TENRAC/EDF--033

DE83 900692

TORBETT-HUTCHINGS-SMITH MEMORIAL HOSPITAL
GEOHERMAL-SYSTEM DEMONSTRATION
AT MARLIN, TEXAS 34

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FINAL DESIGN REPORT

September 17, 1980

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Prepared for
Texas Energy and Natural Resources Advisory Council
Energy Development Fund
Project # G-3-1

Report # EDF-033

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ATTACHED DOCUMENTS: Draft Bid Package (Plans and Specifications)

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This report outlines the final design and economics of the Torbett-Hutchings-Smith (THS) Memorial Hospital geothermal heating system at Marlin, Texas. It includes a brief description of the existing heating system, an overview of the geothermal retrofit, and the results of an economic analysis. This project is sponsored by the U.S. Department of Energy (DOE) and the Texas Energy and Natural Resources Advisory Council (TENRAC) with cost sharing and in-kind services provided by the THS Memorial Hospital and the City of Marlin.

It is estimated that the geothermal heating system will displace approximately 84 percent of the hospital's average annual natural gas consumption. In summer conditions, approximately 45 gpm of geothermal fluid will be utilized at a wellhead temperature of 139°F. In peak demand winter conditions, approximately 160 gpm will be utilized at a wellhead temperature of 148°F. The geothermal fluid temperature drop across the system will range from about 5°F in summer to over 45°F during winter. Total capital costs for the system are estimated to be \$673,000,* including the production well, a geothermal equipment room, engineering and architectural costs, and all equipment. The average annual natural gas savings are expected to be \$28,200 while average annual operating and maintenance costs are estimated to be \$7,750. A before tax life cycle economic analysis of the THS system shows the break-even period (BEP) of 29 years falling slightly below the 30 year expected life. This BEP is significantly influenced by the developmental nature of this project and by its lack of tax incentives. Such tax incentives are not available in this project because the hospital is a not-for-profit organization and because

* All cost estimates shown in 1980 dollars.

the project is government-sponsored. To compare the BEP of the THS system with that of an identical system sponsored and installed in the business (profit) sector, another economic analysis was performed. The resulting BEP of 21 years suggests that the economic incentives for continued geothermal development do indeed exist.

2.0

OVERVIEW OF EXISTING HEATING SYSTEM

The existing heating system at the THS Memorial Hospital relies primarily on natural gas-fired equipment to meet its heating demands. Low pressure boilers produce steam which is distributed throughout the hospital. The steam is passed through steam-to-water or steam-to-air heat exchangers to meet the particular water or space heating load.

Additional space heating is accomplished with natural gas-fired furnaces in rooftop air handling units and with electric duct heaters. The hospital laundry facility also uses natural gas to fire three tumble dryers.

These systems are presented in the utility profile of Figure 2.1. Those parts addressed by the geothermal system design are shown with heavy lines. Natural gas loads not addressed by the geothermal design include food preparation, humidification, and other incidental loads.

Figure 2.1. Utility Profile for THS Memorial Hospital

2.1

Existing Domestic Water Heating System

Steam produced by the low pressure boilers supplies the heat used for the existing domestic water heating system. As shown in Figure 2.2, two 650 gallon hot water generators operate in parallel to provide low temperature (135°F) hot water for the hospital. Temperature of the hot water generators is controlled by thermostatic steam valves that regulate the flow of steam through tube bundles inserted into the generators. The geothermal heating retrofit addresses this low temperature portion of the existing domestic water heating system.

Figure 2.2. Existing Domestic Water Heating Schematic

The existing system also supplies high temperature domestic hot water (DHW) to the laundry and kitchen facilities. On demand, part of the DHW leaving the hot water generators is boosted to approximately 180°F in steam-to-water heat exchangers (convertors). This temperature boost in the existing system is not addressed by the geothermal design because the geothermal resource temperature is approximately 150°F.

2.2 Existing Secondary Space Heating System

The secondary space heating system receives preheated outdoor air from the primary space heating system and tempers it to maintain individual room or zone comfort. A water/air induction system is used in all patient rooms and also in non-patient areas of the original hospital structure. The water/air induction system is schematically presented in Figure 2.3. A two-pipe circuit and three-pipe circuit supply secondary heating water (SHW) to individual induction units. A valve operated by the room thermostat controls SHW flow through the induction unit. For each SHW circuit, the temperature supplied to the induction units is controlled by a convertor and automatic steam valve. The two-pipe circuit provides heating for the third floor and the three-pipe circuit provides heating for the first and second floors. The geothermal heating retrofit addresses the heating loads in both of these SHW circuits.

2.3 Existing Primary Space Heating System

The primary space heating system heats or preheats the large volumes of outdoor air (OA) required for proper hospital ventilation. Much of this primary air is then fed to individual induction units in the secondary space heating system where it is tempered to maintain room or zone comfort. Ten air handling units (AHU) in the hospital define this primary space heating system.

Although some of these AHU's may be more accurately described as "secondary heating" or "building heating: units, they are categorized as primary heating units in this design in order to maintain congruency with the retrofit geothermal heating design.

A. TYPICAL SECONDARY HEATING WATER SYSTEM OPERATION

B. TYPICAL INDUCTION UNIT

Figure 2.3. Existing Secondary Space Heating Schematic.

Table 2-1 summarizes the primary space heating system. As seen in that table, AHU's 1 through 5 condition 100 percent OA

while AHU's 6 through 10 condition either return air (RA) or a RA/OA mixture. AHU's 1 through 6 and AHU 8 use steam coils controlled by modulating steam valves to regulate heating. AHU 7 uses electric duct heaters controlled by zone thermostats. AHU 10 uses a thermostatically-controlled natural gas-fired furnace. AHU 9 uses both a gas-fired furnace and electric duct heaters. The geothermal heating system alternate addresses the primary air heating loads in all ten AHU's.

TABLE 2-1. SUMMARY OF PRIMARY AIR HEATING SYSTEM

AHU	Location	Percent OA	Heating Mechanism	Area Served	Secondary Heating Method
1	Boiler room roof	100	Steam Coil	First Floor (Surgery)	Room Steam Coils
2	Penthouse ME Room	100	Steam Coil	First and Second Floors	3-Pipe SHW Circuit (Induction Units)
3	Penthouse ME Room	100	Steam Coil	First and Second Floors	3-Pipe SHW Circuit (Induction Units)
4	Central Supply Room	100	Steam Coil	First Floor (Kitchen)	None
5	Penthouse ME Room	100	Steam Coil	Third Floor (Patient Rooms)	2-Pipe SHW Circuit (Induction Units)
6	Penthouse ME Room	10	Steam Coil	Third Floor (Nurses Stations, Hallways)	None
7	First Floor Roof	0	Electric Duct Heaters	First Floor (Administrative Offices, Laboratories)	None
8	First Floor ME Room	0	Steam Coil	First Floor (Kitchen)	None
9	First Floor Roof	0	Natural Gas Furnace	First Floor (Radiology, Corridors)	Electric Duct Heaters
10	Third Floor Roof	0	Natural Gas Furnace	Third Floor (Corridor)	None

2.4 Locations of Existing Components

Figure 2.4 illustrates the locations of existing heating system components. The boilers and hot water generators are in

the boiler room. The secondary heating water convertors and AHU's 2, 3, 5, and 6 are in the penthouse mechanical equipment (ME) room. The remaining AHU's are located at various parts of the hospital.

Figure 2.4. Locations of Existing Heating Components

3.0 DESCRIPTION OF GEOTHERMAL HEATING SYSTEM RETROFIT

The geothermal system design is comprised of a base system plus an alternate. The base system supplements the existing domestic water heating and secondary space heating loads. Included in the domestic water heating retrofit is an air-preheat provision for the laundry's three tumble dryers. As in the preliminary design, the alternate system supplements the existing primary space heating loads. This alternate enables the geothermal system to extract the greatest heat energy from the geothermal fluid without increasing the geothermal fluid production rate. The base/alternate format is used to distinguish that the primary space heating loads were not addressed in the original conceptual work.

As shown in Figure 3.1, the geothermal heating design consists of a production system, a domestic water heating system, two secondary heating water (SHW) systems, and the primary heating water (PHW) alternate. An overview description of each of these systems is provided in this section. Additional detail is provided in the draft plans and specifications which are included as separate documents.

3.1 Geothermal Production System

Figure 3.2 shows the components of the production system. The submersible production pump and its controls were originally unanticipated because the resource history suggested that the new well would produce up to 200 gpm artesian flow at up to 40 psig shut-in pressure at the wellhead. The completed well produces approximately 60 gpm artesian flow at only 7 psig shut-in pressure. A production pump is therefore needed. The pump will be set at a depth of approximately 200 feet. Its speed will be

Figure 3.1. Geothermal Heating System Overview

Figure 3.2. Production System Schematic

controlled by a variable frequency drive (VFD) which is automatically set by temperature controls. The automatic controls may be manually bypassed during pump testing or during periods of VFD maintenance.

The VFD enables the production rate to exactly match the heating demand. This control feature is provided without an economic penalty because the VFD is expected to pay for itself through savings in pump operating costs. The VFD should also extend pump life since it eliminates the need for cycling. A side benefit is that VFD conserves the geothermal resource since the geothermal fluid is not produced at peak rates continuously.

The submersible pump/VFD combination will produce a peak flow rate of 160 gpm to provide approximately 82 percent of the average peak wintertime heating loads. The geothermal fluid temperature drop will exceed 45°F under these peak conditions. Moderate weather conditions will produce a flow rate of approximately 100 gpm with a 30°F to 35°F temperature drop. Summer conditions will produce a flow rate of approximately 45 gpm with a 5°F to 10°F temperature drop.

3.2 Domestic Water Heating Retrofit

The domestic water heating retrofit is presented in Figure 3.3. The operation of the hot water generators (HWG) will be changed from parallel operation to series operation so that HWG-1 may be used as a geothermal storage tank. A thermostatically controlled pump will cycle to maintain the HWG-1 at its desired temperature. A conductance probe in the heat exchanger exit stream will continuously monitor DHW conductance to detect the unlikely event of a geothermal fluid leak into the DHW. If an intrusion were to occur, two automatic valves would bypass flow around the heat exchanger and an alarm would alert

Figure 3.3 Schematic of Domestic Water Heating Retrofit.

the operators of the condition. This monitoring will be used to prevent a violation of secondary drinking water standards. (those related to aesthetic qualities of the water). Such a violation would occur at approximately 7.2 percent leakage.* The monitor will permit detection of a 5 percent leakage. The health-and-safety-related primary drinking water standards would not be violated until a 98 percent leakage occurred. The monitoring will therefore also guard against violation of the primary standards.

* Mixture of geothermal fluid and DHW containing 7.2% geothermal fluid.

The tumble dryer air preheat will use a hot water coil installed in each of the three dryer air intakes to preheat air entering the dryers. A manually controlled pump will be operated by laundry personnel to activate the air preheat when the dryers are being used.

3.3 Secondary Heating Water Retrofit

The secondary heating water (SHW) retrofit is presented in Figure 3.4. This system supplements the secondary space heating loads. The two pipe and three pipe heating circuits are addressed separately because they operate at different temperatures. In each circuit, all or part of the SHW return (SHWR) will be intercepted upstream of the convertor and routed to a plate heat exchanger in the geothermal equipment room. Automatic modulating valves will control the amount of SHW passed through the heat exchangers in order to achieve the desired temperature entering the convertors. When needed, convertors will further boost the SHW temperature using their existing steam valves and controls. Freeze protection will be provided for all exterior piping.

3.4 Primary Heating Water Retrofit (Alternate)

The primary heating water (PHW) retrofit is presented in Figure 3.5. This system supplements the primary space heating loads described in Section 2.3. This alternate was added to the conceptual design during the preliminary design phase because it provides a low temperature sink for extracting the greatest heat energy from the geothermal fluid. This additional extraction occurs without increasing the geothermal fluid production rate.

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Figure 3.4. Schematic of Secondary Heating Water (Secondary Space Heating) Retrofit

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Figure 3.5. Schematic of Primary Heating Water (Primary Space Heating) Retrofit

The PHW retrofit will use two pumps in parallel to circulate PHW from a plate heat exchanger through AHU's 2, 3, 5, and 6. A third pump will extract some of the PHW leaving AHU's 2, 3, 5, and 6 to circulate PHW through AHU's 1, 4, and 8. Similarly, a fourth pump will circulate PHW through AHU 7, 9, and 10. Each pump is thermostatically controlled to operate according to the desired sequence. The overall pumping scheme is a primary/secondary system in which the parallel primary pumps also supply a zone (AHU's 2, 3, 5, and 6).

For each of the ten air handling units in the primary space heating system, a PHW coil will be installed ahead of the existing heating component. In AHU's 1 through 6 and AHU 8, this heating component is a steam coil. For AHU 7, the component is a series of electric duct heaters. In AHU 10 the existing heating component is a natural gas-fired furnace. AHU 9 uses both a natural gas furnace and electric duct heaters. The PHW flow through each coil will be controlled with automatic valves. These valves will be modulating in AHU's 1 through 6 and AHU-8 and will be two-position in AHU's 7, 9, and 10.

3.5 Locations of Geothermal Components

The piping layouts and equipment locations for the geothermal heating retrofit are shown in Figure 3.6. The new geothermal equipment room will house the manual and automatic production pump controls. It will also house the plate heat exchangers that will provide heat for each of the retrofit heating systems. These equipment locations and piping routes produce an easily installed energy distribution system. This provision insures that hospital operations will not be adversely impacted during system installation.

Figure 3.6 Locations of Geothermal Components

3.6 Geothermal Fluid Disposal

On March 17, 1980, the Texas Railroad Commission approved a request for the surface disposal of the geothermal fluid into the Brazos River via the City of Marlin storm sewer, City Park Lake, Bean Branch, and McCollough Slough. In June, 1980, a New Source Environmental Questionnaire was submitted to the Environmental Protection Agency (Region VI) in Dallas to determine if the geothermal fluid disposal would cause the hospital to be classified as a "new source". Such a classification would require the hospital to provide additional environmental impact data. Preliminary determinations indicate that the hospital will not be considered a "new source". Official determination is expected in the near future.

In early August, the DOE Assistant Secretary for Environment issued the final Environmental Assessment for the project along with a Finding of No Significant Impact (FNSI). In early September, an application was submitted to EPA Region VI for a National Pollutant Discharge Elimination System Permit for the discharge of the geothermal fluid. Action on this application is expected to take several months.

3.7 Construction Schedule

The schedule for the retrofit of the heating system is illustrated in Figure 3.7. Construction is planned to begin in January, 1981 and to continue through September. This schedule should leave adequate time for the testing of the system prior to the 1981/1982 heating season.

T-H-S MEMORIAL HOSPITAL GEOTHERMAL PROJECT

Figure 3.7 Project Schedule

4.0 SYSTEM ECONOMICS

This section presents the results of two economic analyses. One analysis describes the economics of the THS Memorial Hospital system. Another describes the economics of the THS system if it were to be constructed in the business (profit) sector. This second analysis was performed because the not-for-profit status of the hospital combined with DOE and TENRAC sponsorship eliminated many of the tax benefits that would occur in the business sector. It was felt that this second analysis was vital to provide a true picture of the economics that could be expected with future geothermal development in the business sector.

It is important to realize that the economics of a geothermal heating system can be biased to produce very attractive (or unattractive) results. For example, even small variations on the order of 2 percent in interest rate assumptions (discount rates, escalation factors, etc.) can significantly impact the outcome of the analysis. Tax credits and depreciation techniques can have a similar impact, as can the type of analysis itself. It is therefore imperative that any comparisons of two or more systems or alternatives be made using similar analysis techniques with similar interest rates and tax incentives.

4.1 THS Memorial Hospital System Economics

A before tax break-even analysis was performed for the THS geothermal heating system. The before tax approach was used because the hospital is a not-for-profit organization and because the project is sponsored by DOE and TENRAC. Although an economic analysis can be performed in a variety of ways, a break-even analysis was chosen because it is an excellent method for representing life cycle economics. This method is better than simple payback analysis because the simple payback does not account for

the time value of money. The break-even analysis uses capital costs, annual operating and maintenance costs, and annual savings to determine the number of years required for the total savings to equal the total costs.

4.1.1 Capital Costs

Capital costs for the THS Memorial Hospital geothermal heating system are summarized in Table 4-1. Three components that were not originally anticipated for the system appear in the summary. These include the production pump and its controls, the geothermal equipment room, and the primary heating water system.

4.1.2 Annual Savings, Operating and Maintenance Costs, and Payout

Table 4-2 summarizes the annual savings, the capital costs, the expected annual operating and maintenance costs, and the estimated break-even period (BEP). All cost values are shown in 1980 dollars.

The estimated annual savings of \$28,200 for 9400 MCF of natural gas is substantial. This savings was determined using a computer model developed to simulate the operation of the geothermal heating retrofit with the existing heating system. The savings represents approximately 84 percent of the average annual natural gas consumption.

The operating costs, which stem from the geothermal system's parasitic power consumption, were also determined using computer simulation. The resulting total parasitic power consumption of 60,000 KWH is approximately 3 percent of the

TABLE 4-1. CAPITAL COSTS SUMMARY: THS SYSTEM¹

I. BASE SYSTEM			
A. GEOTHERMAL FLUID PRODUCTION SYSTEM			
1.	Well drilling and completion	\$221,300	
2.	Geothermal equipment room ²	35,000	
3.	Production pump and controls ³	35,200	
4.	Piping, valves, insulation, instrumentation, etc. ⁴	19,600	
5.	Subtotal		\$311,100
B. DOMESTIC WATER HEATING/DRYER AIR PREHEAT SYSTEM			
1.	Heat exchanger, preheat coils	7,800	
2.	Piping, valves, insulation	16,200	
3.	Pumps, controls, instrumentation, etc.	14,200	
4.	Subtotal		38,200
C. SECONDARY HEATING WATER SYSTEMS			
1.	Heat exchangers	11,400	
2.	Piping, valves, insulation, freeze protection	55,600	
3.	Pump modifications, controls, instrumentation, etc.	12,100	
4.	Subtotal		79,100
D. ENGINEERING AND ARCHITECTURAL			
			82,600
E. DISCHARGE/ENVIRONMENTAL PERMITTING			
			16,500
F. TOTAL BASE SYSTEM COSTS			
			\$527,500
II. ALTERNATE SYSTEM²			
A. PRIMARY HEATING WATER SYSTEM			
1.	Heat exchanger, heating coils	21,200	
2.	Piping, valves, insulation	58,600	
3.	Pumps, controls, instrumentation, etc.	31,400	
4.	Subtotal		111,200
B. ENGINEERING			
			34,300
C. TOTAL ALTERNATE SYSTEM CAPITAL			
			145,500
III. TOTAL BASE PLUS ALTERNATE CAPITAL			
			\$673,000
<ol style="list-style-type: none"> Costs shown include labor and materials. Project costs not associated with system design and installation excluded. Cost figures associated with system equipment/installation estimated at <u>+15%</u> accuracy. All values in 1980 dollars. This component not originally anticipated. These components not originally anticipated due to resource history. Includes allowance for storm drain extension to be provided by city. 			

hospital's average annual electricity consumption. The annual maintenance costs include provisions for both labor and materials. Capital costs were extracted from Table 4-1.

TABLE 4-2. COSTS VS. SAVINGS SUMMARY: THS SYSTEM¹

Cost or Savings	Base System	Alternate System	Base Plus Alternate System
Capital Costs (\$) ²	527,500	145,500	673,000
Annual Operating Costs (\$/KWH) ³	1,600[52000]	250[8000]	1,850[60000]
Annual Maintenance Costs (\$)	3,100	2,800	5,900
Annual Nat'l Gas Savings (\$/MCF) ⁴	20,700[6900]	7,500[2500]	28,200[9400]
Simple Payback ⁵	25	19	24
Break-even period ⁷ (yrs)	31 ⁶	28	29

¹Values shown in 1980 dollars

²Extracted from Table 4-1

³Based on \$0.031/KWH

⁴Based on \$3.00/MCF

⁵Capital costs divided by annual natural gas savings

⁶Based on before tax break-even analysis

⁷Assumptions: Discount rate on capital investment = 8 yr avg inflation rate = 6%

Operating costs (electricity) escalate at 7% per year

Maintenance costs escalate at 8% per year

Annual savings (natural gas) increase at 10% per year

⁸Exceeds estimated system life of 30 years

Table 4-2 shows the difference in results between the simple payback analysis that does not account for the time value of money and the break-even analysis that does. Accounting for the time value of money adds approximately 20 percent to the expected system payout. Interest rates for the break-even analysis were determined using input from the Statistical Abstract of the United States and from the utilities that serve the hospital. Although other rates could have been used that would artificially improve the economic picture of the THS system, the ones selected are felt to be most responsible for this economic projection. The resulting break-even period (BEP) falls slightly below the expected system life. For

reasons described below, however, this result should not be generalized to infer that all projects of this nature that use this geothermal resource will have extended BEP's.

An important factor that influences the BEP of the THS system is the developmental nature of the project. Resource evaluation, materials engineering, and environmental "ground-breaking" added substantially to the system's capital costs. Based on information learned in these areas during this project, an estimated \$52,000 could be trimmed from the design and engineering costs of a future similar system. Indeed, one of DOE's and TENRAC's purposes in funding such technical demonstration projects is to firmly establish alternate energy technologies by bearing the costs associated with developing and demonstrating those technologies.

The less than maximum use of the production well also contributes to the extended BEP for this system. Because the well is a large fixed cost item, using it to its full capacity is desirable. This reasoning was one of the driving forces behind the primary heating water addition. If this well supplied other heating loads, it could readily produce up to 400 gpm instead of the 160 gpm required for this system. The annual savings could then be increased by 250 percent while the system capital costs would increase only 70 percent.

The final factor contributing to the extended BEP is that the results represent a before tax analysis. This approach was used because DOE and TENRAC are providing the major portion of project funding. If the project occurred in the business (profit) sector, a substantial tax credit could be taken to reduce the effective capital costs. Equipment depreciation could also reduce the effective operating and maintenance costs. As illustrated in the following sections, these cost reductions would greatly improve

the economics of a similar system.

4.2 Business Sector System Economics

To illustrate that an improved economic picture results if the THS system were to be installed in the business sector, an economic analysis was performed for that case. Except as noted in this section, all cost values and analysis procedures are identical to those used in the THS system analysis.

4.2.1 Capital Costs

Capital costs for the business sector system are summarized in Table 4-3. With the exception of the engineering and architectural costs, these figures are the same as for the THS system. The engineering and architectural costs are reduced by the \$52,000 estimated to be attributable to the technology development which occurred during the THS project.

4.2.2 Annual Savings, Operating and Maintenance Costs, and Payout

Table 4-4 summarizes the break-even analysis performed for the business sector system. The annual operating and maintenance costs and natural gas savings are the same as those estimated for the THS system. The capital costs from Table 4-3 were reduced by the allowable tax credit to determine the effective capital costs. The discount rate for this effective capital was increased from the 6 percent used for the THS system to 8 percent. This adjustment was made to account for the incentive or cushion that a corporation must have to make long term investments. The well and geothermal equipment room were depreciated

TABLE 4-3. CAPITAL COST SUMMARY: PRIVATE SECTOR SYSTEM¹

I. BASE SYSTEM			
A. GEOTHERMAL FLUID PRODUCTION SYSTEM			
1. Well drilling and completion	\$221,300		
2. Geothermal equipment room ²	35,000		
3. Production pump and controls ³	35,200		
4. Piping, valves, insulation, instrumentation, etc. ⁴	19,600		
5. Subtotal		\$311,100	
B. DOMESTIC WATER HEATING/DRYER AIR PREHEAT SYSTEM			
1. Heat exchanger, preheat coils	7,800		
2. Piping, valves, insulation	16,200		
3. Pumps, controls, instrumentation, etc.	14,200		
4. Subtotal		38,200	
C. SECONDARY HEATING WATER SYSTEMS			
1. Heat exchangers	11,400		
2. Piping, valves, insulation, freeze protection	55,600		
3. Pump modifications, controls, instrumentation, etc.	12,100		
4. Subtotal		79,100	
D. ENGINEERING AND ARCHITECTURAL⁵		64,300	
E. TOTAL BASE SYSTEM COSTS			\$492,700
II. ALTERNATE SYSTEM⁴			
A. PRIMARY HEATING WATER SYSTEM			
1. Heat exchanger, heating coils	21,200		
2. Piping, valves, insulation	58,600		
3. Pumps, controls, instrumentation, etc.	31,400		
4. Subtotal		111,200	
B. ENGINEERING⁵		16,700	
C. TOTAL ALTERNATE SYSTEM CAPITAL			127,900
III. TOTAL BASE PLUS ALTERNATE CAPITAL			\$620,600

1. Costs shown include labor and materials. Project costs not associated with system design and installation excluded. Cost figures associated with system equipment/installation estimated at $\pm 15\%$ accuracy. All values in 1980 dollars.
2. This component not originally anticipated.
3. These components not originally anticipated due to resource history.
4. Includes allowance for storm drain extension to be provided by city.
5. Based on 15% of equipment, installation, and construction total.

over 20 years. Remaining costs were depreciated over 10 years. All equipment was assumed to have a 10 percent salvage value.

The effect of considering the time value of money is again very evident in the results, with the BEP again exceeding the simple payback by approximately 20 percent. The 21 year BEP for the business sector system is shown to fall well below the expected system life of 30 years. Thus, if tax incentives and technology developments are utilized, the economic payout for the business sector system is reduced by almost 30 percent compared to that for the THS system. This result may well provide an added incentive for continued geothermal development.

TABLE 4.4. COST VS. SAVINGS SUMMARY: PRIVATE SECTOR SYSTEM¹

COST OR SAVINGS	BASE SYSTEM	ALTERNATE SYSTEM	BASE PLUS ALTERNATE SYSTEM
Capital Costs ² (\$)	492,700	127,900	620,600
Less Tax Credit ³ (\$)	-123,200	- 32,000	-155,200
Effective Capital Investment (\$)	369,500	95,900	465,400
Annual Operating Costs ⁴ (\$/KWH)	1600 [52,000]	250 [8,000]	1850 [60,000]
Annual Maintenance Costs (\$)	3100	2800	5900
Annual Depreciation Savings ⁵ (\$)	16,800 ⁶	5,900 ⁷	22,700
Annual Nat'l Gas Savings ⁸ (\$/MCF)	20,700 [6900]	7,500 [2500]	28,200 [9400]
Simple Payback ⁹ (Yrs)	19	16	17
Break Even Period ¹⁰	23	17	21

¹ Costs shown in 1980 dollars

² Extracted from Table 4-3

³ 10% Investment Credit plus 15% Energy Credit

⁴ Based on \$0.031/KWH

⁵ Based on 10% salvage value for equipment, 0% salvage value for engineering and installation

⁶ Equipment room and well depreciated over 20 years (\$900/yr); remaining capital depreciated over 10 years (10,900/yr)

⁷ Capital depreciated over 10 years

⁸ Based on \$3.00/MCF

⁹ Effective capital investment divided by annual nat'l gas savings

¹⁰ Assumptions: Long term corporate discount rate = 8%
Operating costs (electricity) escalate at 7% per year
Maintenance costs escalate at 8% per year
Natural gas savings increase at 10% per year