Geothermal Energy and the Geothermal Energy Potential of Colorado

These two talks were given by Jeff Winick and Jen Livermore, respectively, at the Thursday, November 15th meeting of the Colorado Scientific Society.

Jeff Winick has more than 18 years of experience in energy, mineral, and water resource management. He works for Allegheny Science and Technology and is currently on contract to the US Department of Energy where he is the lead author and project manager for the GeoVision study. The study establishes a vision for growth of the U.S. geothermal industry based on R&D advancements in cost reduction, improved performance across geothermal resources and technologies, and techno-economic analysis of industry growth scenarios out to the year 2050. Mr. Winick holds a master's degree from New Mexico Tech and a bachelor's degree from Franklin and Marshall College.

Jen Livermore is a consulting geophysical engineer with a specialization in electrical and electromagnetic geophysical methods for natural resource exploration. Her primary areas of geoscientific focus include deep imaging of geothermal systems utilizing the magneto telluric method and direct-use applications of geothermal resources. Ms. Livermore received a BS in Geophysical Engineering from the Colorado School of Mines in 2006, attended the inaugural National Geothermal Academy at the University of Nevada Reno in 2011, and completed an MS in Global Energy Management from the University of Colorado Business School in 2014. She is currently a board director of the Geothermal Resources Council industry group and an advocate for the geothermal industry.

Remains of a Geothermal Plant at El Tatio, Chile at a height of 14,170 ft

Mr. Winick provided an introductory overview of geothermal energy, with topics that included the formation and characteristic elements of geothermal resources, and the basic technologies used to discover and develop them for a range of applications. Geothermal energy was defined as the heat of the earth, which is not distributed uniformly. A favorable combination of porosity, permeability and accessibility is necessary to exploit it. The uses can be broadly divided into non-electric applications, such as heat pumps and direct electrical power generation. Geothermal heat pumps use the earth's thermal storage capacity to transfer energy in order to heat buildings in winter and cool them in summer. Heat pumps are 20-40% more efficient than the direct use of electricity. There are about two million buildings using heat pumps nationwide. High up front costs, lack of awareness and the difficultly of retrofits tend to reduce their use.

Direct use applications of geothermal energy involve the unidirectional extraction of a heat source. Low grade applications include recreational hot springs, district heating, and greenhouse heating. One of the oldest of such applications of geothermal energy is in Boise, Idaho where district heating has been in use since 1890. There are 21 such uses across the USA.

Identified geothermal systems are a resource for electricity power generation and generally have some surface manifestation such as hot springs or fumaroles. Blind systems may share the same resource characteristics, but exhibit no obvious surface expression. These could be magmatic systems associated with volcanic activity and located near plate margins. They generally consist of water saturated rocks above hot magma, which drives hydrothermal convection. There is usually some colder marginal system which provides recharge and pressure maintenance. Drilling production and injection wells accelerates this heat flow. There tends to be rock alteration associated with geothermal water flow. Enhanced systems have been artificially fractured for production.

Geochemistry and geophysics can be used to define Identified systems. Geochemistry gives an indication of temperature of the system while geophysics provides an estimate of its size and geometry. A good understanding of the hydrology is necessary for the optimal development of the resource. Geothermal wells tend to require 30-40 days to drill, which is slower than oil and gas wells. As the profit margins are lower, older rigs are used, and the rock column is generally harder than the sedimentary formations associated with oil production.

The USGS in Menlo Park estimated the size of US geothermal resources in 2008 to be 9 gigawatts for identified systems, 30 gigawatts for blind systems, and 500 gigawatts for enhanced geothermal systems. By comparison, the total annual US energy base is 1000 gigawatts.

Types of geothermal energy plants include dry stream, flash steam and binary. Dry steam plants are the simplest design. The dry steam is used to drive a generator, after which steam is then condensed and re-injected into the reservoir. Dry steam plants require vapor dominated reservoirs, which are not common. Flash stream plants are used for liquid dominated systems, and have pressure vessels to reduce the pressure and generate steam. The byproduct geothermal brine is then re-injected into the reservoir. Binary systems are closed loop. The geothermal fluids are used in a heat exchanger to boil a low flash point liquid, such as pentane, which is then used to drive the turbine.

In the early stage of a geothermal project the risks are high, but the costs are low. A small amount of money is spent on geochemical and geophysical surveys. As drilling starts the costs increase but the risks are still high. The long time frame from evaluation to production, from 7 to 10 years, makes it more difficult to take advantage of the federal government's production tax credits, which are renewed on a short-term basis. Resources in the western USA are generally located on federal lands and projects must complete the NEPA process, which may also increase the time to production. In contrast, solar and wind projects can reach production stage within a year.

Both solar and wind are intermittent, unlike the base load resources of coal and natural gas. Geothermal and hydropower are the only two renewable resources that provide consistent power to the grid. The current paradigm is to use solar and wind backed up by natural gas. The manufacture of batteries for energy storage tends to transfer environmental problems to third world countries where the raw materials are mined.

An audience member asked about earthquake hazards and Mr. Winick replied that it was mainly a problem with enhanced geothermal systems and that a project in Switzerland had been shut down for this reason. Earthquakes are not generally a problem with conventional geothermal systems. Subsidence can occur if the project is poorly managed. In response to another question, Mr. Winick said that because solar and wind were surface projects they tend to progress through NEPA more easily than geothermal projects. He commented that silica scaling on injection wells can be dealt with by managing water temperatures and using chemical additives.

Jennifer Livermore began her talk by discussing the work done by the Colorado Geological Survey (CGS) on Colorado's geothermal resources. CGS has produced GIS maps showing locations of hot springs and potential geothermal prospects. Their maps of Quaternary and Neocene Faulting, and volcanism are particularly useful to geothermal exploration. Elevated heat flow is prevalent in the Southern Rockies and Rio Grande Rift. There are 59 hot springs and 34 geothermal well sites in the state, but as yet no power is generated by geothermal energy.

Colorado has the first state capitol to use a geothermal heat pump for cooling. The system was funded by the DOE at a cost of $6 million. It is an open loop system and uses two 850-ft wells of 6-inch diameter, drilled into the Arapahoe Aquifer for both heating and cooling. In 2015 energy cost savings were $100,000. Private developers funded the geothermal system at the IKEA building at I-25 near County Line Rd, which has 130 500- ft wells of 5 ½ inch diameter. This is a closed loop system using glycol for heat exchange. Because of the large number of customers in the building, cooling is the main concern, and at night nine 1,200 gallon tanks are filled with chilled water to supplement the cooling system during the day.

The one district heating project in Colorado is located in Pagosa Springs. It uses two wells, one at 300 ft in depth and the other at 274 ft in depth. The project was funded by DOE, cost $1.4 million, and came on line in 1982. Only one well is currently in use and it sends 249 degree water to the utility room where it is cooled to 146 degrees and discharged to the surface. The end users are 13 public buildings. The system operates at reduced capacity as it uses 250 gallons per minute and is designated a consumptive use. The City of Aspen attempted to emulate Pagosa Springs and drilled a 1500-ft well in the middle of town to the Leadville Limestone Aquifer, where the temperatures can vary between 90 and 140 degrees Fahrenheit. However, the temperatures found were too low and it was converted to a monitoring well.

There are two geothermal greenhouses in Colorado, one in Chaffee County near the Mt. Princeton hot springs area and the other in Pagosa Springs at the Geothermal Greenhouse Partnership. In the San Luis Valley the hot springs are used for alligator rescue. Tilapia are raised in the warm water to feed the alligators.

Amax drilled 31 thermal gradient wells at the Mt. Princeton Hot Springs area in the 1970s. This prospect has since been investigated by the Colorado School of Mines and CGS, and Mt. Princeton Geothermal is interested in the commercial development of this property. Geophysical surveys indicate that the water temperature is between 120 and 150 degrees centigrade. Five additional geothermal gradient wells were drilled in 2009 to delineate the western edge of the field. The BLM offered a geothermal lease in 2010, but it was purchased by a local landowner who opposed geothermal development. Mt. Princeton Geothermal wants to drill three additional wells on adjacent property, but has yet to obtain funding. The earth's normal temperature gradient is 30 degrees centigrade per kilometer, but it was found to be 75 degrees centigrade per kilometer in one of the 2009 wells. In one well, a zone was found at 140 meters with water temperatures of 270 degrees centigrade.

Three evaluation wells were drilled at Pagosa Springs in 2014. However, the developer faced local opposition from people who were concerned about the impact on existing production. Waunita Hot Springs in Gunnison County was rated one of the best geothermal prospects in the state by the CGS. At a lease sale in 2012, the lease was purchased by persons against development. However, the stipulations of the lease sale were daunting to any operator.

Some of the sedimentary basins in Colorado exhibit elevated heat flow. In North Dakota, a binary geothermal unit was placed on a well and produced enough power to supply the local oilfield operation. There is the opportunity to have the same co-production in Colorado. MIT has rated the state as having the best geothermal prospects in sedimentary basins at depths from 10,000 to 13,000 ft. Colorado was the first state to vote in a Renewable Energy Portfolio in 2004. Governor Polis is proposing a mandate for 100% of the electricity in the state to be supplied by renewable energy by 2040. This mandate includes streamlined permitting for geothermal projects on public land.