bob Lawrence & Associates, Inc. and the California Geothermal Energy Collaborative will gather and analyze manufacturing and installation costs and geological and geographic data to assess the costs and economic, environmental, and social benefits resulting from three varying scenarios of nationwide geothermal heat pump deployment.

INTRODUCTION

According to the U.S. Energy Information Administration (EIA), buildings annually account for almost half (48 percent) of energy consumption and greenhouse gas (GHG) emissions in the United States. Residential, commercial, and industrial building operations consume 76 percent of total U.S. electricity generation. Weather-related energy use, in the form of heating, cooling, and ventilation, accounted for more than 40 percent of all delivered energy use in residential and commercial buildings in 2006 (U.S. Energy Information Administration, 2008b). And trends show that the building sector is growing faster than any other energy-use sector. The building sector is one of the best areas in which to economically reduce energy consumption and limit GHG emissions.

GHPs currently account for about 1.54 percent of the North American heating, ventilating, and air conditioning (HVAC) market. In 2008, total shipments of geothermal heat pumps were up more than 40 percent to 121,243 units; capacity shipped rose almost 43 percent to 416,105 tons (U.S. Energy Information Administration, 2008a). Figure 1 shows geothermal heat pump shipments from 1994 (when EIA first began surveying the GHP industry) through 2008. No survey was conducted in 2001. The total market for U.S. GHPs in 2008, including equipment and installation cost (not reduced by government or other incentives), was estimated at $3.7 billion dollars. Effective 1 January 2009, for residential GHPs, the American Reinvestment and Recovery Act (ARRA) of 2009 provides a tax credit of 30 percent of the cost (including installation and labor costs) with no upper limit through 2016. The previous federal tax credit was limited to $2,000. For commercial applications, the ARRA provides a 10 percent tax credit and allows for accelerated depreciation. The GHP market is expected to triple in value by 2013 (Priority Metrics Group, 2009).

Since geothermal heat pumps (GHPs) use the constant temperature of the earth, they are among the most efficient heating and cooling technologies currently available (U.S. Environmental Protective Agency). GHPs move heat between buildings and the earth three to five times more efficiently than other HVAC systems.

According to an Oak Ridge National Laboratory (ORNL) study (Hughes, 2008) which examined the barriers to increased GHP use in the United States, although the U.S. was once the world leader in GHP technology and market development, Europe now absorbs two to three times the number of GHP units per year as the U.S. Market growth rates in Europe, China, South Korea, and Canada exceed those in the United States. While the U.S. has the greatest number of GHPs installed, on a per capita basis it falls behind many European countries.

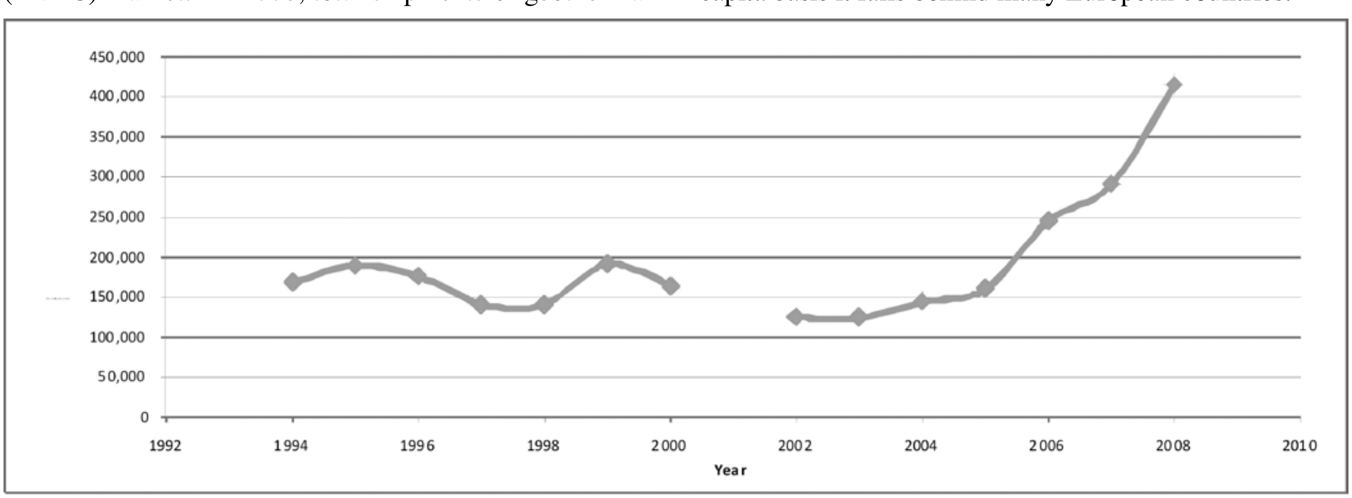


Figure 1. Geothermal heat pump shipments, 1994-2008

The ORNL study concluded that:

- "If the federal government set a goal for the U.S. buildings sector to use no more nonrenewable primary energy in 2030 than it did in 2008…it is estimated that 35 to 40 percent of this goal, or a savings of 3.4 to 3.9 quads annually, could be achieved through aggressive deployment of GHPs." (A quad is equal to 10^{15} BTU, or 1.055×10^{18} joules).
- GHPs could avoid the need to build 91 to 105 GW of electricity generation capacity, or 42 to 48 percent of the 218 GW of net new capacity additions projected to be needed nationwide by 2030.
- Aggressive deployment of GHPs could result in $33 to 38 billion annually in reduced utility bills (at 2006 rates).

ORNL determined that the two most significant actions that could be taken to increase GHP use in the U.S. were to:

1. Assemble independent, hard data on costs and benefits, and
2. Independently assess the national benefits of GHP deployment.

With support from the United States Department of Energy Geothermal Technologies Program through the American Recovery and Reinvestment Act of 2009, the three-year Geothermal Heat Pump Cost-Benefit Project will focus on independent data collection and analysis. Bob Lawrence & Associates, Inc. (BL&A) and the California Geothermal Energy Collaborative (CGEC) will collect two types of data: 1) manufacturing and installation cost data, and 2) geological and geographical data. BL&A will take the lead on the former, the CGEC on the latter. Figure 2 illustrates the project's overall data collection and analysis approach.

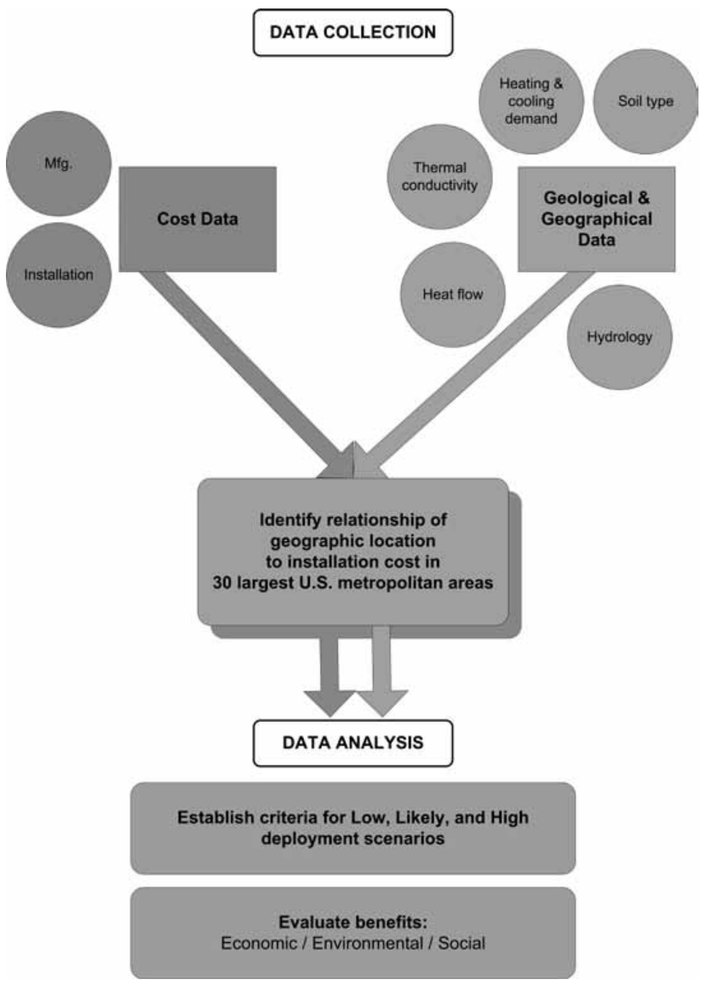


Figure 2. Geothermal Heat Pump Cost-Benefit Project data collection and analysis approach

Manufacturing and Installation Cost Data

In 2008, there were about 23 known U.S. manufacturers of geothermal heat pumps (Table 1). Four of the total 23 account for over 80 percent of annual GHP sales. An additional 10 to 15 companies account for the remainder of the U.S. market. Some serve the entire U.S.; others cater to specific markets. Some GHPs are rebranded and sold under different names. BL&A will seek economic data from the 23 GHP manufacturing companies that responded to the EIA's most recent annual survey.

Manufacturing cost data sought may include:

- Number and locations of full-time, part-time, and contractual jobs;
- Location of factories;
- Annual sales;
- Number of GHP models manufactured;
- Names and contact information for suppliers;
- Number and location of dealers; and
- Plans for future manufacturing expansion.

Table 1. Respondents to the Energy Information Administration, Form EIA-902, "Annual Geothermal Heat Pump Manufactures Survey," for 2008

Company	Location
Addison Products Company	Orlando, Florida
AquaCal AutoPilot, Inc.	Petersburg, Florida
Bard Manufacturing Company	Bryan, Ohio
Carrier Corporation	Syracuse, New York
Climate Master, Inc.	Oklahoma City, Oklahoma
Earth To Air Systems, LLC	Franklin, Tennessee
EarthLinked Technologies, Inc.	Lakeland, Florida
EarthSource Energy Solutions, Inc.	Brookline, Massachusetts
ECONAR GeoSystems, LLC	River, Minnesota
ECR Industries Incorporated (does business as Advanced Geothermal Technology)	Reading, Pennsylvania
Enertech Manufacturing, LLC	Greenville, Illinois
FHP Manufacturing Company	Ft. Lauderdale, Florida
GeoFurnace Manufacturing, Inc.	De Smet, South Dakota
GeoMaster, LLC (GeoExcel Inc,)	Fort Wayne, Indiana
Heat Controller, Inc.	Jackson, Michigan
HydroHeat, LLC	Monroeville, Pennsylvania
Hydro-Temp Corporation	Pocahontas, Arkansas
Mammoth Inc.	Chaska, Minnesota
McQuay International	Auburn, New York
Rittling - Hydro-Air Components Inc.	Buffalo, New York
Sunteq Geo Distributors	Howard, Pennsylvania
Trane Company	Clarkeville, Tennessee
Water Furnace International, Inc.	Fort Wayne, Indiana

In addition to seeking data from GHP manufacturers, the economic analysis will also consider manufacturers of GHP system and loop components, i.e., heat exchangers, high-density polyethylene (HDPE) and cross-linked polyethylene (PEXa) pipe (only high-density polyethylene (HDPE) or cross-linked polyethylene (PEXa) are acceptable for use in the underground loop), and geothermal grouts. Figure 3 illustrates the various segments of the GHP industry.

In addition, BL&A will seek installation cost data from GHP system and loop installers, contractors, designers, and drillers dating back to 2005. Installation cost data sought may include:

- Installation zip code;
- Installation date;
- Installation type, i.e., residential, commercial, industrial, school;
- Building size (square feet);
- Installer information;
- Equipment, i.e., heat pump(s), controls, hot water heater, humidifier/dehumidifier, cooling tower; and
- Ground loop, i.e., closed, open, or Direct Geoexchange (DGX); horizontal or vertical.

BL&A will coordinate with Technical Committee 6.8 - Geothermal Energy Utilization of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to determine the precise installation cost data that will be requested. The objective is to define installation costs in terms of dollars per ton or square foot. In the interest of keeping proprietary company data confidential, all manufacturing and installation cost data collected will be aggregated.

Geological and Geographical Data

The geographic analysis includes developing a quantitative analysis of the thermal properties that influence heat pump performance. The first step in this effort is to identify regions in the U.S. that share similar geological and hydrological characteristics and climate patterns. For each of those regions the CGEC will compile a database in which soil and bedrock characteristics are assembled (e.g., soil types, thermal conductivity, heat flow, depth to bedrock, depth to the water table, hydrological properties, etc.) and heat-cooling demand. These data will be made web-accessible for general use. Although much of this data is already available, assembling it in a coherent, single database has not been done.

Once assembled, the data will be used to generate optimized ground loop design parameters for each region. Of course, local variability in the geological, hydrological, and climatic parameters dictates that these optimized designs should not be taken as necessarily the best design for any specific application. Rather, they will form the basis for a standardized approach to examining cost.

The standardized designs can then be used to examine the sensitivity of the analyses to variations in specific parameters using the range of geological, hydrological, and climatic values identified for each region. This approach will allow uncertainty bounds to be established for the base case results. This approach will also allow comparisons across regions of costs, and provide a basis for establishing a national "roll-up" of the results to allow a thorough cost-benefit analysis at a higher resolution than previously achieved.

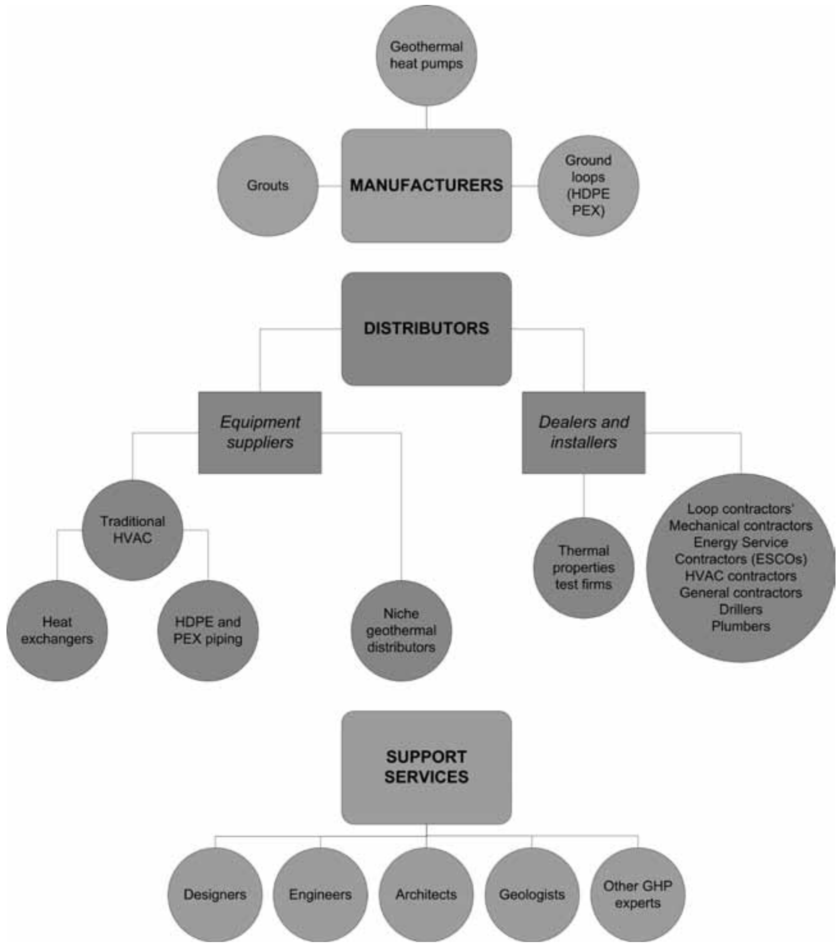


Figure 3. Geothermal heat pump industry segments

Because the greatest potential benefit will be achieved in regions of high population, the project will focus on the 30 largest metropolitan areas (see Figure 4, U.S. Census Bureau, 2009) and conduct the analyses using the representative properties in those areas that are appropriate for their respective geological, hydrological, and climatic conditions. Since these are often areas that have a strong impact on greenhouse gas emissions and electricity consumption, evaluating the impact on these elements will be an important part of the analysis.

This approach provides a way to characterize geological provinces, i.e., the metropolitan areas can be grouped by geological characteristics. For example, New York, Chicago, and Philadelphia are classic "old continental basement" geology. Los Angeles, San Diego, and San Jose are "young, convergent margin" geology. Houston, San Antonio, and Dallas are "Great Plains sedimentary basin" geology. And Phoenix is Basin and Range geology. Each city has layered on to this different degree heating and cooling days. This break out will be done for all 30 areas which will be broken down into groups of 10 each. In this way, the analysis can examine how results vary by geological province, how results vary within a geological province, and how local climate affects the results within a geological province.

Data Analysis

The project's data analysis effort contains three inter-related components:

- Identify the relationship of geographic location to installation cost in the 30 largest U.S. metropolitan areas;
- Establish criteria for Low, Likely, and High scenarios; and
- Evaluate and quantify the economic, environmental, and social benefits resulting from the Low, Likely, and High scenarios.

Installation cost and geological and geographical data will be overlaid to examine if and how the cost of installing a GHP varies across the country. Second, the data analysis will consider the installation of GHPs across the U.S. wherever they make "economic sense." "Economic sense" will be defined vis-à-vis current sources of heating, cooling, and electricity, and geographic factors. The criteria for Low, Likely, and High scenarios will thus be defined. Finally, BL&A and the CGEC will estimate the economic, environmental, and social benefits resulting from the Low, Likely, and High deployment of GHPs. Economic benefits include jobs created; taxes paid by manufacturers, designers, and installers; business expansion; and energy savings. Environmental benefits include reduced GHG and air pollutants and the decreased need for new electricity generation. Social benefits include improved quality of life.

BL&A and the CGEC will seek to engage a wide range of groups to gather the most reliable and comprehensive data. BL&A and the CGEC will seek data from state energy offices and agencies; the U.S. Geological Survey and state geological surveys; GHP manufacturers; the International Ground Source Heat Pump Association (IGSHPA) and IGSHPA-accredited installers and designers; ASHRAE; the Geothermal Exchange Organization, Inc.; and other relevant trade associations, architects, engineers, developers, drillers, and interested parties. With their help and support, the ambitious Geothermal Heat Pump Cost-Benefit Analysis will be a unique and powerful tool for evaluating the benefits and costs of installing GHPs in the United States.

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

REFERENCES

Hughes, P.J, 2008. *Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers.*

Priority Metrics Group, 2009. *Energy Beneath the Backyard - Global Geothermal Heat Pump Market 2009.*

U.S. Census Bureau, 2009. *Population Division.*

U.S. Energy Information Administration, 2008a. *Geothermal Heat Pump Manufacturing Activities.*

U.S. Energy Information Administration, 2008b. *Independent Statistics and Analysis, Trends in Heating and Cooling Degree Days: Implications for Energy Demand, Issues in Focus, AEO2008.*

Figure 4. Thirty largest metropolitan areas in the United States (listed below in order of size, from largest to smallest)

Group One

New York - Northern New Jersey - Long Island, NY-NJ-PA

Los Angeles - Long Beach - Santa Ana, CA

Chicago - Naperville - Joliet, IL-IN-WI

Dallas - Fort Worth - Arlington, TX

Philadelphia - Camden - Wilmington, PA-NJ-DE-MD

Houston - Sugar Land - Baytown, TX

Miami - Fort Lauderdale - Pompano Beach, FL

Atlanta - Sandy Springs - Marietta, GA

Washington - Arlington - Alexandria, DC-VA-MD-WV

Boston - Cambridge - Quincy, MA-NH

Group Two

Detroit - Warren-Livonia, MI

Phoenix - Mesa - Scottsdale, AZ

San Francisco - Oakland -Fremont, CA

Riverside - San Bernardino - Ontario, CA

Seattle - Tacoma - Bellevue, WA

Minneapolis - St. Paul - Bloomington, MN-WI

San Diego - Carlsbad - San Marcos, CA

St. Louis, MO-IL

Tampa - St. Petersburg -Clearwater, FL

Baltimore - Towson, MD

Group Three

Denver -Aurora, CO

Pittsburgh, PA

Portland - Vancouver - Beaverton, OR-WA

Cincinnati - Middletown, OH-KY-IN

Sacramento - Arden - Arcade - Roseville, CA

Cleveland - Elyria - Mentor, OH

Orlando - Kissimmee, FL

San Antonio, TX

Kansas City, MO-KS

Las Vegas - Paradise, NV

GEOTHERMAL HEATING OF KLAMATH FALLS SCHOOLS

John W. Lund, National Renewable Energy Laboratory, Golden, CO

Thomas E. Lund, Klamath Union High School, Klamath Falls, OR

ABSTRACT

Seven of Klamath Falls, Oregon public schools and college are heated with geothermal energy. All of the schools have individual wells, extracting the heat with either downhole heat exchangers, or pumping the water directly into the building heating system and then disposing of the water into injection wells. A student can attend all his schools, from grade school through to college, that are heated with geothermal energy. A description of the energy use and heating system for Roosevelt Grade School, Ponderosa Middle School, and Klamath Union High School are described - all of which the author (Thomas) has attended. Roosevelt Grade School has two wells in its playground/ parking lot, each 150 m deep with temperatures around 90°C, using downhole heat exchangers to extract the heat. Ponderosa Middle School also uses downhole heat exchangers to extract the heat from a 170-m deep geothermal well at 93°C. This well is located near the original "Devil's Tea Kettle", a spring that was used by transients before being covered by highway construction. Klamath Union High School, due to its high heat demand, pumps the water directly from a geothermal well 78 m deep at 89°C, and then extracts the heat inside in the mechanical room. The spent water is then injection into a second well 76 m away. The high school also used to heat a swimming pool, site of an old natatorium that was used in the 1920s and 1930s. The wells are located on what was called "Big Springs", the high school football field. These natural springs were used by the Native Americans and early European settlers for cooking food, bathing, and warming benches for ice skating. The total peak energy use of these three schools is 6.8 GJ/hr (2.0 MWth) and the annual energy use is 14.9 TJ/yr (4.1 GWh/yr), saving US $206,000 annually in heating cost.

INTRODUCTION

Native American used the hot springs in the area for about 10,000 years, several of which were located within the present Klamath Falls City limits. These springs were used to cook game and for healing various ailments. The most famous of these springs were "Big Springs" located in the present Klamath Union High School athletic field, and "Devils Tea Kettle" located near the present Ponderosa Middle School athletic field. "Big Springs" was used by the European settlers during the early 1900s for cooking and scalding meat, cooking vegetables, bathing and just to keep warm (Lund, 1978). Picnic parties held at the hot springs were a favorite outing for the local residents. The area was flooded in the winter and used for ice skating. Benches were placed around the skating area and warmed underneath with hot water piped from the springs. In summer, these pools were used for swimming (Fig. 1 and 2). A bath house was constructed adjacent to the field in 1928, known locally as Butler's Natatorium. Here both swimming and bathing were available, where 38 m^3 of geothermal water were used daily during the summer months, as the water in the swimming pool was changed daily. Natural steam baths and mineral water tub baths were also available. The building was later replaced with the current structure for the high school field house and swimming pool. Water was also piped from the spring area to heat the White Pelican Hotel in 1911. Unfortunately, the hotel burned in 1926 and was replaced with the Balsiger Motor Company building, which still stands today, however, geothermal water is not longer supplied to this building.

Figure 1. "Big Springs" in the early 1900s.

Figure 2. "Big Springs" in the early 1900s.

"Devil's Tea Kettle", another hot springs area, was located near the present Ponderosa Middle School athletic field and the Klamath Falls City School District bus barn (Lund, et al, 1974). These springs are reported to have been used by transients to warm themselves and wash their clothes. Some, sleeping on boards above the springs, are reported to have rolled off in the night and scalded themselves. These springs, the location of which the author (John) has attempted to find without success, appear to have been covered over by the construction of the Kit Carson Expressway in town. Adjacent excavations for the Bureau of Reclamation canal in 1906, opened hot springs in the banks of the canal that may have been related to the original "Devil's Tea Kettle."

In the 1890s local sheepherders dug holes in the ground to obtain hot water in areas adjacent to the artesian springs. Around the turn of the century homes were heated by direct use of the artesian water, and both hot and cold water (after cooling in tanks overnight) were used for drinking and bathing. In 1925, residents started drilling wells using cable drilling methods in the area to the east of "Big Springs" in the Pacific Terrace area on the flanks of the large normal fault block that runs along the east side of the city. During the period from 1920 to 1932, plunger pumps were used on the dug and drilled wells due to the lack of knowledge concerning principles of "thermo siphoning" or the natural convection movement of hot water in a downhole heat exchanger. The first down-hole heat exchangers, designed and installed by Charlie Leib, an Austrian immigrant, was place in 1931 utilizing the thermo siphoning principal (Lund, 1974; Fornes, 1981; Culver and Lund, 1999) (Fig.3).

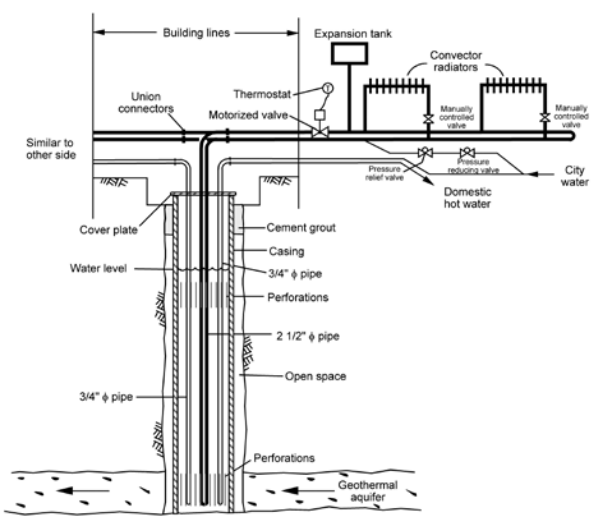


Figure 3. Examples of downhole heat exchangers.

Today most of the buildings in the eastern portion of the City of Klamath Falls are heated by hot water, including the three schools described in this paper: Roosevelt Elementary School, Ponderosa Middle School, and Klamath Union High School, all attended by the author (Thomas), along with the Oregon Institute of Technology (where the author - John - works) and a City district heating system (Brown, 2007; Lund and Boyd, 2009). Approximately 600 wells are used in the city for space heating, domestic hot water heating, heating of swimming pools, and for sidewalk snow melting (Boyd, 2003). The principal heat extraction system is the closed loop downhole heating exchanger utilizing city water in the heat exchanger. Some users, not using the downhole heat exchanger system or requiring more energy, pump the water directly from the well and run it through a plate heat exchanger transferring the heat energy to city water, and then dumping the spent geothermal water in to the storm sewer. Others pump and dump directly into the storm sewer to improve the performance of their downhole heat exchanger (Culver and Lund, 1999). An injection well is required by the City for these systems, which include some residences and the Oregon Institute of Technology, Sky Lakes Medical Center, and the City district heating systems.

The present wells in the city vary from 30 to 600 m in-depth and produce fluids from 40 to 105˚C, usually in a sub-artesian mode. Typical water chemistry for geothermal wells in the area tend to be high in sodium (201 mg/L) and sulfate (410 mg/L) and low in potassium (5 mg/L), calcium(22 mg/L) and chloride (49 mg/L), with silica at 91 mg/L. Total dissolved solids are 1000 mg/L and pH around 8.0 (slightly basic) (Lund, et al., 1976).

ROOSEVELT ELEMENTARY SCHOOL

Roosevelt Elementary School (named after President Theodore Roosevelt) (K through 6th grade) was built in 1928. It is a two-storied brick building with about 6,240 m^2 of floor space. Originally the building was heated by two large oil-fired boilers located in the basement. These boilers are still in the building, but unused. In 1960 two geothermal wells were drilled in the playground/parking lot on the east side of the building, as the school is located in one of the hottest geothermal zones in the city, with subsurface temperatures around 95˚C. They were drilled to 152 m and completed with a 30.5-cm diameter casing perforated at three places below about 100 m. The temperature recorded at the time of drilling was 94˚C. Measurements made in 1974 recorded 76˚C at the top of the water column and 92.5˚C at 107 m depth. Water level was at 24 m below the surface. Two black iron 6.4-cm diameter, closed loop downhole heat exchangers to around 100 m are used to extract heat from each well (Fig. 4). Originally, waste oil was poured down the well to coat the downhole heat exchangers at the air-water interface. This was to prevent pitting and corrosion of the pipes, which typically happens in most of the wells in Klamath Falls.

Figure 4. Roosevelt geothermal well.

Today, the water enters the building at 79˚C and returns at varying temperature depending upon the outside temperature and building heating load. The water is circulated with a pump on the return line to the wells. City water is used in the downhole heat exchanger with the water then transferring heat directly to classrooms. Each classroom has baseboard radiators under the windows and supplemental forced air through a vent in the interior wall. The heat flow is controlled manually in each classroom as the thermostats no longer work. There are three separate classroom loops, sidewalk snow melting loops for two street entrances (50 m^2) , and two large fan coil heat exchangers providing heated air to the auditorium and as supplemental heat for the classrooms (Figure 6). The domestic hot water in the cafeteria is boosted with natural gas. No cooling is provided to classrooms.

Figure 5. Roosevelt geothermal well with two 6.4-cm diameter downhole heat exchangers. The pipes in the upper part of the photo are connected to the second well.

Figure 6. One of the two large force air units supplying heat air to the auditorium and supplemental heat to the classrooms.

We estimate the peak use is 1.2 GJ/hr (0.35 MWth) and annual load of 2.7 TJ. This would amount to an annual savings of approximately $37,000 as compared to natural gas or fuel oil.

PONDEROSA MIDDLE SCHOOL

Ponderosa Middle School (7th and 8th grades) was built in 1969, and has had several changes over the years. The most recent was the removal of a wing that was damaged by ground heaving and cracking, possibly cause by the shallow geothermal system. The school athletic field is also located adjacent to the estimated site of "Devil's Tea Kettle" hot springs and right next to one of the major fault systems in the area supplying most of the geothermal water to the wells in the city. Today, there are 7,844 m^2 of floor space over a single story. Two geothermal wells were drilled, one in 1956 to 140 m and the other in 1969 to 171 m. The temperatures varied from 82 to 99˚C (98˚C is boiling at our elevation of 1,370 m). The shallower well was originally used as a backup well and for sidewalk snow melting, but due to the failure of the snow melting pipes, is no longer used. The deeper well is now the only one used to heat the building. A temperature profile in 1976 showed that the well was almost isothermal at around 92˚C.

The well has two 5-cm and one 7.5-cm diameter downhole heat exchangers extending 122 m into the well (Fig. 7). The water level is 10 m below the surface. The maximum flow into the building through the downhole heat exchangers is estimated at 29 L/s and currently at 77˚C (it was originally as high as 82˚C).

Figure 7. Downhole heat exchangers at Ponderosa Middle School: 2@5-cm and 1@ 7.5-cm diameter feeding into a common header.

The secondary water (city water) from the downhole heat exchanger enters the building mechanical room, assisted by two 5.6 kW circulation pumps, one on the supply line and one on the return line with variable frequency drives. The heated water is then stored in three former oil fired boilers (Fig. 8). From here the water is distributed to the various parts of the building by small circulation pumps. Centralized forced air units are heated with the water and the heated air is then transferred through duct work to the ceilings of the various rooms. All 14 zones and the main circulations pumps are controlled by computers (Fig. 9). In addition, the school is cooled by electric chillers that are integrated with the heat exchangers. Solenoid valves control whether the finned tubed heat exchangers will receive heated or chilled water (Fig. 10). The RC Webview computer system keeps track of the temperature in each classroom and adjusts the pneumatic thermostats for the heat or cooling demand. The computer has an override to keep the rooms from freezing. Domestic hot water is provided at 64˚C through a shell-and-tube heat exchanger under one of the boilers (Fig. 8).

The downhole heat exchangers, as is typical in Klamath Falls, corrode (mainly pin-hole corrosion) at the air water interface. Originally, used turbine oil was dumped down the well to coat the pipes at the water level, but, this is no longer allowed. The black iron pipes at the water level have to be replaced about every two years.

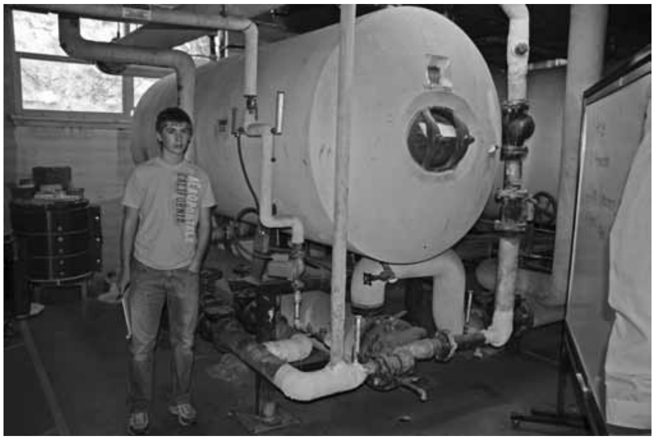


Figure 8. One of the three former oil fired boilers used as a storage tank for the heated secondary water at Ponderosa Middle High School.

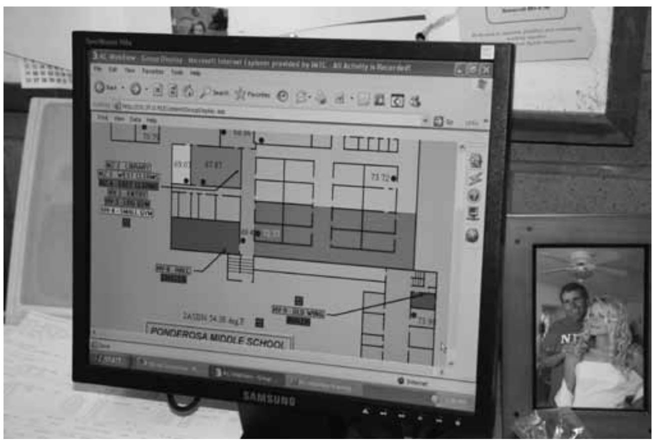


Figure 9. RC Webview computer controlling heat supplied to rooms at Ponderosa Middle School.

Figure 10. Finned tube heat exchangers supplying heated or chilled air to classrooms at Ponderosa Junior High School. Note the solenoid valves at the top of the heat exchanger that can be controlled to supply heated or chilled water.

We estimate that the peak heating load is 2.3 GJ/hr (0.67MWth) and 5.0 TJ/year saving approximately $69,000 annually in heating cost as compared to natural gas or fuel oil. A schematic of the system is shown in Figure 11.

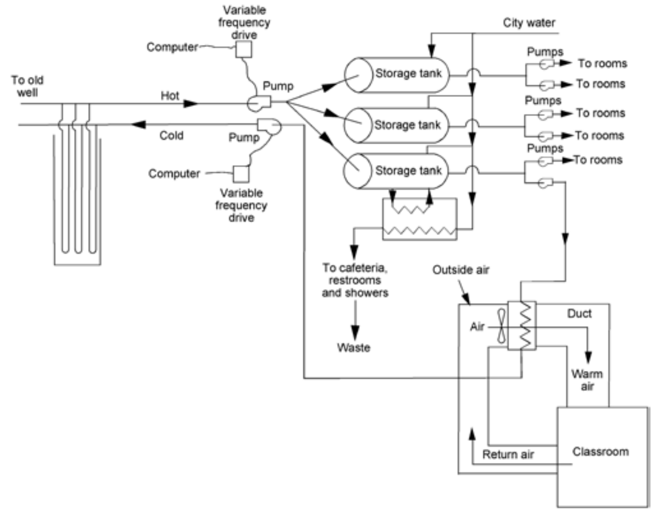


Figure 11. Schematic of the Ponderosa Middle School geothermal heating system.

KLAMATH UNION HIGH SCHOOL

Klamath Union High School is located next to the original "Big Springs" and uses the water from wells in this area for heating the school. The main building was constructed in 1928, the gymnasium (Pelican Court) in 1938, and the south building consisting of the cafeteria and band room in 1958. A separate field house which incorporated the swimming pool for the original Butler's Natatorium, was built in the early 1940s. The entire complex, except for the field house cover 19,200 m^2 wings extending to three stories. The geothermal water is pumped directly from a well to the building mechanical room, as the heating load is too large to use downhole heat exchangers. The spent water is returned to an injection well.

Four geothermal wells have been drilled in the field, after the water level from the artesian "Big Springs"dropped below ground level: the 1911 well drilled for the White Pelican Hotel (which burned in 1926) and then later used for the Balsiger Motor Company building, is no longer used; a well drilled in 1940 for the field house and swimming pool, which has since been abandoned; and a production and injection well for the High School. The latter wells were drilled in 1964, the production well to 78m with a temperature of 89˚C completed with 32-cm diameter casing to 55 m, and 27-cm diameter casing from 54 to the bottom (Fig. 12). Perforation was provided at 54 and 72 m to the bottom. The water level, now sub-artesian, is approximately 3 m below the surface. The injection well is 73 m deep and 76 m from the production well. The temperature of the injection well varies with the heat load, but is typically 67˚C (Culver, 1989). There are other production wells within 150 m in all directions. In theory the system should have cooled down years ago to the point where it was no longer useful for space heating, but it is still in operation. When the system is turned on in the fall, well temperatures fall 3 to 4˚C within 7 to 10 days and then remain constant through the heating season. The next fall the production well is back to its original temperature (Culver, 1989).

Figure 12. Klamath Union High School geothermal production well.

A line-shaft turbine pump originally provided 25 L/s at 74˚C water to the school mechanical room (6˚C is lost between the well and the building), where heat is transferred through two plate heat exchangers, estimated at 2 and 4GJ/hr. Originally several large shell-and-tube heat exchangers were used, but these proved inefficient and difficult to clean. The smaller plate heat exchanger receives heat from the secondary water of the larger heat exchanger and then circulates a glychol-water solution to air pre-heaters for two fresh air intakes. Since only outside air is used, this glycol-water distribution runs all the time so as to prevent the untreated heated secondary water from the main heat exchanger from freezing on cold days. The larger or primary heat exchangers provides heated secondary water to the smaller plate heat exchanger and to two large storage tanks (originally oil-fired boilers) where the temperature of the water can be boosted with natural gas, if necessary (Fig. 13 and 14).

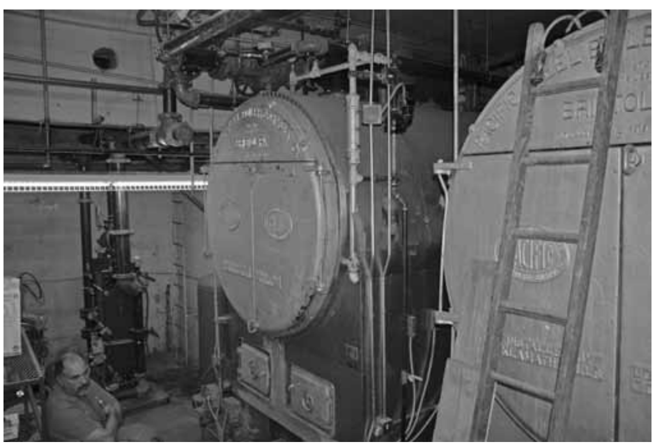


Figure 13. Main plate heat exchanger and hot water boilers for Klamath Union High School.

The secondary water heats two main finned coiled forced air units in two smaller mechanical rooms along with numerous hot water heaters and other smaller forced air units that provide heated air through vents in the classroom walls. The field house is heated by water by the return water from the main building through radiant floor pipes and hot water radiators before being injected in the second well. The secondary water also melts snow on two entrance steps. There were other snow melt systems, but these have been shut down due to failures in the pipes. A bridge deck approaching the school was recently retrofitted for snow melting using geothermal energy from the city district heating system (Boyd, 2003). A small enclosed parking lot where it is difficult to remove and stockpile the snow, uses the secondary water directly by spraying to melt the snow. The water has also been used to melt heavy snow loads on the Pelican Court roof, and a permanent roof snow melt system is being considered. A third plate heat exchanger provides domestic hot water to the building.

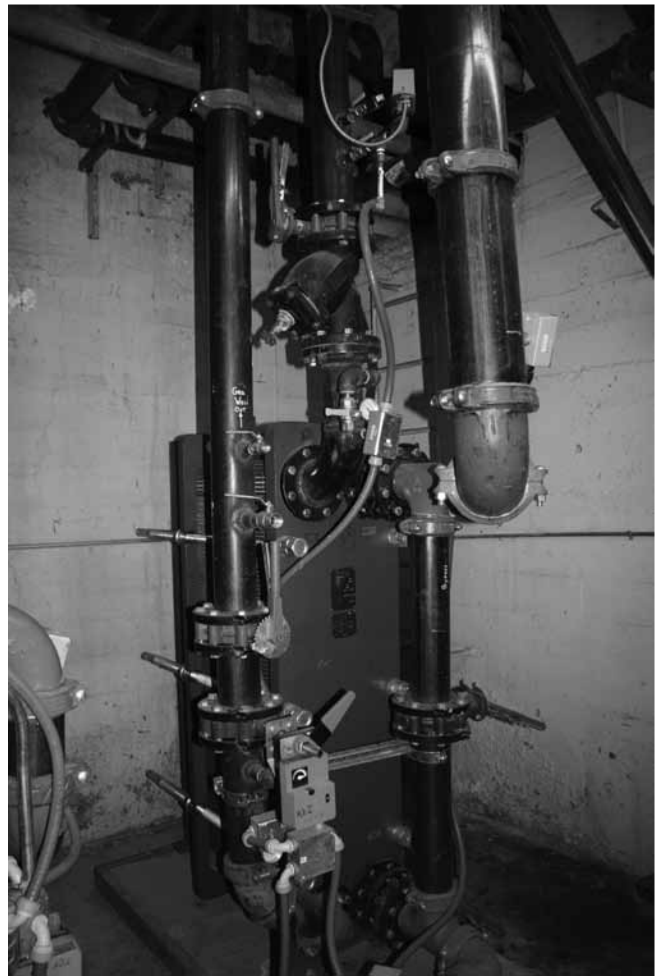


Figure 14. Detail of the main plate heat exchanger at Klamath Union High School.

Scaling deposits on the main plate heat exchangers have reduced the efficiency of the heat transfer and thus have to be cleaned or replaced periodically. Recently, the geothermal water has cooled and has been entering the main plate heat exchanger at 54˚C and leaving at 41˚C, into the smaller heat exchanger at 43˚C and out at 38˚C, and into the boilers at 48˚C and out at 44˚C.

It is estimated that 3.3 GJ/hr (1.0 MWth) of peak heat and 7.2 TJ/yr geothermal energy is used. This provides a savings of approximately $100,000 annually.

CONCLUSIONS

The three local schools that the author (Thomas) has attended have been using geothermal water for heat for over 50 years. They tap into the geothermal water upwelling along a high angle normal fault – part of the Basin and Range geologic system – along the east side of the City of Klamath Falls. The water is around 90˚C and either uses downhole heat exchanger to extract the heat from the well water (Roosevelt Elementary School and Ponderosa Middle School), or pumps the water directly into the building and then sends the waste geothermal water to an injection well (Klamath Union High School). All the wells are fairly shallow, at less than 200 m deep and are sub-artesian. The estimate peak energy use of the three schools is 6.8 GJ/hr (2.02 MWth) with an annual energy use of 14.9 TJ. The estimated annual savings is $206,000 as compared to using natural gas.

ACKNOWLEDGMENTS

We would like to thank Paul Carney, maintenance supervisor at Roosevelt Elementary School; Del Horton, maintenance supervisor at Ponderosa Middle School, and John Kellum and Ron Bryant, maintenance supervisors at Klamath Union High School for providing a time to visit the school and explaining how their geothermal heating system operated.

REFERENCES

Boyd, T. L.: "New Snow Melt Projects in Klamath Falls, OR," *Geo-Heat Center Quarterly Bulletin, Vol. 24, No. 3*, pp. 12-15,Klamath Falls, OR, (2003)

Brown, B.: "Klamath Falls Geothermal District Heating System at 25 Years", *Geo-Heat Center Quarterly Bulletin, Vol. 28, No. 1*, pp. 10-15, Klamath Falls, OR, (2007).

Culver, G.: "Direct Use Injection Wells", *Geo-Heat Center Quarterly Bulletin, Vol. 11, No. 4*, pp. 1-5, Klamath Falls,OR, (1989).

Culver, G. and J. W. Lund: "Downhole Heat Exchangers," *Geo-Heat Center Quarterly Bulletin, Vol. 20, No. 3*, pp. 1-11,Klamath Falls, OR, (1999).

Fornes, A.: "Charlie Leib – Veteran of Geothermal Development," *Geo-Heat Center Quarterly Bulletin, Vol. 6, No. 1*, pp. 10-13,Klamath Falls, (1981).

Lund, J. W.: "Big Springs." *Geo-Heat Center Quarterly Bulletin,Vol. 3, No. 3*, pp. 7-13, Klamath Falls, OR, (1978)

Lund, J. W., Culver, G. G. and L. S. Svanevik: "Utilization of Geothermal Energy in Klamath Falls." *Proceedings, Multi-purpose Use of Geothermal Energy, Oregon Institute of Technology*, pp. 146-178, Klamath Falls, OR, (1974)

Lund, J. W., Culver, G., and P. J. Lienau: *Groundwater Characteristics and Corrosion Problems Associated with the Use of Geothermal Water in Klamath Falls, Oregon*, Geo-Heat Center, Klamath Falls, OR, (1976).

Lund, J. W., and T. Boyd: "Oregon Institute of Technology Geothermal Uses and Projects – Past, Present and Future," *Proceedings*, 34th Workshop on Geothermal Reservoir Engineering, Sanford University, (2009)

INSIDE THE GREENHOUSE: GEOTHERMAL ENERGY AND SPIDER MITE PRODUCTION

Linda Riley, Oregon Institute of Technology, Klamath Falls, Oregon

INTRODUCTION

Variety is intrinsic to Tracey Liskey's agricultural operations and the use of geothermal water at Liskey Farms. In past decades, the 190 – 200°F water was used to soften cull potatoes which were fed to cattle. The softening, Tracey explains, "eliminated the choke problem." Currently, the water is used for space heating, aquaculture pond heating, biodiesel production and greenhouse heating. The greenhouses, divided into two areas, are leased to two different companies; Fresh Green Organics, a community supported agriculture (CSA) organization that grows a plethora of produce, and Biotactics, a bio-controls company that raises spider mites and predator mites. This mite operation, (I have nick-named it "entomoloculture"), consists of harvesting the eggs of the spider mites, feeding the eggs to predator mites and then using predator mites in place of pesticides. Only the spider mites are raised at Liskey farms – just another crop to Tracey. With a compendious manner, Tracey simply states, "we're the hay to the feedlot."

THE MITES:

Biotactics leases 11 greenhouses (a total of nearly an acre) from Liskey Farms, one of which is used to germinate lima beans (food for the mites). The remaining 10 (each 30 x 120 feet) are used for the production of the spider mites. Spider mites are members of the *Acari* (mite) family Tetranychidae, which includes about 1600 species. The spider mite raised by Biotactics, *Tetranychus urticae* (the 'glasshouse red spider mite' or 'two-spotted spider mite') is the most common of the family, particularly in tropical and warm temperate zones and in greenhouses. Spider mites generally live on the under sides of leaves of plants and use modified mouthparts to pierce plant cells. The destruction of the chloroplasts in the leaves leads to a decrease in photosynthesis and eventually plant death. Spider mites are known to feed on several hundred species of plants. They are less than 1mm in size, lay small, spherical eggs and may spin silk webbing to help protect their colonies from predators, the behavior that leads to the 'spider' part of their common name (Figure 1). In optimal conditions, spider mites can hatch in as little as 3 days and become sexually mature in as little as 5 days. One female can lay up to 20 eggs per day and can live for 2 to 4 weeks. A single mature female can spawn a population of a million mites in a month or less. Because of this accelerated reproductive rate, spider mite populations can quickly adapt and become resistant to pesticides. According to Skip Maltby, owner of Biotactics, spider mite populations are now completely resistant to the common insecticide "Sevin."

At the Liskey Farm/Biotactics operation, a patented process is used to wash the spider mites and their eggs off the lima bean leaves into small canisters. These canisters are then shipped via one-day UPS to the Biotactics labs in Romoland, California (east of Los Angeles) where they are fed to a variety of predator mites; each variety is raised in a climate controlled environment that simulates its native region. Biotactics currently sells eight different species of predator mites including *Neoseiulus Fallacies*, a predator mite native to the northern California/southern Oregon region. This practice of using predator mites, or bio-controls, in place of pesticides is called Augmentative Biological Control (ABC). Different predator mites are used for different applications, some are most effective in greenhouses, some on low growing plants, some for avocados, others for strawberries, and some for fruit trees, grapes and other deciduous trees. Biotactics explains on their website that the beneficial predator mites feed only on spider mites and do not bite or harm humans or animals. Once they have consumed the plant pest spider mites, they leave in search of more spider mites elsewhere. Strawberry growers are Biotactics' largest client; a recent contract with a strawberry farmer totaled approximately $1 million.

Figure 1. A colony web of spider mites.

As Tracey led me from greenhouse to greenhouse to show me the different levels of mite population growth, I couldn't help but wonder how the mites were contained in the greenhouse – what measures had to be taken to ensure that they didn't infest other areas? "Oh, mites are everywhere," Tracey shrugged casually. "We keep the perimeter of the greenhouses weed-free, and occasionally an insecticide is used to clean out a greenhouse before new plants and mite populations are brought in." "Generally," he explained, "the mites stay in the greenhouse – they've got all the food they need, and the 90 °F (32.2°C) climate is ideal." Indeed, I thought. On the chilly day I'd chosen to visit, I thought I'd much rather be in the gentle 90 degrees than the blustery 45 degrees outside. Tracey and other Liskey Farm employees also take precautions when touring people through the CSA greenhouses and the Biotactics greenhouses. Tours always finish with Biotactics to ensure people don't track unwanted mites into the CSA greenhouses.

THE BEANS:

Of the 11 greenhouses rented by Biotactics, one is used for the sole purpose of sprouting lima beans which become food for the spider mites. Lima beans grow quickly in the 90°F heat – approximately three inches in two days, and provide a large leaf area (a lot of chloroplasts) for the mites to munch (Figure 2 and 3). The beans do not require any fertilizer for the amount of time they are grown, and are irrigated using a drip irrigation system. When it is time to harvest the spider mite eggs from one greenhouse, two thirds of the mite-infested plants are harvested and the remaining one-third is used to inoculate a new batch of bean plants. The harvest rotates between the houses; all ten houses are harvested in a two week period.

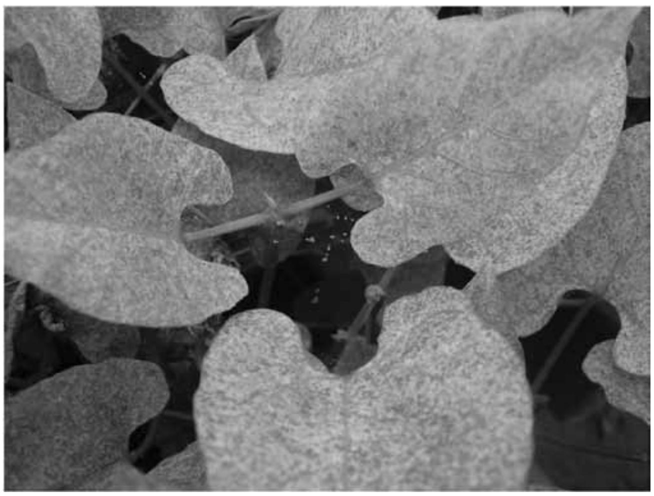


Figure 2. Leaves of plants appeared speckled as spider mites eat the chloroplasts and the plants lose their ability to photosynthesize.

Figure 3. Rows of potted lima bean plants inoculated with spider mites.

Skip estimates that approximately 30,000 pounds of lima beans are used each year for the operation. When asked if the beans could be grown at Liskey Farms, Skip replied with lament that he wished it was possible, but the risk for a killing frost at any month in the Klamath Basin was too high–instead, the beans come from California or Idaho. In order to prevent disease in the lima bean monoculture, the bean seeds are treated with an herbicide prior to arrival at Liskey Farms. Spent bean plants are cycled into a compost pile and used to grow new bean plants.

THE HISTORY:

The partnership between Liskey Farms and Biotactics began in 2006 with Skip's simple desire to find a cheaper way to heat the greenhouses. "The fuel prices were just killing me," Skip explained, so he typed in "geo-heat" in an internet search engine, and, as he recalls, the first site that popped up was one about Liskey Farms. After conducting a thorough search of other possible geothermal sites which could host the spider mite operation, Biotactics returned to Liskey Farms, moving their mite operation in 2007. "Of all the places we looked," Skip said, "Liskey's was simply the best, especially because of the good water quality." The water quality is such that minerals do not build up in the pipe networks, resulting in a system that is less costly to maintain.

The water isn't the only thing that's comparatively clean. If Biotactics had kept the spider mites in California, they would still be using propane and natural gas to heat the greenhouses. Instead, geothermal water heats the greenhouses and fossil fuels are displaced, or offset. This made the relocation project a good candidate for funding from The Climate Trust. The Klamath County Economic Development Association (KCEDA) assisted Biotactics with securing a 10-year performance-based grant for $127,500 from The Climate Trust. Under this award, funds are provided to Biotactics as certain levels of emissions are offset. Heat (measured in btus) used in the greenhouse is measured and verified by a third party on an annual basis. The btus measured are then used to calculate the emissions that would have been generated if propane and natural gas were still being used. Because of varying levels of emissions, The Climate Trust could not disclose at this time the projected total emissions reductions that will result from the project.

While the funding from the Climate Trust is helpful, it may still only make up a small percentage of the nearly half million dollars required to move the operation from Romoland to Klamath Falls. The debt continues to decrease, albeit slowly. Skip is hoping his small company can continue to convince agriculturalists and horticulturists that his predator mites are superior and that demand for the predators will grow as more farms pursue organic certification. Large chemical companies and other predator mite suppliers remain Skip's largest competitors.

THE GEOTHERMAL SYSTEM:

Liskey Farms (Figure 4) is a Known Geothermal Resource Area (KGRA). The geothermal resource has been described by Laskin (1978), Lund (1994) and Chiasson (2007).

Groundwater ranging from 190 to 200 °F (87.7 to 93.3°C) is pumped out of three wells on Liskey Farms. The wells are capable of producing several hundreds of gallons per minute: a recent pump test for a renewed water right pumped 2,500 gallons per minute resulting in only a few inches of draw down. Each well is approximately 300 feet deep with a 40 foot static water level. The water is pumped with 30, 40 and 50 horsepower pumps to a 12,000 gallon tank with a float system. It is then gravity fed to the greenhouses, the aquaculture ponds and Liskey's home. Liskey explained that most of the transit pipe has been replaced with ductile iron pipe bonded and wrapped in plastic. Similar to the pipe protection methods used by utility companies, Liskey has included bags of magnesium at specific locations on the pipes. According to Liskey, the magnesium absorbs the effects of the heat-activated electrolysis that occurs in the ground as a result of the high water temperatures and the soil surrounding the pipe. In this case, only the bags of magnesium require occasional replacement, thus eliminating the need to replace entire sections of pipe.

The geothermal water from the tank is then piped into the greenhouses and distributed using various methods. In the lima bean germination greenhouse, the water is split off the mainline into a series of loops consisting of 2 inch diameter piping secured underneath the growing-bed tables. Skip reports that while this system works, the radiant heat is not always adequate for consistent germination and that more water would be preferred for higher temperatures and higher germination rates. In the spider mite greenhouses, the geothermal water is piped through copper coils of modified radiators (Figure 5). Large fans blow air over the coils and through a large thin plastic distribution tube that runs the length of the greenhouse. The original radiators, Skip explained, consisted of small (3/16 – 1/4 inch) copper tubing unsuitable for the high water pressures resulting from the tank delivery system. Turbulence in the copper piping caused pipe knocking and would generally accelerate the wear of the piping – at times, this was resulting in the replacement of radiators every 6 months. Biotactics replaced the small copper piping with 1/2 inch copper pipe which solved the knocking and degradation issues. Heated air is also forced between the double-ply polycarbonate walls that form the structure of the greenhouse. This increases the insulation and thermal properties of the greenhouse.

CONCLUDING SUMMARY

Geothermal water at Liskey Farms has been put to use for a variety of purposes since the mid 1900s including potato softening, biodiesel production and greenhouse heating. Currently, 11 greenhouses making up an acre of land are leased by Biotactics to raise spider mites. The spider mite eggs are harvested and shipped to California where they are fed to predator mites and these predators are then sold to agriculturalists as an augmentative biological control (ABC). Both Tracey Liskey and Skip Maltby have been successful in renovating pipe systems outside and inside the greenhouses to reduce maintenance costs and increase the lifetime of the geothermal system. The Climate Trust provided some initial funding to support the relocation and the offset emissions of the spider mite operation. Skip plans to continue and perhaps one day expand Biotactics' operations in Klamath Falls, a plan that is fine by Tracey."The mites are kind of like retirement for me," Tracey smiles as he looks back on the row of greenhouses. Certainly for a farmer who still raises cattle and hay, it might be as close to retirement as he gets.

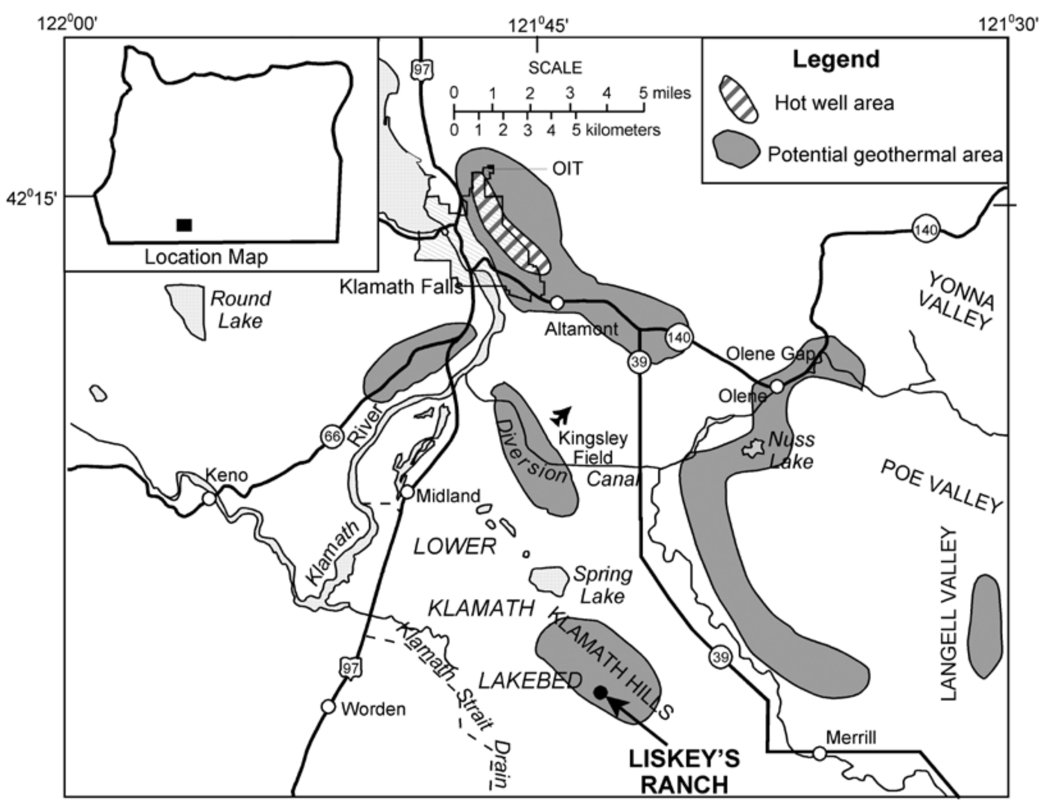


Figure 4. Location map of "Liskey Ranch"

MORE INFORMATION:

Biotactics (spider mites and beneficial predator mites):
www.benemite.com

Geothermal energy utilization: geoheat.oit.edu

The Climate Trust: www.climatetrust.org

ACKNOWLEDGEMENTS

The Geo-Heat Center wishes to thank Tracey Liskey of Liskey Farms and Skip Maltby from Biotactics for their time and the information presented in this article.

REFERENCES

Laskin, S., 1978. "Klamath Greenhouses". *Geo-Heat Center Quarterly Bulletin*, July 1978, Oregon Institute of Technology, Klamath Falls, Oregon.

Lund, J., 1994. "Agriculture and Aquaculture Cascading the Geothermal Way". *Geo-Heat Center Quarterly Bulletin*, November 1994, Oregon Institute of Technology, Klamath Falls, Oregon.

Figure 5. The radiator/fan heating unit used to heat the spider mite greenhouses.

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