A SPREADSHEET FOR GEOTHERMAL ENERGY COST EVALUATION

Kevin Rafferty
Geo-Heat Center

INTRODUCTION

In order to be seriously considered as an alternative in any project, an energy source must be easily characterized in terms of cost, both capital and unit energy cost. Historically, this has been a difficult hurdle for geothermal energy. Its costs vary with the depth and character of the resource, number of production and injection wells, and a host of other parameters. As a result, even in cases where developers are interested in using the geothermal, identifying its costs has been a cumbersome process. To address this problem, the Geo-Heat Center is developing a spreadsheet which will allow potential users to quickly evaluate the capital cost and unit energy cost of accessing a geothermal resource.

Using resource, financing and operating inputs, the spreadsheet calculates the capital cost for production well(s), well pump(s), well head equipment, injection well(s), and connecting pipelines. These capital costs are used along with the quantity of annual energy to be supplied and financing information to produce a unit cost of energy. Unit costs for operation (maintenance and electricity) are added to arrive at a total unit cost in $ per million Btu for geothermal heat. To put this value into perspective, similar costs for an equivalently sized gas boiler plant are also calculated. These values can then be compared to determine the relative economic merit of geothermal for any specific set of circumstances. This information is particularly useful at the conceptual stage of a project when decisions as to fuel source are typically made by the developers.

Cost data for geothermal systems was drawn primarily from past projects and vendor price data. Costs for well head piping and gas boiler equipment was taken from standard industry estimating guides (Means, 1994), (Konkel, 1987), Khashab, 1984), (Lienau, 1991).

SYSTEM DESCRIPTIONS

The spreadsheet compares two basic approaches to producing heat: a geothermal system, and a gas boiler plant.

For the geothermal system, up to 3 production wells can be specified. Well casing is sized to accommodate a pump capable of supplying the required flow rate. Costs are included for drilling, casing, cementing, packers, bits and drill rig mobilization. An option is provided for open hole completion.

Wells can be equipped with production pumps at the users discretion. Pumps are assumed to be oil lubricated/lineshaft type and can be equipped with electronic variable-speed drives. The spreadsheet calculates the total pump head (including injection pressure if applicable), bowl size, number of stages, lateral requirements, column size and length, and all costs.

Well head equipment includes piping, check valve and shut-off valve along with electrical connections and accessories for the motor. All of these items are assumed to be located in an enclosure.

Injection wells (up to 3) can be included in the system at the users discretion, along with a user defined casing depth. Cost components for the injection wells are similar to those described for the production wells; although, the drilling cost rates used for injection are higher than those used for production. This rate is 20% higher to allow for alternate drilling methods sometimes employed for injection wells.

Finally, piping connecting the production wells and injection wells to the building (or process) are included to complete the geothermal system. A 15% contingency is added to all major cost categories

For the boiler plant costs are calculated for a cast iron gas-fired boiler including: boiler and burner, concrete pad, breaching to flue, gas piping, combustion air louvers, expansion tank and air fitting, air separation, relief valve and piping, feed-water assembly, boiler room piping and shut-off valves. The spreadsheet is intended to compare geothermal to other conventional methods of supplying heat. As a result, it focuses upon the heat source only. Costs necessary for interface with a specific use, such as a heat exchanger, fan coil units or distribution system are not included.

INPUT

Table 1 presents the input items for the spreadsheet. Peak load refers to the load to be supplied. Load factor is used to calculate the annual energy supplied. Temperature drop is the difference between the geothermal production and injection temperatures, and is used to calculate peak flow requirements. Electricity inputs are used to determine pumping costs for the geothermal. Interest rates and loan terms are used in the calculation of ownership cost for the system. The number of production wells can be specified by the user up to a maximum of 3. Well depth should be limited to maximum of 3000 feet due to the cost data on which the spreadsheet is based. Production temperature is used in the calculation of pump lateral. Hard and soft drilling conditions affect drilling costs for the wells.

Specific capacity and static water level are used in the calculation of casing and pump sizes, and depth requirements. Open hole completion eliminates casing in the production well below the pump housing. Up to 3 production well pumps can be specified in Input #16. Each of these pumps can be equipped with an electronic variable-speed drive (VSD). Up to 3 injection wells can be specified in Input #18. Injection well efficiency is an input that allows the user to adjust the

TABLE 1

INPUT

1.	Peak Load	15,000,000 Btu/hr
2.	Load Factor	0.2 decimal
3.	Temperature Drop	50 F
4.	Electricity Cost	0.05 $/kWh
5.	Electricity Cost	3 $/kWh
6.	Interest Rate	0.08 decimal
7.	Loan Term	20 years
8.	No. of Prod. Wells	3
9.	Depth	1,600 ft
10.	Temperature	193 F
11.	Hard Drilling %	0.6 decimal
12.	Soft Drilling %	0.4 decimal
13.	Specific Capacity (drawdown rate)	8 gpm/ft
14.	Static Water Level	300 ft
15.	Open Hole?	1 Y=1,N=0
16.	No. of Prod. Pumps	3
17.	No. of VSDs	0
18.	No. of Inj. Wells	0
19.	Inj. Well Efficiency	1 decimal
20.	Depth	0 ft
21.	Static Water Level	0 ft
22.	Casing Depth	0 ft
23.	Boiler Efficiency	0.75 decimal
24.	Natural Gas Cost	0.43 $/therm

TABLE 2

OUTPUT

1.	Required Flow	600 gpm
2.	Production Well	$ 281,698
3.	Well Pump	$ 117,131
4.	Wellhead Equipment	$ 25,913
5.	Injection Well	$ 0
6.	Pipeline	$ 32,120
7.	Total Geothermal Cost	$ 456,861
8.	Boiler Plant Cost	$ 96,509
	Geothermal System[1]:	
9.	Unit Capital Cost[1]	1.77 $/MMBtu
10.	Unit Maintenance Cost	0.49 $/MMBtu
11.	Unit Electricity Cost	0.43 $/MMBtu
12.	Total Unit Cost	2.69 $/MMBtu
	Boiler System:	
13.	Boiler Fuel Cost	5.73 $/MMBtu
14.	Equipment Unit Cost	0.43 $/MMBtu
15.	Maintenance Unit Cost	0.11 $/MMBtu
16.	Total Unit Cost	6.27 $/MMBtu
17.	Simple Payback	3.83 Years

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1. $/MMBtu = $1/million Btu

ability of the well to accept fluids. It is used as a multiplier for the specific capacity input above. Injection well depth, as in the case of production wells, should be limited to 3000 feet. Injection well static water level is used in the calculation of required injection pressure. Input #22 allows the user to specify the casing depth in the injection well.

The fuel input items relate to the calculation of gas boiler supplied heat. Boiler efficiency is used to calculate the unit cost of heat related to the fuel. Natural gas cost is the local natural gas rate (in $ per therm) applicable to the project.

OUTPUT

The primary output appears in Table 2. These values are derived from a long list of secondary outputs appearing in the lower portion of the spreadsheet.

Item 1 is the peak geothermal flow required to meet the conditions specified in the input. Based on local information, if the selected number of wells cannot supply this flow, then additional wells will be needed. This is followed by the capital costs for the production well (or wells), well pump (or pumps), well head equipment, injection well (or wells) and inter-connecting pipelines. These 5 costs are summed to arrive at the total cost for accessing the geothermal resource. The total capital cost is converted into a unit capital cost of energy based on a 20-year loan term at the interest rate specified. Unit maintenance cost is based primarily upon production pump maintenance. It is based on the assumption of 5-year overhauls and 15-year replacement of the pump bowl assembly. Unit electrical costs are based upon the electrical costs specified in the input and the pump horsepower calculated by the spreadsheet. These 3 costs are summed to arrive at the total unit cost of geothermal heat in $ per million Btu.

For the boiler system, the same general procedure is used. The unit fuel cost is based on the boiler efficiency and natural gas rate specified in the input. The Equipment Unit Cost corresponds to the Unit Capital Cost of the geothermal system. It is based upon the capital cost for the boiler plant. The unit maintenance costs is based on a value of 3% of the boiler plant capital cost. The 3 boiler plant unit costs are summed to arrive at a Total Unit Cost for Boiler supplied heat.

Simple Payback relates to the unit costs for the two methods of supplying heat to their capital costs. The capital cost premium for the geothermal system (over the boiler system) is divided by: the difference in the unit heat costs and the quantity of heat supplied annually (the peak load multipled by the load factor).

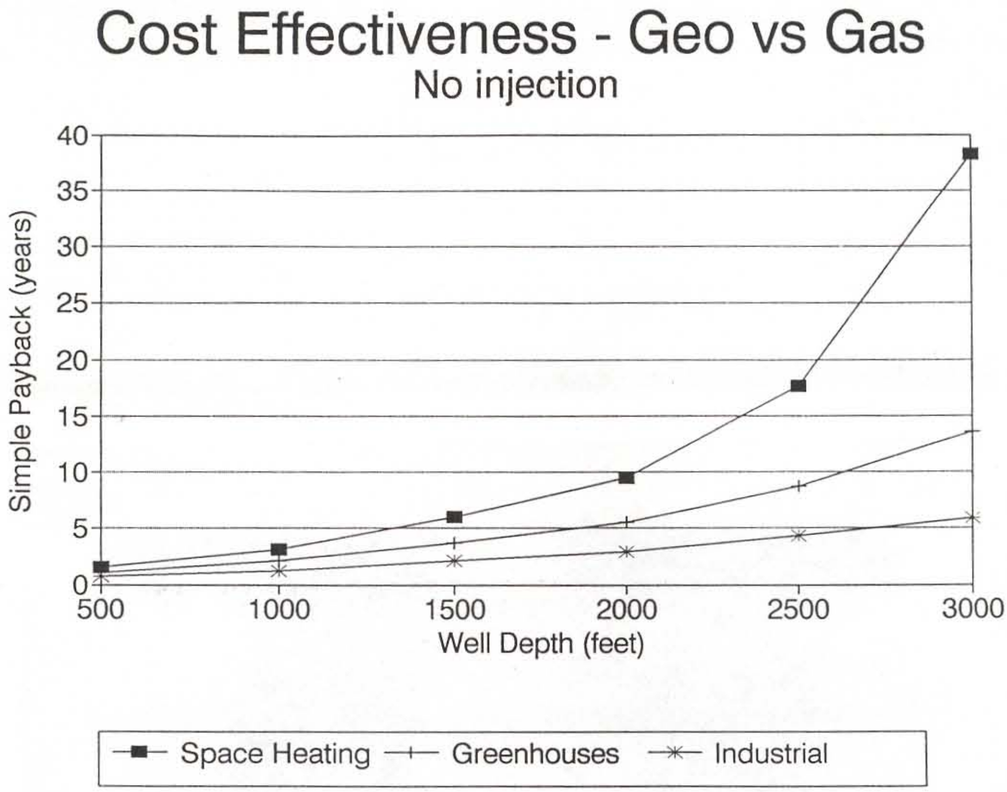

Figure 1.

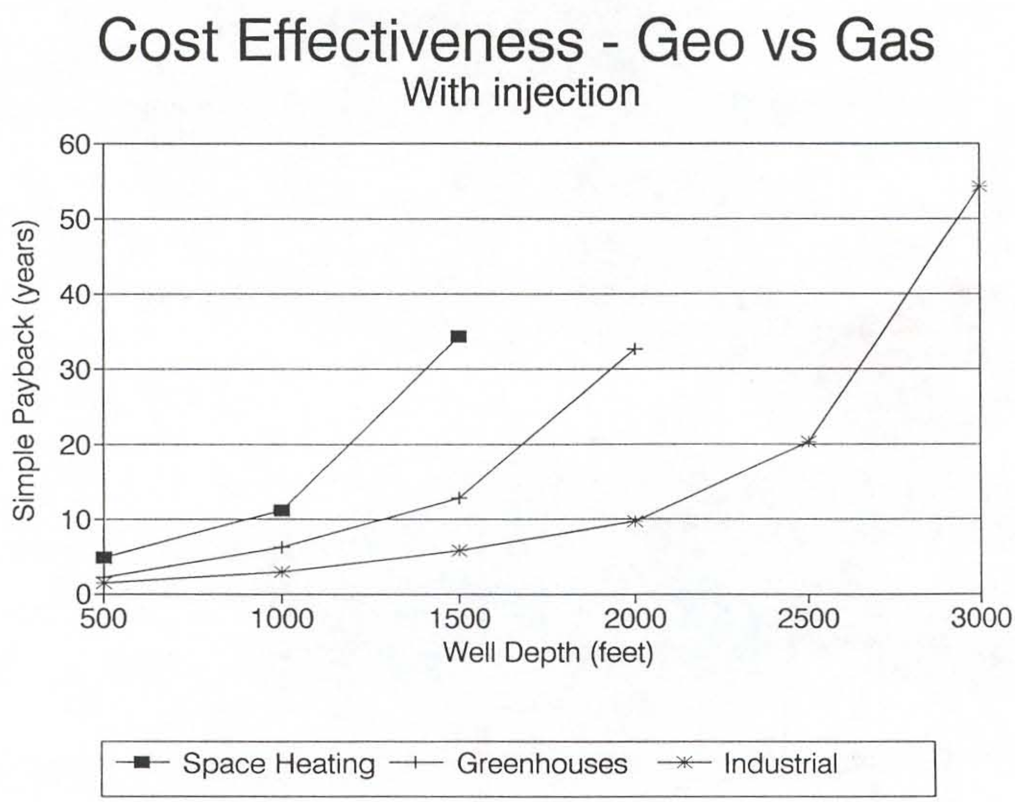

Figure 2.

TABLE 3.

OUTPUT

1.	Required Flow	600 gpm
2.	Production Well	$ 281,698
3.	Well Pump	$ 117,131
4.	Wellhead Equipment	$ 25,913
5.	Injection Well	$ 251,487
6.	Pipeline	$ 46,182
7.	Total Geothermal Cost	$ 722,410
8.	Boiler Plant Cost	$ 96,509
9.	Unit Capital Cost	2.80 $/MMBtu
10.	Unit Maintenance Cost	0.49 $/MMBtu
11.	Unit Electricity Cost	0.42 $/MMBtu
12.	Total Unit Cost	3.71 $/MMBtu
13.	Boiler Fuel Cost	5.73 $/MMBtu
14.	Equipment Unit Cost	0.43 $/MMBtu
15.	Maintenance Unit Cost	0.11 $/MMBtu
16.	Total Unit Cost	6.27 $/MMBtu
17.	Simple Payback	9.28 Years

EXAMPLES

Using the original OIT campus geothermal system as an example and assuming it was constructed today (instead of in 1963), the geothermal resource portion of the system would cost approximately $460,000 and produce heat for a unit cost of $2.69 per million Btu (Table 2). At the current cost of natural gas locally, a gas boiler plant (costing $96,000) would supply the same quantity of heat for $6.27 per million Btu. This would result in about a 4-year simple payback on the additional geothermal investment.

The current OIT system includes two injection wells which were added in the last few years. Incorporating the injection well costs into the picture raises the cost of geothermal supplied heat to approximately $3.71 per million, still only about 60% of the natural gas supplied heat (Table 3). Under these conditions, the simple payback on the geothermal would amount to about 9 years when compared to a natural gas system.

A more general example of the use of the spreadsheet is illustrated in Figures 1 and 2. Consider a local economic development agency in an area of known geothermal resources. The economic development agency may wish to determine the relative economic merit of geothermal use for new industrial developments as a function of required well depth. Output from the spreadsheet can be used to develop the curves illustrated. These plots assumed a 5,000,000 Btu per hour load at 3 different load factors: 15% representing a typical space heating load, 20% representing greenhouse or multi-building district heating, and 30% representing an industrial process load. The costs of geothermal were compared to natural gas at 75% efficiency and $0.43 per therm.

As illustrated, even for this relatively small load, conditions are favorable (simple payback less the 5 years) for geothermal for all applications up to a well depth of 1500 ft without injection. For higher load factor applications; a well depth of up to 1000 ft with injection provides simple paybacks of less that 5 years.

CONCLUSION

This spreadsheet is intended to be a preliminary tool for evaluating the cost associated with using geothermal heat. It provides the opportunity to quickly identify the cost of geothermally supplied heat in a similar fashion to that used for conventionally fueled heat sources. The availability of these cost figures will allow developers to consider geothermal more realistically at the conceptual stage of a project.

REFERENCES

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