GEO-HEAT CENTER

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EXECUTIVE SUMMARY

The Geo-Heat Center conducted a pre-feasibility study for Geothermal Industrial Rail Development (GRID) to implement a geothermal district heating (and possibly cooling) system at the proposed Dark Horse Geo Center, located near Fernley, NV. This work was funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-05, Task 4: *Feasibility Study of Geothermal Resources for GRID, Fernley, NV.*

The main objective of this project has been to determine the viability of a district heating and cooling system for the Dark Horse Geo Center and two neighboring residential subdivisions. However, since the geothermal resource at this time has not yet been fully characterized, a number of assumptions had to be made regarding available geothermal water temperature and flow rate. A spreadsheet was developed to examine a number of possible geothermal resource scenarios, and an economic analysis was conducted under a base case assumption of availability of a 300°F geothermal resource at a flow rate of 2000 gpm. Given the uncertainty of the economic assumptions, a sensitivity analysis was conducted on the major cost items.

Providing geothermal cooling to the Dark Horse Geo Center with the use of absorption chillers does not appear to be economically viable. The cost of the absorption chiller equipment would be prohibitive and the temperature of the water required for absorption chilling would compete with and limit the electricity that could be generated by a binary power plant. From analysis of geothermal resource temperature and flow rate scenarios, all of the Dark Horse Geo Center buildings (1.87 million sq. ft) could be heated with a resource temperature of 300°F and flow rate of 2000 gpm. In addition, about 4 MW of electrical power could be generated by a geothermal binary power plant. In order to produce 10 MW of electricity with a 300°F geothermal resource, about 4800 gpm of water flow would be required. Under that condition, all of the Dark Horse Geo Center buildings could be heated, along with the additional 1000 homes under consideration in the adjacent subdivisions.

The simple payback period of a district heating system at the Dark Horse Geo Center is estimated at 11.6 years, with an estimated capital cost of $5.89 million and an annual net income of $0.508 million. The main factors affecting the simple payback of the district heating system are the geothermal resource flow rate, capital cost, and retail price of the heating water. Decreasing the resource flow rate from the assumed value of 2000 gpm rapidly makes a district heating project at the Dark Horse Geo Center look economically unattractive. Decreasing the heating water retail price below $1.00/therm makes a district heating system progressively less attractive; a heating water retail price of $1.10/therm brings the simple payback period down to just less than 10 years. Decreasing capital costs by 10% decreases the simple payback period to less than 10 years.

INTRODUCTION AND BACKGROUND

This work was funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-05, Task 4: *Feasibility Study of Geothermal Resources for GRID, Fernley, NV*.

An industrial/commercial park is being proposed for renewable energy-related businesses, developed by GRID, LLC (Geothermal Rail Industrial Development). The development is referred to as the Dark Horse Geo Center Commercial Subdivision, and consists of 412 acres of land located near Fernley, NV.

The Geothermal Resource

The regional geothermal resource in the Fernley, NV area is believed to be similar to other Basin and Range resources. Conceptual models of geothermal reservoirs attempt to describe their mode of recharge, fluid circulation path, heat source, and discharge or outflow path. The generalized conceptual model of Basin and Range geothermal reservoirs is that recharge to the geothermal reservoir is by meteoric waters (rain and snowmelt) that sink to considerable depths, usually along fault lines and fracture zones at higher elevations. Groundwater then becomes heated at depth, circulates and rises due to buoyancy effects along lower faults.

The local geothermal resource at the proposed Dark Horse Geo Center is not fully characterized at this time. An exploratory borehole was drilled near the center of the parcel that revealed a subsurface temperature of approximately 225^{o}F at a depth of 700 ft. The groundwater occurrence and yield of the formation has not yet been examined. Geothermometers indicate possible subsurface temperatures of up to 350^{o}F (Coolbaugh, 2007).

Proposed Geothermal Energy Utilization

The geothermal energy utilization at the Dark Horse Geo Center is proposed by the project developers to be anchored by a geothermal power plant producing up to 10 MW of electrical energy if possible. The geothermal effluent from the power plant could then be made available to a district heating (and potentially cooling) system serving the Dark Horse Geo Center. In addition, the geothermal effluent is proposed to be made available to two additional district heating systems serving residential customers.

OBJECTIVE AND SCOPE

The main objective of this project is to determine the viability of a district heating and cooling system for the Dark Horse Geo Center buildings and neighboring residential subdivisions. The specific questions to be answered are: (*i*) how much commercial and residential floor space can be heated with geothermal effluent from a power plant and (*ii*) what is the economic feasibility of a district heating and cooling system.

METHODS

At this early phase of the project, the geothermal resource is not fully characterized, nor is the subdivision completely designed. Therefore, the methods undertaken to accomplish the project objectives were as follows:

- Developed a spreadsheet analysis tool to examine various scenarios of geothermal resource temperature and flow yield. The spreadsheet calculates power plant output and allowable heated/cooled floor space under the following assumptions:
    - The geothermal power plant would be a binary plant,
    - Binary geothermal power plant efficiency was calculated as a function of resource temperature,
    - The geothermal power plant effluent would be cascaded to a plate heat exchanger serving the district energy system,
    - A heat loss of 22 Btu/hr per sq. ft of floor space plus an additional 20% for residential domestic hot water loads,
    - Conditioned floor space in the Dark Horse Geo Center is 1.87 million sq. ft,
    - Conditioned floor space in the additional residential subdivisions includes 1000 homes at 2000 sq. ft each,
- Conducted an analysis of cooling options using absorption chillers,
- Conducted an economic analysis of a district energy system, and
- Conducted a sensitivity analysis of the input assumptions.

RESULTS OF THE STUDY

Geothermal Cooling

Providing geothermal cooling using absorption chillers to the Dark Horse Geo Center does not appear to be economically viable for a few reasons described below.

The main reason that absorption cooling was eliminated from further consideration was due to the high capital cost and availability of equipment. Currently available absorption chillers are manufactured in nominal sizes for commercial applications. Therefore, geothermal cooling would be limited to the Dark Horse Geo Center buildings. With the Dark Horse Geo Center comprising 1.87 million sq. ft of conditioned floor space, and assuming a cooling load of 400 sq. ft/ton, approximately 4675 tons of absorption chiller capacity would be required. Installed costs of absorption chillers are approximately $2500/ton, resulting in a total cost to condition all the Dark Horse Geo Center buildings of $11.7 million. As discussed below, this cost exceeds the cost of the district heating system itself. These costs would not be competitive with cooling by conventional evaporative methods.

Secondly, absorption chillers available today require 190^{o}F water at a flow rate of about 3.75 gpm per ton of chiller capacity. This means that the water temperature exiting a binary power plant would need to have a lower temperature limit of about 195^{o}F (assuming a 5^{o}F approach to the heat exchanger serving the district heating system). With most binary plants being able to achieve exiting geothermal water temperatures of about 160^{o}F to 170^{o}F, there would be a tradeoff between generating electricity and providing hot enough water for cooling of buildings at the Dark Horse Geo Center buildings. With current and developing renewable portfolio standards (RPS) in Nevada, electricity could likely be sold at a premium price to the grid, and thus it would be desirable to generate as much electricity as possible, particularly during the cooling season when electricity demands are at their greatest. Figure 1 shows the percent reduction in electricity generation from a binary power plant with increased leaving geothermal water temperature for purposes of absorption cooling. The graph shown in Figure 1 was produced by calculating available energy for a binary geothermal power plant with 170°F leaving geothermal water temperature as compared to 195°F leaving geothermal water temperature at various geothermal resource temperatures. For example, with a 300°F geothermal resource providing absorption cooling, there would be about a 20% reduction in electricity produced.

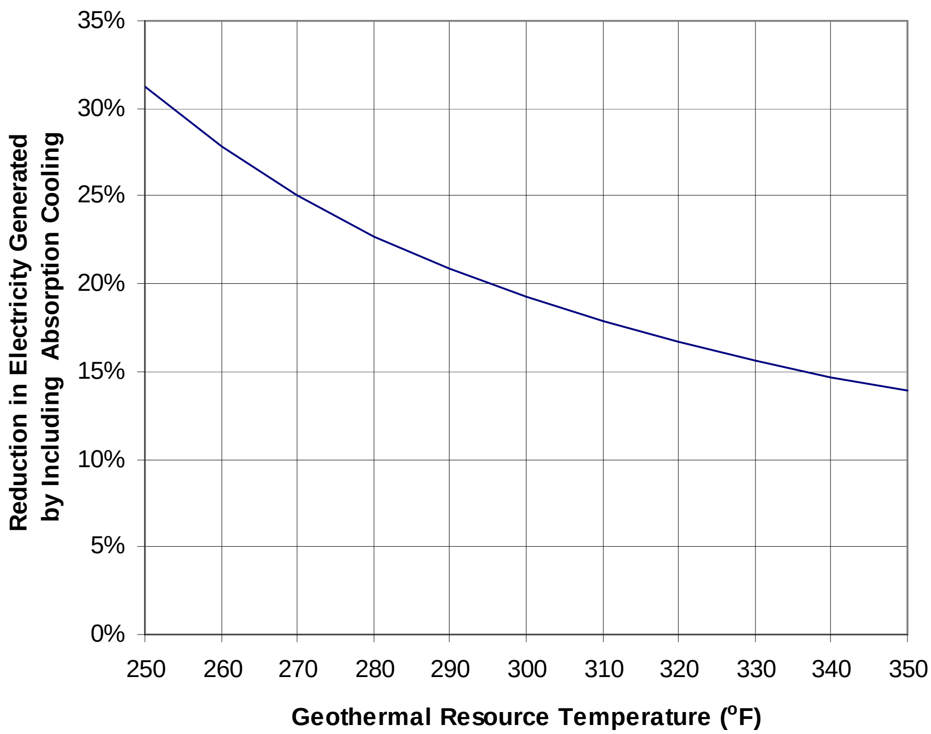

Figure 1. *Percentage reduction in electricity produced by a geothermal binary power plant by including absorption cooling. .*

Geothermal Heating

As previously mentioned, a spreadsheet analysis tool was developed to examine various scenarios of geothermal resource temperature and flow yield. The spreadsheet calculates power plant output and allowable heated floor space from geothermal water cascaded from a binary geothermal power plant.

A contour map was constructed showing geothermal power plant output (in MW) along with potential floor space (in square feet (sq. ft)) that could be heated with cascaded geothermal water (Figure 2). As seen in Figure 2, all of the Dark Horse Geo Center buildings (1.87 million sq. ft) could be heated with a geothermal resource temperature of 300°F and flow rate of 2000 gpm. In addition, about 4 MW of electrical power could be generated by a geothermal binary power plant. In order to produce 10 MW of electricity with a 300°F geothermal resource, about 4800 gpm of water flow would be required. Under those conditions, all of the Dark Horse Geo Center buildings could be heated, along with the additional 1000 homes under consideration in the adjacent subdivisions.

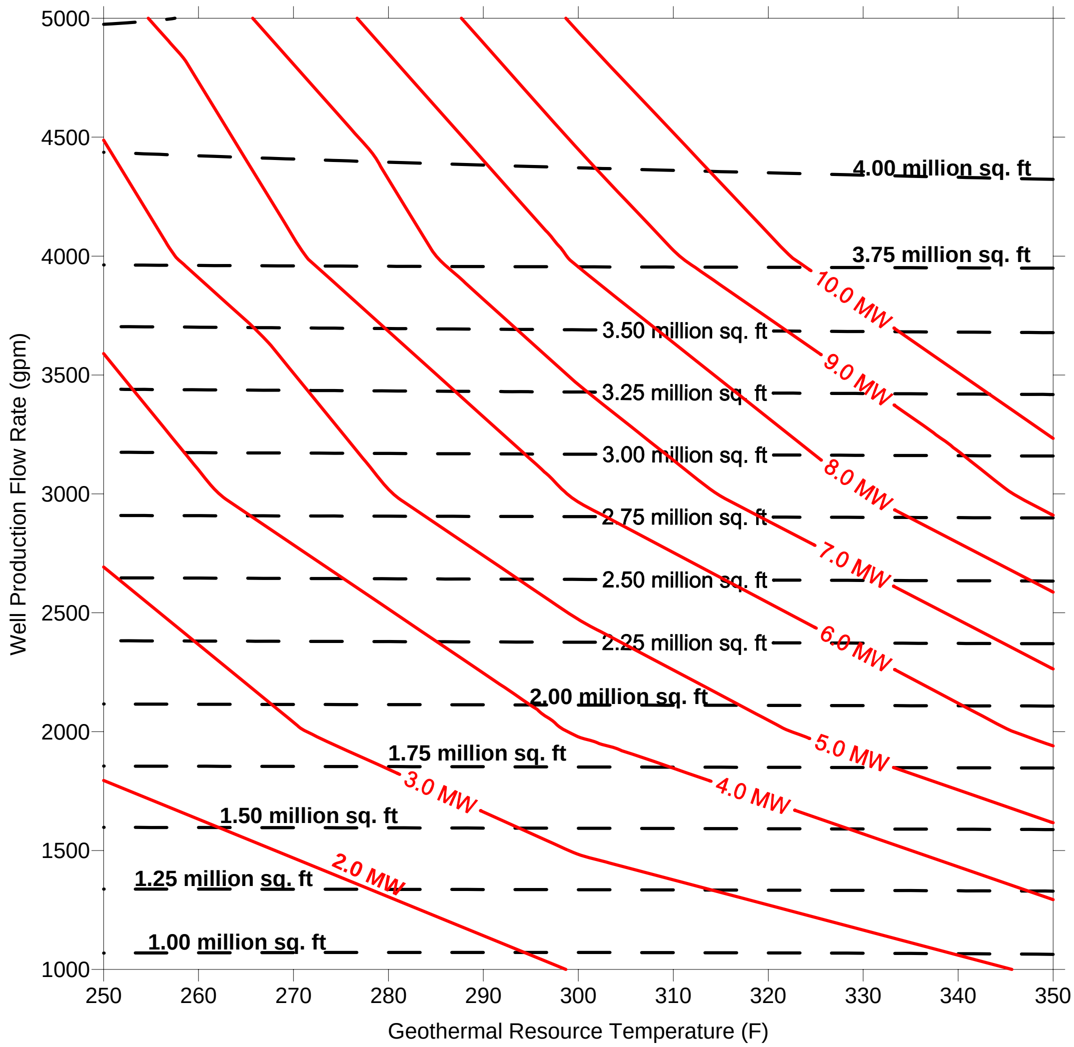

Figure 2. *Contour map of potential heated floor space and corresponding electric power output from a binary geothermal plant.*

System Layout

At this early stage in the Dark Horse Geo Center project, only a conceptual district heating system layout is possible as shown in Figure 3. Although the production and injection wells have not yet been sited, their location doesn't have a major impact on the district heating piping layout because the district system will be a closed loop system as shown in Figure 3. In general, the district system piping layout will consist of a main distribution line with branch lines feeding individual buildings or building clusters. The production well(s) should be sited at the location of maximum resource energy production, yet to be determined by future exploration activities. The injection well(s) should be sited such that pipeline length between wells is minimized, but should be far enough away from the production well(s) to minimize thermal interference.

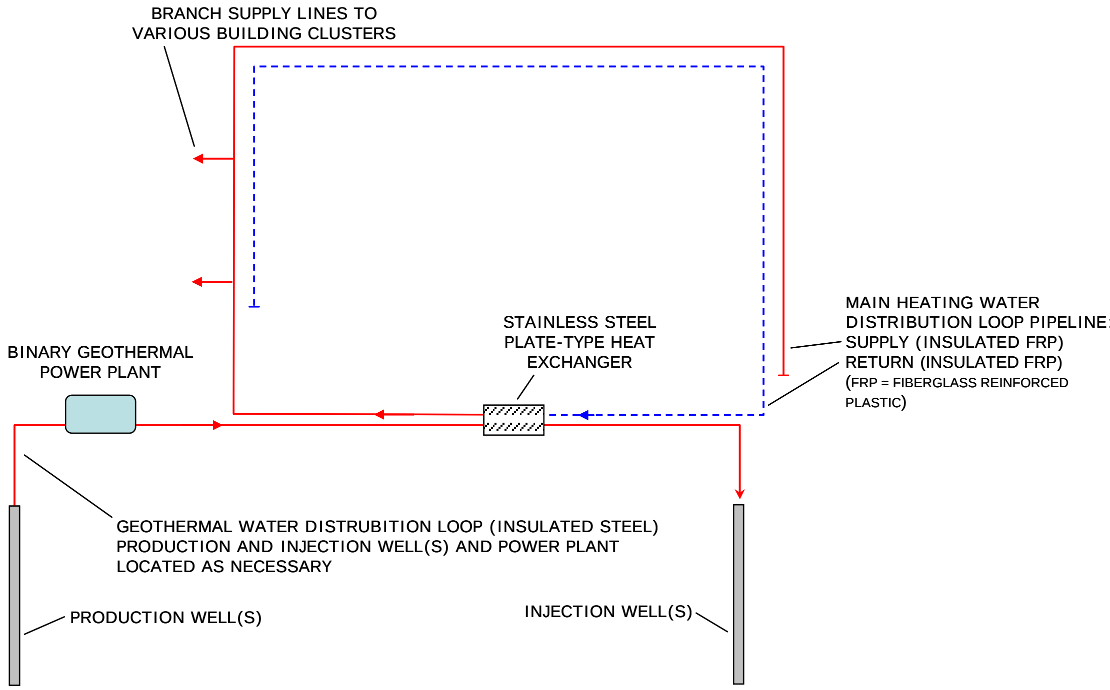

Figure 3. *Conceptual schematic of the layout of the Dark Horse Geo Center geothermal project layout.*

Economic Considerations

As previously mentioned, geothermal cooling with absorption chillers does not appear economically viable, and thus was not considered further. At this preliminary stage, the geothermal resource temperatures and flow rates are not known, but these are needed to estimate economic viability. Thus, our approach was based on a base case of starting with heating all the Dark Horse Geo Center buildings and conducting a sensitivity analysis (or more appropriately a "what if?" set of scenarios) of the input assumptions. All the Dark Horse Geo Center buildings could be heated by geothermal energy if a geothermal resource of 300^{o}F at a flow rate of 2000 gpm was found (see Figure 2), and in addition, a geothermal binary power plant could produce about 4 MW of electrical power. At lower geothermal resource temperatures and/or flow rates, it was assumed that the heating water loop temperature would be boosted by a natural gas-fired boiler. At higher geothermal resource temperatures and/or flow rates, it was assumed that partial heating of the residential subdivisions could be undertaken.

Well costs were not considered, as they were assumed to be tied to the geothermal power plant project and will be drilled regardless of the feasibility of the district heating project. District heating installation costs and operation and maintenance (O&M) costs were taken per square foot of heated floor space from Brown (2006), escalated to 2007 dollars. Engineering design and O&M costs are estimated as a percent of the capital cost of the district system. A summary of the economic analysis of the base case is shown in Table 1. The simple payback on investment of a district heating system at the Dark Horse Geo Center is estimated at 11.6 years. The capital cost is estimated at $5.89 million with an annual net income of $0.508 million.

Table 1
Economic Analysis Summary of the
Dark Horse Geo Center Geothermal District Heating System (base case)

	Unit	Quantity	Unit Cost	Amount	TOTALS
GEOTHERMAL RESOURCE					
Temperature	°F	300			
Flow rate	gpm	2,000			
INITIAL COSTS					
Design & Engineering	% capital	5%	$5,610,000	$280,500	-
District energy system	sq. ft	1,870,000	$3.00	$5,610,000	-
Supplemental boiler	therm	0	$1400	$0	-
					$5,890,500
ANNUAL COSTS & INCOME					
Operation & Maintenance	% capital	7.0%	$5,610,000	$392,700	
Supplemental heating by boiler	therm	0	$1.25	$0	
Sale of water for heating	therm	900,966	$1.00	$900,966	
					$508,266
Simple Payback Period	yrs				**11.6**

The main factors affecting the simple payback of the district heating system are: geothermal resource flow rate, capital cost, and selling price of heating water. The geothermal resource flow rate dictates how much floor space can be heated (note from Figure 2 that available energy with higher geothermal resource temperature does not impact allowable heated floor space because it was assumed that generating more electricity would be the primary use of the higher resource temperatures). The capital cost is an obvious factor affecting payback period. The selling price of the heating water was estimated at $1.00/therm (based on the current price in Klamath Falls, OR), but could be adjusted lower to attract customers or higher to improve economics to the project owners.

Given the uncertainty of the main factors affecting the simple payback period of the district heating system, a sensitivity analysis was conducted to observe how these parameters affect the payback. The uncertain parameters were adjusted +/- 25% of the assumed values shown in Table 1. Results of the sensitivity analysis are shown graphically in Figure 4.

A review of Figure 4 clearly shows that the geothermal resource flow rate is the most sensitive parameter affecting the simple payback period. Decreasing the resource flow rate from the assumed value of 2000 gpm rapidly makes a district heating project at the Dark Horse Geo Center look economically unattractive. If greater flow rates exist, the payback period begins to decrease, as it was assumed that the neighboring residential subdivisions can begin purchasing water, or that other uses of hot water might be found at the Dark Horse Geo Center.

The next most sensitive parameter on the simple payback period is the heating water retail price. From the assumptions made here, decreasing the retail price below $1.00/therm makes a district heating system progressively less attractive. A heating water retail price of $1.10/therm brings the simple payback period down to just less than 10 years.

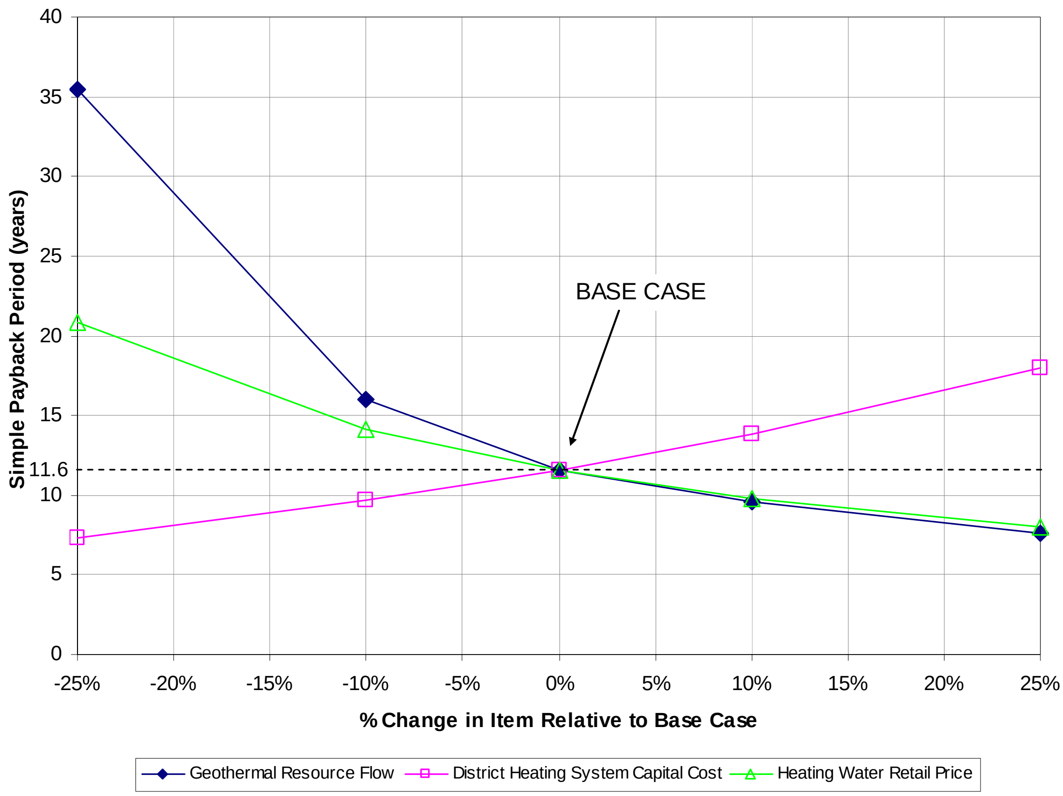

Figure 4. *Sensitivity analysis of major cost assumptions on the simple payback period of a district heating system at the Dark Horse Geo Center.*

The simple payback period of a district heating system is also, as one would expect, sensitive to the capital cost of the project. If capital costs are lowered by 10%, then the simple payback drops to less than 10 years.

CONCLUDING SUMMARY

The Geo-Heat Center has conducted a pre-feasibility study of a proposed industrial/commercial park located in Fernley, NV. The development is referred to as the Dark Horse Geo Center Commercial Subdivision, and consists of 412 acres of land. The main objective of this study was to determine the viability of a district heating and cooling system for the Dark Horse Geo Center and neighboring residential subdivisions.

At this early phase of the project, the geothermal resource has not been fully characterized, nor has the subdivision been completely designed. Therefore, we examined a number of scenarios of various geothermal resource temperatures and flow yields. It was assumed that the primary use of the geothermal resource would be to generate electrical power with a binary power plant, and then the leaving water from the plant would be cascaded to a district heating and possibly cooling system.

Some specific conclusions of this study are as follows:

- Providing geothermal cooling using absorption chillers to the Dark Horse Geo Center buildings was not considered economically viable. The cost of the absorption chiller equipment would be prohibitive and the temperature of the water required for absorption chilling would compete with and limit the electricity that could be generated by a binary power plant.
- From analysis of geothermal resource temperature and flow rate scenarios, all of the Dark Horse Geo Center buildings could be heated with a resource temperature of 300^{o}F and flow rate of 2000 gpm. In addition, about 4 MW of electrical power could be generated by a geothermal binary power plant. In order to produce 10 MW of electricity with a 300^{o}F geothermal resource, about 4800 gpm of water flow would be required. Under that condition, all of the Dark Horse Geo Center buildings could be heated, along with the additional 1000 homes under consideration in the adjacent subdivisions.
- The simple payback period of a district heating system at the Dark Horse Geo Center is estimated at 11.6 years. The capital cost is estimated at $5.89 million with an annual net income of $0.508 million.
- The main factors affecting the simple payback of the district heating system are the geothermal resource flow rate, capital cost, and selling price of the heating water.
- Decreasing the resource flow rate from the assumed value of 2000 gpm rapidly makes a district heating project at the Dark Horse Geo Center look economically unattractive.
- Decreasing the heating water retail price below $1.00/therm makes a district heating system progressively less attractive. A heating water retail price of $1.10/therm brings the simple payback period down to just less than 10 years.
- Decreasing capital costs by 10% decreases the simple payback period to less than 10 years.

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Coolbaugh, M., 2007. Personal communication, Great Basin Center for Geothermal Energy, University of Nevada, Reno.