THE FEASIBILITY OF GEOTHERMAL POTENTIAL IN THE RIO GRANDE RIFT AREA OF NEW MEXICO AND TEXAS

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ABSTRACT

This paper will summarize the feasibility findings for the geothermal potential of the Rio Grande Rift in New Mexico and Texas by the Oregon Institute of Technology (OIT) Team at the Geo Heat Center, Klamath Falls, Oregon. The Rincon and Hatch area was selected as having the highest prospects for geothermal development, specifically for cascading geothermal power production and district heating. The following criteria were investigated: estimated reservoir temperature, reservoir volume, flow-rate, drilling feasibility, environmental effects, local infrastructure, social considerations, diversity and efficiency of end use, and maximum potential cost including estimated time of payback.

INTRODUCTION

The Rio Grande Rift is a location of great interest for geothermal utilization. The forces that shaped the region have created a high thermal gradient at relatively shallow depths. The initial site location in northern Doña Ana County, near the towns of Rincon and Hatch presents good thermal gradients resulting in an estimated 250°F (121°C) at 2,000 ft. (610 m) with a potential of flow rates exceeding 1,000 gpm. The water quality found in the Rincon and Hatch region is significantly high in dissolved ions causing a high corrosion factor for piping.

The State of New Mexico currently uses geothermal heat to produce approximately 0.24 MW of electricity with two more projects in the development phase. Future projections for the state estimate a capacity increase of approximately 15 MW with many different incentives supporting these programs. These factors suggest the immediate possibility for the large-scale utilization of geothermal energy in New Mexico, including power generation (Jennejohn, 2011).

The financial assessment holds the most authority over the feasibility of the proposed power plant and direct use applications. The simple payback time of the capital investment is subject to the power plant's output, the cost of electricity sold to the consumers, and revenue generated from direct use applications. The simple payback can also be further reduced through exercising cascading options between the power plant and district heating.

GEOLOGY AND GEOTHERMAL RESOURCE

The Rio Grande Rift (RGR) is a prominent geophysics element dividing the craton of North America and the Basin and Range Province. With a recent history of volcanism (Plocene-Late Pliestocene), a large thermal structure is not a surprise. Gravity surveys suggest that an up warp in the underlying layer of the athenosphere, causing dense igneous intrusions, is present along the length of the Rio Grande Rift (Ramberg, 1978). The underlying crustal thickness at this location is expected to be 6.2-9.3 mi (10-15 km) thinner than the surrounding regions (Cook, 1978).

Geothermal energy use requires the presence of a high geothermal gradient and fluid medium. Near Rincon NM, the shallow temperature gradient of 33.4˚F/100 ft. extended through the Camp Rice Formation. These formations are depicted in Fig. 1. This value is substantially above the RGR average. Near the stratigraphic boundary at 330 ft. (100.6 m), a temperature inversion occurs between 185-162˚F (85-72˚C), likely due to a localized outflow plume. Below this point, a linear gradient of 7˚F/100 ft. extends the length of the test well and is likely to continue through the Thr Formation to a depth approximately 2,500 ft. (762 m) dependent on the inclination of the East Rincon Hills fault.

Rincon is south of the Albuquerque Basin where the rift is divided into a series of smaller north trending grabens (Seager, 1973), one of which is the Rincon Valley with the primary basin deposits being of the mid-to-upper Santa Fe group (Witcher, 2011).

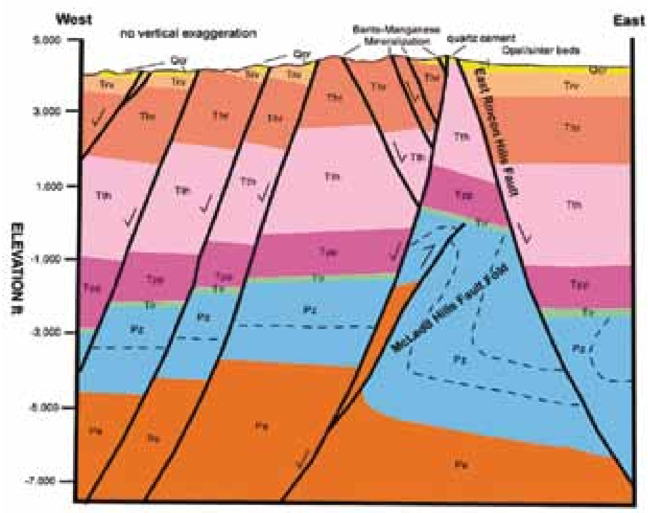

Fig. 1: Estimated Geologic Cross Section of the Rincon Valley, NM (Witcher, 2011).

The hydrothermal chemistry, while not directly sampled during the test well construction, is likely similar to the Radium Springs KGRA given its proximity and similar composition (Witcher, 2011). As such the dissolved chemical content is likely to have excessively high values for chlorine, sodium, calcium, and silicon ions.

SOCIAL AND CULTURAL CONSIDERATIONS

The land around Rincon and Hatch is primarily used for agricultural needs and cattle ranges for dairy purposes. The main exports produced by the agricultural lands are: chili peppers; alfalfa; onions; pecans; and wheat. The local populous is mainly located at the northern part of the city, the farming and dairy lands can be found south of the residential dwellings.

The current unemployment rate in Rincon is 7.2%, which is below the U.S. average of 10.2%; even so, the recent job growth in the area has shrunken by 3.98% (Onboard Informatics, 2009).

Hatch is demographically and economically similar to Rincon, but about six times its size with a population of 1,667 as of July 2009, spread out over a land area of 3.1 square miles. The top industries in Hatch are agriculture, construction and educational services. They have an unemployment level of 8.1%. Furthermore, Hatch has a median household income of $28,864 and an estimated per capita income of $11,376 (Onboard Informatics, 2009).

ENVIRONMENTAL CONSIDERATIONS

The environmental assessment of the geothermal project proposed for the Rincon site is critical to ensuring all local, state, and federal regulations are complied with. These regulations are outlined in the Geothermal Resources Conservation Act (Sections 71-5-1 to 24) of the 1978 New Mexico State Acts (NMSA). As a renewable resource, geothermal energy focuses on generating power and direct-use in a clean, responsible way. All potential hazards and dangers associated with using geothermal energy must be thoroughly inspected and addressed for a successful project. The affected areas in the environmental assessment are: air quality, geology and soils, biological resources, water resources, noise, human health and safety, and social and cultural considerations.

Because the site is located in a desert region, water rights can be difficult to acquire and water usage must be closely monitored. The option of having an air-cooled system to condense the refrigerant is a better option than the water cooled system because of the demand for the scarce resource. The re-injection of the fluid must also be very closely regulated according to all state and federal standards. The permitting for a re-injection well is acquired from the Oil Conservation Division (OCD). The re-injection temperature can be regulated depending on the diversity of the fluid's heat utilization. A re-injection well of geothermal fluid in New Mexico is considered to be a Class V injection well based on 20,6.2 NMAC (New Mexico Administration Code).

OWNERSHIP AND LAND USE

In general, the primary concern when trying to obtain land-use and ownership rights for implementing a geothermal resource is its location. The four primary categories of land ownership for geothermal resources within the United States are federal land, public land, private land, and tribal land. Where the geothermal resources lie determines which set of regulations that must be adhered to, which agencies have jurisdiction, and what permits need to be obtained.

Rincon is mainly under the control of the Bureau of Land Management (BLM), an agency of the U.S. Department of the Interior. Due to the Geothermal Steam Act of 1970, the BLM leases and controls permit applications for any geothermal development on most federal lands, and also private land where mineral rights are held by the Federal Government. All geothermal operations on BLM-managed land must meet environmental, operational standards, prevent unnecessary impacts to surface and subsurface resources, conserve geothermal resources and minimize waste, protect public health, safety and property, and comply with Title 43 of the Code of Federal Regulations (CFR) 3200.4.

Leasing is another very important aspect when considering land use and ownership for developing geothermal resources at any location. Leasing can be both competitive and noncompetitive, each with their own price index and stipulations for leasing regulations. When the BLM issues a lease for geothermal development, it gives the lessee the right to use geothermal resources under the provisions of the Geothermal Steam Act of 1970, Sec. 3 (30 USC 1002). For a competitive lease, property is given to the highest and most qualified bidder; if the land is not sold it can then be obtained as a noncompetitive lease which is available for two years after the original bid (Witherbee, 2011).

If the geothermal plant is to be used as a direct use plant, then, in addition to a geothermal lease, a direct use lease is required. A direct use lease can be obtained through an application process in which a description of the structures (well and pipelines), utilization process, analysis of anticipated production/ injection, and other aspects of the site are included. There is a limit on the amount of land granted for geothermal direct use, which is determined by what the BLM deems necessary within a maximum amount of 5,120 acres (Braff, 2009).

EQUIPMENT AND CAPABILITIES

Drilling varies depending on reservoir depth, hydrology, and geology unique to the location. Only one slim-hole well and several radon gas anomaly and temperature gradient borehole sites have been drilled in the hills to the north of Rincon. Data from these test sites show potential for geothermal development. Currently, no active geothermal operations exist in Rincon and its incorporation into local industry requires further exploration.

For this geologic makeup, the OIT team recommends either dual-wall drilling, or the combination of dual wall and reverse rotary drilling. The additional casing placed during dual-wall drilling may prevent project threatening circulation losses, but will require costly titanium materials for the casing. According to the Geothermal Direct-Use Engineering and Design Guidebook (1998), dual-wall and reverse circulation drilling are suitable for the geophysical characteristics of Rincon. Dual-wall reverse circulation drilling, according to the Layne Christensen Company, addresses the issue of circulation losses, containing highly corrosive water chemistries from potentially contaminating other water tables. The boreholes can be drilled at diameters ranging from 4.5-30 in. in diameter (10-76 cm) which is large enough to accommodate a flow rate between 500 and 1,000 gpm.

Dual-wall reverse circulation drilling values provided at the Geothermal Resource Council's, An Introduction to Geothermal Resource Exploration and Development Conference, estimate production wells between 3,500 ft. and 13,000 ft. to cost between $857/ft. and $537/ft., respectively. The deeper the well is drilled, the less the cost of drilling per foot. By interpolation, a 2,000 ft. (610 m) well will cost approximately $1.8 million ($908/ft.) (Suemnicht, 2011). This cost estimate does not factor in titanium components.

Titanium will have to be used in the casing. Any materials that are not as durable will corrode away, resulting in a loss of flow and exposure to shallow aquifers. Before drilling operations begin, the drilling company will provide quotes and recommendations for materials used and borehole diameters. The desired flow rate for power generation based on predicted reservoir temperatures will be between 500 and 1,000 gpm. Larger well diameters are more expensive than smaller diameters (OSHA, 2009).

Slim-hole SLH1, in the Rincon hills, requires blowout prevention equipment (BPE) consisting of double gate rams, an annular device, and an accumulator shut-in. The accumulator shut-in provides hydraulic pressure to close a blowout prevention valve in an emergency blowout situation. The double gate rams and the annular device both seal the well bore when a blowout does occur (Witcher, 1995).

Potential power generation is shown in Fig. 2. The graph in Fig. 2 was calculated assuming a geothermal water output of 160ºF (71ºC) which is a reasonable estimate and allows for many cascading options (Rafferty, 2000). The pump power requirement, assuming a well depth of 2,000 ft. (610 m), is 617 hp (460 kW). The output temperature can be changed to maximize the options of a cascading system, but will decrease the power output of the power plant. A closed system could be used to supply hot water for direct use.

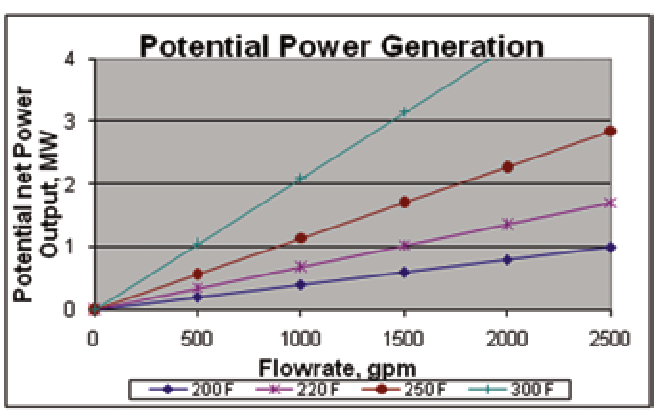

Fig. 2: Net Potential Power Generation (Lund & Boyd, 1999)

The cascading system could be a separate closed system using water, or an open system with water and an injection well in Hatch, at a temperature that can be transported by a less expensive piping system. Due to the pressure that will occur by the drop in elevation from the site to the usable areas, and with the major losses, such as friction and heat loss, insulated steel piping needs to be used because of the pressure required to pump the water back in a closed system.

The distance from the resource to Hatch, where the hot water could be most utilized, is approximately 7.7 mi. (12.4 km) via the most direct road route. The elevation change from the resource to Hatch will result in a 550 ft. (168 m) head difference 238.15 psi (1,642 kPa). The power required to overcome the elevation difference is 69.44 hp (51.8 kW) for 500 gpm (1,893 L/m) and 138.89 hp (103.6 kW) for 1,000 gpm (3,785 L/m). Minor losses were not calculated due to the large variation in how the piping system could be installed and manufactured. The head loss, due to major friction losses, in a pipe that would carry hot water to Hatch is shown in Table 1 below.

Table 1: Pressure Drop to Hatch (Engineering Toolbox, 2011)

Flow gpm)	Diameter (in)	Pressure loss (psi/1000ft.)	Total Pressure (psi)
500	8	1.732	69.28
500	10	0.6495	25.98
750	8	3.897	155.88
750	10	1.299	51.96
1000	8	6.928	277.12
1000	10	2.165	86.6

Fig. 3 shows the heat loss of the piping. The assumed conditions are: 150˚F (71˚C) starting temperature, a ground surface temperature of 25˚F (3.9˚F), pipe depth of 48 in.

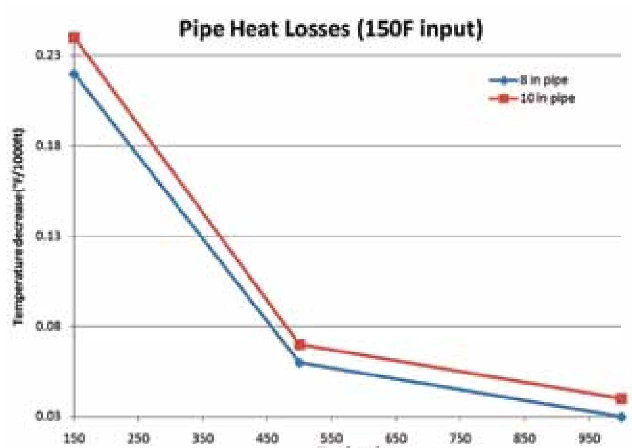

Fig. 3: Heat Loss (Lienau, 2007)

(1.22 m), approximately 3 in. (7.6 cm) of insulation, and 0.2 in. (5.1 mm) of sand around the pipe. The closed system highest temperature can be assumed to be 10˚F less than the input temperature from the hot geothermal side of the heat exchanger (Lund J. W., *Development of Direct-Use Projects*, 2010). Table 2 shows the thermal values assumed (Engineering Toolbox, 2011). Table 3 shows the estimated heat losses in the Rincon and Hatch area assuming an 8 in. pipe with a resource temperature of 150˚F (66˚C).

The heat exchanger characteristics needed for the cascading system to heat the direct use water back to 150˚F (65.6˚C), at the different flow rates can be seen in Table 4 (Rafferty, 1990). The assumed overall heat transfer coefficient was 1000 Btu/(hr∗ft^2∗˚F), the hot side input temperature was 160˚F (71.1˚C), and the hot and cold fluids were assumed to be water (Lund, et al., 1998).

Table 2: Thermal Conductivity Values (Engineering Toolbox, 2011)

Material	Thermal conductivity (Btu/ft.∗h∗˚F)
Steel pipe	24.850
Insulation (Polyurethane foam)	0.012
Jacket (PVC)	0.110
Sand fill	0.670
Soil	0.231

INFRASTRUCTURE

Rincon and Hatch are located near a railway line and an interstate highway (I-25), which could serve as primary methods for transportation of construction and drilling supplies. These infrastructural benefits cut down on overall costs of transportation of any major materials required to be imported or exported. It should be noted that when the geothermal pipeline is installed there is a good chance that it would need to cross over or under I-25.

ECONOMIC AND FINANCIAL CONSIDERATIONS

The cost analysis of the binary power plant assumes a resource temperature of 250^{o}F, and a flow rate of 500 or 1,000 gpm. The cost per kWh is derived from the binary power plant currently in operation on the campus of OIT (Geo-Heat Center, 2010). A 30% increase per kWh for Titanium piping through the power plant was also added to the total cost per kWh yielding $5,107/kWh. The cost for both a 0.5 MW (net) and a 1.0 MW (net) were considered with an estimated parasitic load of 500 kW for both power plant scenarios. Production well pump was also estimated at $300,000 for both power plants. The prices that were used to sell the produced electricity for the cost analysis were $0.05/kWh and $0.07/kWh for each power plant.

Table 3: Heat Losses

	Site B Temperature (˚F) (South of Rincon) 3.4 mi	Site C Temperature (˚F) (intersection of 140 and 185) 4.7 mi	Site D Temperature (˚F) (Hatch) 7.7 mi	Site E Temperature (˚F) (187 river crossing north of Hatch) 10.4 mi	Site F Temperature (˚F) (Salem) 12.8 mi
150 gpm flow	146.19	144.76	141.54	138.71	136.84
500 gpm flow	148.84	148.40	147.40	146.50	145.89
1000 gpm flow	149.42	149.20	148.69	148.24	147.83

Table 4: Heat Exchanger Areas

Hot side flow rate (GPM)	Cold side flow rate (GPM)	Cold side input temperature (˚F)	Heat exchanger surface area (ft^2)
500	150	115	133
500	500	115	880
500	150	105	153
500	500	105	1130
1000	150	115	122
1000	500	115	505
1000	1000	115	1750
1000	150	105	139
1000	500	105	590
1000	1000	105	2250

Table 5: System 1: District Heating for Rincon, 150 gpm

SYSTEM	TOTAL CAPITAL COST	O & M $/YR	PEAK ENERGY (mill. Btu/hr)	ANNUAL ENERGY (bill. Btu/hr)	GROSS GEOTHERMAL INCOME/YR	NET GEOTHERMAL INCOME/YR	SIMPLE PAYBACK YEARS
100% hookup 82 Residential Homes	$2,211,496	$8,990	3.09	8.93	$66,852	$57,862	38.2
100% (no retrofit costs)	$1,990,836	$8,990	3.09	8.93	$66,852	$57,862	34.4
75% hookup 61 Residential Homes	$2,125,374	$6,742	2.32	6.70	$50,139	$43,397	49.0
75% (no retrofit costs)	$1,959,879	$6,742	2.32	6.70	$50,139	$43,397	45.2
50% hookup 41 Residential Homes	$2,039,252	$4,495	1.54	4.47	$33,426	$28,931	70.5
50% (no retrofit costs)	$1,928,922	$4,495	1.54	4.47	$33,426	$28,931	66.7

Table 6: System 2: District Heating for Hatch, 500 gpm

SYSTEM	TOTAL CAPITAL COST	O & M $/YR	PEAK ENERGY (mill. Btu/hr)	ANNUAL ENERGY (bill. Btu/hr)	GROSS GEOTHERMAL INCOME/YR	NET GEOTHERMAL INCOME/YR	SIMPLE PAYBACK YEARS
100% hookup 280 Residential Homes	$5,410,251	$30,847	10.60	30.64	$229,386	$198,539	27.3
100% (no retrofit costs)	$4,653,108	$30,847	10.60	30.64	$229,386	$198,539	23.4
75% hookup 210 Residential Homes	$5,114,744	$23,135	7.95	22.98	$172,039	$148,905	34.3
75% (no retrofit costs)	$4,546,887	$23,135	7.95	22.98	$172,039	$148,905	30.5
50% hookup 140 Residential Homes	$4,819,237	$15,423	5.30	15.32	$114,693	$99,270	48.5
50% (no retrofit costs)	$4,440,666	$15,423	5.30	15.32	$114,693	$99,270	44.7

The 0.5 MW (net) power plant would annually produce 4,161 MWh. Selling this electricity at $0.05/kWh yields a net income of $203,050, giving a simple payback of 35.7 years. Selling the electricity at $0.07/kWh yields a net income of $286,270, giving a simple payback of 25.3 years.

The 1.0 MW (Net) power plant would annually produce 8,322 MWh. Selling this electricity at $0.05/kWh yields a net income of $416,100, giving a simple payback of 23.8 years. Selling the electricity at $0.07/kWh yields a net income of $577,540, giving a simple payback of 17.0 years.

To provide heating for the nearby cities of Rincon and Hatch a geothermal pipeline needs to be constructed. The distance from the power plant site to the city of Rincon is approximately 3.4 mi. and 7.7 mi. to Hatch. The insulated supply pipeline is estimated to cost $63/ft. The un-insulated return pipeline is estimated to cost $41/ft. The total geothermal pipeline cost to Rincon is $1.87 million. The total geothermal pipeline cost to Hatch is $4.2 million.

The cost analysis for district heating was based on the following assumptions: the targeted region was the residential sector with an average size of 1800 ft^2 ;the average residence heat load was estimated to be 37,800 Btu/hr; and the annual heating loading factor used was 0.33 (Lund, 2010).

To accommodate the geothermal heating a building retrofit must be done, as well as a cost for the geothermal distribution pipeline. The building retrofit was estimated to be $2,700/house and a distribution pipeline cost of $1,515/house.

Three cascading district heating systems were considered. Each system assumes an initial district heating temperature of 160˚F, and power plant costs are excluded in the total capital cost for each system. For Rincon the flow rate was set at 150 gpm, yielding a ΔT of 41.19˚F providing equivalent heating for 82 homes (Table 5). The second system is for heating Hatch at 500 gpm, this provides a ΔT of 42.4˚F heating up to 280 homes (Table 6). The third system is for heating Hatch at 1,000 gpm, this system provides ΔT of 43.69˚F heating up to 578 homes (Table 7). Assuming the natural gas costs are $0.94/therm (U.S. Energy Information Administration, 2011), the cost for the district heating would be 80% (Brown, 2007) of the natural gas costs yielding $0.75/therm.

Table 7: System 3: District Heating for Hatch, 1,000 gpm

SYSTEM	TOTAL CAPITAL COST	O & M $/YR	PEAK ENERGY (mill. Btu/hr)	ANNUAL ENERGY (bill. Btu/hr)	GROSS GEOTHERMAL INCOME/YR	NET GEOTHERMAL INCOME/YR	SIMPLE PAYBACK YEARS
100% hookup 578 Residential Homes	$6,664,202	$63,570	21.85	63.15	$472,730	$409,160	16.3
100% (no retrofit costs)	$5,103,845	$63,570	21.85	63.15	$472,730	$409,160	12.5
75% hookup 433 Residential Homes	$6,055,208	$47,678	16.38	47.36	$354,547	$306,870	19.7
75% (no retrofit costs)	$4,884,940	$47,678	16.38	47.36	$354,547	$306,870	15.9
50% hookup 289 Residential Homes	$5,446,213	$31,785	10.92	31.57	$236,365	$204,580	26.6
50% (no retrofit costs)	$4,666,035	$31,785	10.92	31.57	$236,365	$204,580	22.8

Table 8: Cascading Best/Worst Case, Simple Payback.

Scenario	Case	Simple Payback
Scenario 1: District Heating for Rincon, 150 gpm	Best Case:	**18.5 years**
	Worst Case:	**40.0 years**
Scenario 2: District Heating for Hatch, 500 gpm	Best Case:	**18.6 years**
	Worst Case:	**39.9 years**
Scenario 3: District Heating for Hatch, 1,000 gpm	Best Case:	**19.5 years**
	Worst Case:	**31.1 years**

The simple paybacks for the district heating systems are not great. In fact if the district heating costs included the drilling capital costs, they would be considered not feasible. However when the district heating system is based off the exit temperature of the power plant, and the costs for wells, power plant, geothermal pipeline, and district heating are viewed as a complete system, then the system simple payback brings the project feasibility into a new light. This uses the combined revenue of the district heating and power plant to reduce the time needed to pay off the total capital cost of the system. This was viewed in two ways for each scenario, best case and worst case as seen in Table 8. The best case uses the larger power plant (1.0 MW net) selling power at the higher rate ($0.07/kWh) and 100% hookup with no retrofit costs. The worst case uses the smaller power plant (0.5 MW net) selling power at the lower rate ($0.05/kWh), and 50% hookup with retrofit costs.

CONCLUSION

The area of Rincon and Hatch has all the necessities of a comprehensive, all-inclusive, geothermal power system. The resource has an expected temperature of 250˚F (121˚C) at 2,000 ft. (610 m) deep, and could have a flow rate from 500 to 1,000 gpm. Since the proposed site is on BLM land, obtaining rights and permissions to drill and produce should not be difficult. With the main use of the resource being electricity production (from 0.5 MW to 1.0 MW), the resource may also be easily cascaded into direct-use applications. A closed-loop pipeline will transport the heat from the site through Rincon to Hatch distributing the resource to the local communities with little loss of heat and power consumed.

Although the water chemistry of the resource is harmful to traditional equipment used in geothermal production, using titanium piping on site will not only resist the corrosiveness of the ionized and dissolved solids, but also increase the lifetime of the binary power plant. There are no detrimental environmental, social, or cultural issues that could halt progress on the project; the community has a history of accepting geothermal applications and other renewable energies. The implementation of geothermal power into the community will stimulate the economy through employment opportunities, decreased utility costs, and science oriented educational opportunities aimed at teenagers.

Through utilizing cascading geothermal systems the project feasibility becomes quite possible. By using the waste geothermal fluid from the power plant for district heating, the annual revenue can be combined to reduce the long simple payback of the power plant. Between the three proposed scenarios the overall best case is a payback of 18.5 years, with a worst case being 31.1 years.

Along the whole Rio Grande Rift, a production well in Rincon is the best place to implement a complete geothermal system. The site poses little issues to development, the resource has a good temperature and flow and the community will benefit from the project. The Rincon site has the highest possibility of success that stretches further than utilizing a geothermal resource. The project will demonstrate the wide-ranging effectiveness of utilizing a low-temperature resource in small communities and serve as a basis for a community-focused geothermal system internationally.

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