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# THE ECONOMICS OF MULTI-PURPOSE GEOTHERMAL HEAT UTILIZATION WITHIN THE CITY OF EL CENTRO

Peter B. Sherwood
Roger N. Yamasaki

WESTEC Services, Inc.
San Diego, California

## ABSTRACT

The engineering and economic feasibility of utilizing geothermal heat from the Heber KGRA for space heating/cooling and water heating for domestic and industrial process applications within the City of El Centro was investigated. The analysis proceeds through a survey of present conventional energy utilization within the City. This evaluation was performed to generate technical data for input into a modified Battelle Pacific Northwest Laboratories "GEOCITY" computer program to model the economics of large-scale district heating and cooling systems within the City of El Centro. A cost-effect.ive plan for large-scale utilization of geothermal energy in El Centro for district heating/cooling and industrial applications was developed from this evaluation.

## BACKGROUND

The City of El Centro, California, is located in the heart of the vast Imperial Valley agriculture zone. The City is a major gathering point for agricultural products raised in the Valley and has become an important processing, packing and shipping center, as well as a servicing and supply town for agricultural crops valued at over one half billion dollars per year.

WESTEC Services, Inc. teamed with the City of El Centro to conduct a DOE sponsored study of the engineering, economic, environmental, and institutional factors associated with the non-electric utilization of the Heber KGRA hydrothermal resources beneath the City.

An energy utilization survey of present conventional energy consumption levels within the City of El Centro was completed. Documented sales records from the utility companies serving the El Centro area were used as the primary source of information. Consumption estimates were then broken down into specific end uses. Potential geothermal energy applications were identified from these end uses.

The energy utilization survey indicated that electricity and natural gas are the major sources of energy for the City of El Centro. Consumption of these two sources by the residential and the commercial sectors is tabulated in Table 1. The survey has also revealed that there are no industrial-level users of electricity and only one industrial natural gas user with a potential for geothermal applications within the City limits. Therefore, a breakdown of end uses for an industrial sector is excluded from this survey.

Table 1

ENERGY CONSUMPTION FOR THE CITY OF EL CENTRO BY SECTOR

| | Electricity | | Natural Gas | |
|---|---|---|---|---|
| | (KWH/yr) | (BTU/yr) | (Cu.Ft./yr) | (Btu/yr) |
| Residential | 104,279,960 | $3.56 \times 10^{11}$ | 233,521,500 | $2.34 \times 10^{11}$ |
| Commercial | 75,364,079 | $2.57 \times 10^{11}$ | 135,962,700 | $1.36 \times 10^{11}$ |
| TOTAL: | 179,644,039 | $6.13 \times 10^{11}$ | 369,484,200 | $3.70 \times 10^{11}$ |

Total = $9.6 \times 10^{11}$ BTU/yr

Table 2 lists the total energy consumption for the City by end use. Air conditioning, space heating, water heating, and commercial refrigeration along with industrial process heat appear to have the greatest potential for geothermal applications. These end uses make up over 75 percent of the total energy consumed in the residential and commercial sectors of the City.

## 1.0 GENERAL ENGINEERING EVALUATION

### 1.1 INTRODUCTION

A preliminary evaluation of the practical methods of geothermal heat extraction, and delivery to the consumer was made. This was done to determine the technical feasibility of utilizing indigenous geothermal energy to replace conventional forms of energy.

Table 2

TOTAL ENERGY CONSUMPTION BY END USE FOR CITY OF EL CENTRO

| | % | BTU/yr |
|---|---|---|
| Air Conditioning | 37 | $3.6 \times 10^{11}$ |
| Water Heating | 16 | $1.6 \times 10^{11}$ |
| Space Heating | 19 | $1.9 \times 10^{11}$ |
| Commercial Refrigeration | 5 | 0.5 x 1011 |
| Residential Refrigeration | 6 | $0.6 \times 10^{11}$ |
| Cooking | 10 | $1.0 \times 10^{11}$ |
| Residential Clothes Drying | 2 | $0.2 \times 10^{11}$ |
| Other | 5 | $0.4 \times 10^{11}$ |
| TOTAL: | 100 | $9.8 \times 10^{11}$ |

## 1.2 WEATHER ANALYSIS

The temperature in El Centro ranges from a maximum of 120F to a minimum of 25F. The average mean dry-bulb temperature is 74F. El Centro has 1,216 heating degree days and 3,794 cooling degree days, based on the traditional 65F base temperature. Naval weather data shows the hottest month in El Centro to be July with an average temperature of 93F. The coldest month is January with an average temperature of 55F.

With knowledge of the available weather data, it appears that El Centro would benefit more from the conversion of geothermal energy to space cooling than heating . Therefore, efforts were made to develop concepts for district cooling systems using geothermal energy as well as utilizing existing concepts for district heating systems.

## 1.3 GEOTHERMAL HEAT EXTRACTION

The Heber KGRA is the energy source for this study. The City of El Centro is 4-1/2 miles north of the center of the KGRA and in an area where well temperature gradients should be 2 to 4F per 100 feet in depth.

The southeast section of the City, which is presently zoned for industrial use, has been identified as a likely site for geothermal production drilling. The prevailing geothermal heat gradient in the drilling area is expected to be in the range of 2.0-3.3F per 100 feet of depth. The high gradients (>3.0) were only observed at shallow depths of less than 1000 feet, while lower gradients (around 2.0) prevail at depth. Therefore, it is highly probable to find 250F brine at about 8500 feet and it is moderately probable to find that temperature at about 6500 feet.

# 2.0 GENERAL ECONOMIC EVALUATION

## 2.1 INTRODUCTION

To evaluate the economic feasibility of substituting geothermal energy for all residential/commercial space heating/cooling and domestic hot water for the entire City of El Centro, a comparison was made between the costs of providing geothermal district heating/cooling systems and conventional energy sources. Capital cost estimates for centralized hot water and chilled water distribution systems were made, using the modified "GEOCITY" program. The financing scenario was based on resource exploration and development by a municipally owned district heating and cooling utility. Capital cost estimates for home retrofit and chiller plant costs were made using information available in the open literature. Geothermal energy charges were computed using a base price factored by the appropriate thermal conversion efficiency and utilization factor.

## 2.2 PRELIMINARY ECONOMIC FEASIBILITY

From a base case computer model, various parameters were modified to test their economic sensitivity. Some of these modifications are explained further in this section. It was felt that the sensitivity of parameter modifications could best be analyzed by dividing the geothermal system into the heating system and the cooling system and observing each as a separate entity with the thought that later they would be combined into one district heating and cooling system.

### 2.2.1 Preinsulated Piping

Preinsulated pipe offers a vast savings over conventional carbon steel pipe. Because the pipe--insulation-casing combination is prefabricated at the factory, a savings of approximately 35 percent was realized on the cost per linear foot of pipe in capital cost savings.

### 2.2.2 Reduced Load Demand

Analysis was made to reduce the distribution system costs by reducing the total load demand on the geothermal system. It was felt that at some load less than 100 percent of the annual load the geothermal system would be at an optimum economic point.

The cost per million BTUs of delivered geothermal heat/cold drops when the geothermal load is reduced from 100 percent to 91 percent of the total load. Below 91 percent load, the cost steadily rises. At this point, as the load is decreased, both the capital costs for the distribution system and the amount of annual delivered BTUs drop as expected, however, the amount of delivered BTUs drops faster than the capital costs resulting in an increase in the cost of annual delivered BTU's. Therefore, at approximately 91 percent of the total load (for both heating and cooling), optimum use of the distribution system is obtained.

### 2.2.3 Conclusion

The result of the sensitivity analysis was that the hot water distribution system costs for residential/ commercial space and domestic hot water heating were reduced from $13.36 per million BTUs to $7.00 per million BTUs of building heat load, and the chilled water distribution costs for residential/ commercial space cooling were reduced from $10.32 per million BTUs to $5.40 per million BTUs. These costs do not include energy supply costs (cost of reservoir exploration and operation), distribution system operating costs, nor insurance costs and capital replacement costs. These factors will be addressed in the following section.

## 2.3 FINAL ECONOMIC FEASIBILITY

### 2.3.1 Central Plant Concept

Section 2.2 described various methods of reducing the cost of the distribution system per delivered BTU for the district heating and cooling cases. These costs were reduced drastically but do not include all of the costs involved in the system. By adding in the additional costs, mentioned in Section 2.2.3, the total delivered costs for the district heating system and for the district cooling system now become $9.91/10^6 BTU and $14.06/10^6 BTU, respectively.

Combining the district heating system and the district cooling system into a single two--pipe system to supply chilled water in summer and hot water in winter, and adding in the costs for building interface equipment retrofit and the costs of absorption refrigeration equipment, results in an overall cost of $13.79/10^6 BTU. The total capital cost for a city--wide central plant system would be in the order of 90 million dollars, including 15 million for residential and commercial retrofit.

Additional methods of reducing the overall geothermal system life cycle costs are investigated in the following sections.

### 2.3.2 Modular Concept

This concept entails the decentralization of the chiller facilities into modular units serving at least one hundred buildings per module. This concept results in the large scale distribution of hot water to the modular units and the subsequent distribution of either chilled or hot water to the area served by each module. This concept eliminates large scale chilled water distribution from one central chiller plant. The advantage of this system is that the higher allowable delta-T for the hot water results in cost savings based on the reduced size of the pipe mains. Computer analysis has shown that pipe costs can be reduced by as much as 20 percent by use of the modular concept. The drawback to this system is the fact that the economic advantages of a central plant are lost due to the increased number of cooling towers, auxiliary pumps! etc. The total capital cost for a city-wide modular system would be in the order of 70 million dollars, including 15 million for residential and commercial retrofit. The application of the modular system concept to the district heating and cooling system for the entire City results in an overall cost of $10.04/10^6 BTU.

### 2.3.3 High Energy Density Concept

Areas within El Centro were searched for high energy demand density. A more concentrated load will increase' the delivered BTUs per area and correspondingly reduce the relative size and cost of the distribution system.

El Centro is basically a suburban community. The highest energy density is in the commercial area. A high density computer model was established with the districts chosen for their energy density characteristics. These districts cover about half the area of the City. The modular high energy density case resulted in a total capital cost of 27 million dollars. This cost includes approximately 5 million dollars for residential and commercial retrofit. Applying the modular system techniques to this high energy density model reduced the cost of district heating and cooling to $9.79/10^6 BTU.

### 2.3.4 Industrial Park Concept

Industrial use of geothermal heat on a constant, year around, high volume basis can bring about economic benefits to the overall geothermal system. By methods of energy cascading, more heat can be extracted from the production wells already established by the residential/commercial district heating and cooling energy base thereby reducing the cost per delivered BTU.

A wide range of prices for geothermal energy can be obtained based upon varying-industrial usage and increased utilization efficiency. For example, when the annual energy consumption typical of a dehydration plant (sized to handle alfalfa drying and onion dehydrating for a typical annual crop yield in the Imperial County) is included with the high density system, the overall utilization efficiency can be increased from 20 percent to approximately 27 percent. With the greater use of the existing brine wells, the cost of delivered heat can be reduced from $\$9.79/10^6$ BTU to $\$6.74/10^6$ BTU.

2.3.5 Acceptable Costs for Geothermal Systems

There are many factors involved in defining an acceptable cost for geogeothermal energy, a cost which the consumer will regard as a "money-saving" investment. The influence of items such as government tax incentives, property tax, and insurance will alter the acceptability of geothermal energy to the consumer. Merely matching the life cycle cost of a geothermal system with a comparable conventional system will not create an incentive to convert to the geothermal system. Therefore an analysis was made comparing the cash flow of a conventional energy space conditioning and water heating system with the cashflow of a geothermal system with supplemental conventional fuel equipment. It was felt that consumers would be willing to install a geothermal system in a business or home if the real after tax return on their investment was in the vicinity of 4 percent for a commercial business and 2 percent for a residential home, in constant dollars. Therefore the incremental cash flows for typical commercial and residential geothermal/conventional systems over straight conventional systems, i.e., the difference in energy costs, operations and maintenance costs, income taxes, etc. were calculated. Through a trial and error calculation, levelized annual energy savings required of the geothermal/conventional system were determined in order to affect the specified rate of return for the residential and commercial consumers.

For the geothermal equipment, annual operations and maintenance costs were estimated to be about 2 percent of the capital cost of the equipment. Payment of the new equipment was assumed to be through 90 percent financing on a three year loan at a 12 percent interest rate on the unpaid balance. The income tax rate was taken to be 25 percent for the residential consume-r and 40 percent for the corporate consumer. Government tax incentives were included in the analysis based on the National Energy Act of 1978.

Minimum annual levelized energy cost savings were calculated to be $11.25 for the residential case and $147.50 for the commercial case in real 1977 dollars. In order to realize these savings, the annual levelized costs for delivered geothermal energy only must be no more than $\$5.86/10^6$ BTU for combined residential and commercial applications. This cost reflects the most a consumer would be expected to pay a utility for geothermal energy charges in order to obtain the minimum rate of return desirable for his investment.

In order to compare this cost with previous analyses, we must now add in the same retrofit changes assessed in those earlier calculations. The comparable composite residential/commercial acceptable cost for the High Energy Density Modular Case would be $\$8.80/10^6$ BTU. This figure represents the maximum acceptable cost and can now be directly compared with the costs calculated previously for delivered geothermal combined heating and cooling.

A comparison of these figures reveals that, because of the low utilization efficiency of 20 percent, the use of geothermal energy exclusively for large scale district heating and cooling will not be economically feasible, based on the many assumptions made in this analysis. However, increasing the overall utilization efficiency a few percent (to approximately 22 percent) will result in an acceptable price for geothermal energy making large scale district heating and cooling economically viable. The increased utilization efficiency could result from energy cascading to an industrial park with process heat requirements in a compatible temperature range.