MASTER

EVALUATION OF GEOTHERMAL ENERGY IN ARIZONA

Arizona Geothermal Commercialization Team

Quarterly Topical Progress Report,
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Introduction

Dwindling oil supplies, dependence on foreign oil and steadily rising energy prices have encouraged a more intensive review of alternative energy resources. Geothermal energy reserves are abundant in the western U.S. and may be able to supplement this country's energy supply. Consequently, planning efforts have been directed toward estimating the potential of geothermal energy utilization in Arizona, and for providing information necessary for its prospective commercialization.

The Department of Energy (DOE) through its San Francisco Operations Office has delegated responsibilities for the industrialization of geothermal energy in Arizona to the Arizona Solar Energy Commission (ASEC) via a cooperative agreement. The ASEC assumed authority for monitoring the progress of the project through its director James Warnock and its associate director Dr. Frank Mancini. The ASEC in turn subcontracted the commercialization and planning activities to the University of Arizona.

The Arizona Geothermal Commercialization Team consists of three key personnel, one support person, and additional temporary personnel. Key personnel are: (1) Frank Mancini, Ph.D., Project Administration; (2) Don H. White, Ph.D., Team Leader; and (3) Larry Goldstone, Project Manager. The support person is Lani Malysa, Group Leader. Their tasks are listed in the organization chart of the Arizona Geothermal Commercialization Team (Figure 1-1).

Efforts during the first years of the Geothermal Team were characterized as planning. Planning activities included the identification and delineation of geothermal prospects, the comparison of conventional energy use patterns with geothermal sources, the preparation of area development plans and the compilation of detailed economic and energy data for each area.

During 1980 and continuing on through 1981, the Geothermal Team changed their emphasis from planning to commercialization. During 1981 the main emphasis for this project is to produce plans and provide information for geothermal energy commercialization. The technical approach for achieving this goal is to characterize geothermal resources and possible users. A program of direct interaction with business and community leaders has been undertaken. Several approaches have been taken, including the publication of a monthly newsletter, to increase awareness of geothermal resources and uses and to open channels for further communication.

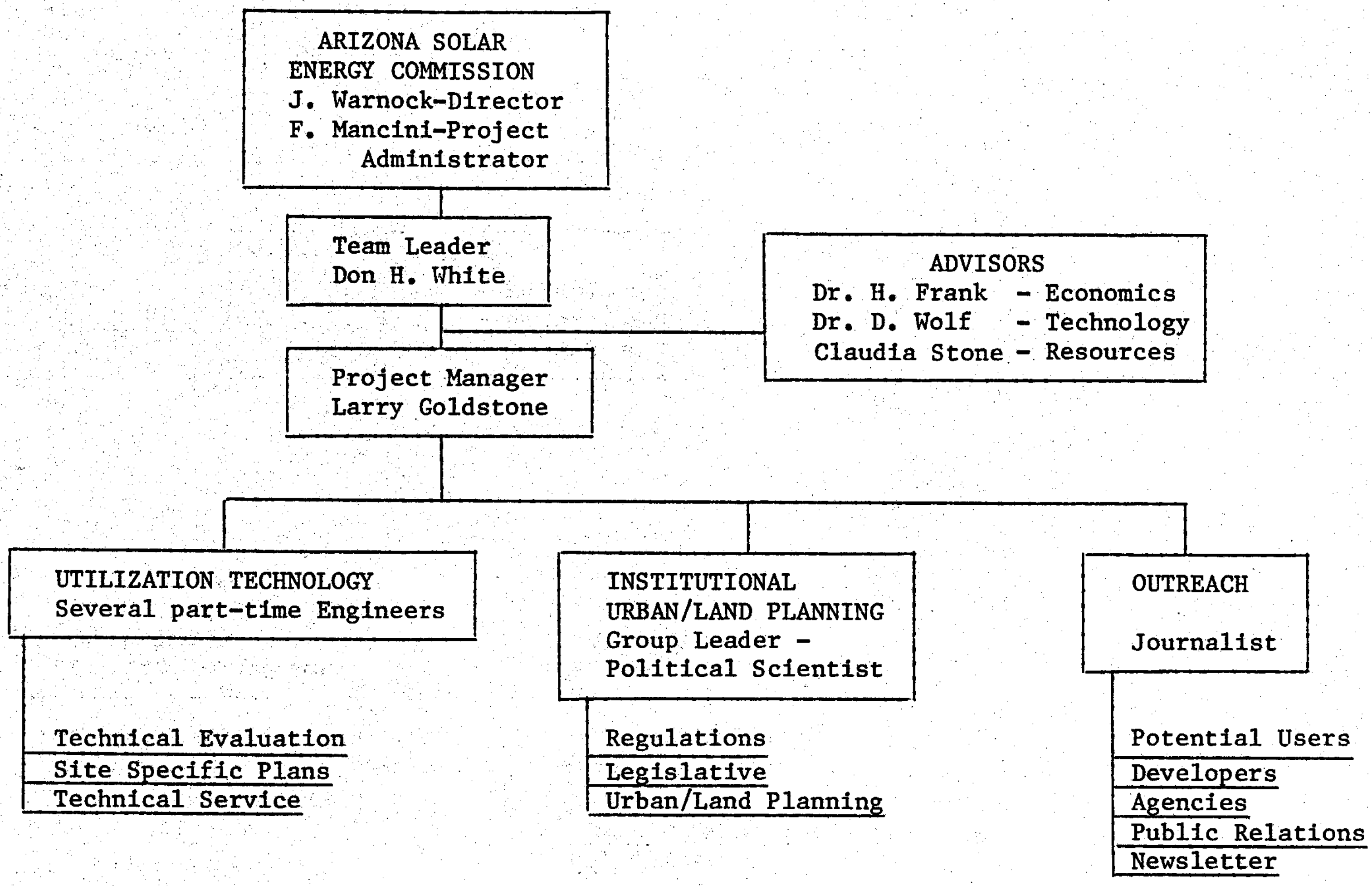

Figure 1-1: Organizational Chart
Arizona Geothermal Commercialization Team

2.0 Tasks and Objectives

The overall objectives of the Arizona Geothermal Commercialization Team have been to produce geothermal development plans to be used by the private sector and to provide a source of information for interested parties in the state. These objectives have been met through a balanced planning, commercialization, and outreach program. Each task has played a significant role in providing assistance to potential geothermal developers. Examples of tasks performed in the past include the following:

1) The formulation of Area Development Plans involved the compilation and analysis of detailed energy and economic data for seven areas in the state. The result of these studies are a determination of potential market penetration of geothermal energy in each of the areas investigated. Also, potential developers were identified from the residential, commercial, industrial and agricultural sectors.

2) The evaluation of geothermal applications (formerly referred to as Site Specific Development Analyses) involved preliminary engineering and economic analyses for selected applications for geothermal energy in Arizona. Particular emphasis was placed on space cooling and heating, geothermal power plants, direct thermal use for food and industrial processing, geothermal energy utilization in cattle feedlots, and satellite urban development.

3) The evaluation of geothermal resources provided information of Arizona geothermal resource locations and characteristics.

4) In certain instances, more complete engineering and economic analyses were performed and technical assistance provided. The most important instances were on geothermal energy utilization for gasohol production and

geothermal energy for space heating/cooling for John F. Long, a Phoenix developer.

5) Growth pattern impacts were studied to provide a better understanding of the role of geothermal energy in a fast-growing state such as Arizona.

6) An outreach program for the purpose of providing information has been conducted over the past two years.

Tasks for 1981 consist of six specific contractual tasks plus the completion of three tasks that were started during CY 1980. In addition to these tasks, the Arizona Geothermal Commercialization Team plans to make modifications in order to broaden the scope of work for CY 1981. Due to some positive results and findings during CY 1980, four additional tasks are being added for CY 1981. The six main contractual tasks for 1981 are as follows:

Task 1. Integrated Alcohol/Feedlot/Geothermal Operation

The Contractor shall evaluate the integration of alcohol production by fermentation with a cattle feedlot, utilizing geothermal energy as much as it is practical. Specific locations will be considered where agricultural crops and cattle feedlots overlap high potential geothermal energy resources, especially (a) in the Safford/Willcox area and (b) in the Casa Grande/Chandler area, to the south of Phoenix. The drilling of at least one exploratory geothermal well in these areas will be encouraged.

Task 2. Geothermal Energy in Mining Industry

The Contractor shall work with a subcontractor knowledgeable of and serving the mining industry of Arizona, to utilize low- and medium-temperature geothermal energy in such applications as copper dump leaching, solvent extraction plants of bulk leaching, flotation plants and in-situ mining of copper, uranium and other metals. Special attention will be paid to the Clifton/Morenci area and to interactions with Phelps Dodge of that area, where extensive copper operations and potential geothermal resources overlap. The drilling of at least one exploratory well in this area will be encouraged and assisted from resource and use standpoints.

Task 3. <u>Geothermal Space Cooling/Heating</u>

The Contractor shall continue the evaluation of using geothermal energy for absorption cooling and heat pumps in order to back out electricity during the heavy summer peak load of May-September, and will attempt to interest certain major corporations and/or subdivision developers to participate in one or more exploratory wells in both the Phoenix and Tucson areas.

Task 4. <u>Identification of Suitable Industry for a Remote Geothermal Resource</u>

The Contractor shall evaluate and make preliminary technical and economic studies of the feasibility of attracting a new industry to the remote San Bernardino Valley of Southeast Arizona, which is believed to have one of the best geothermal resources in the state.

Task 5. <u>Food Processing/Irrigation Pumping/Biosalinity Agriculture/Geothermal</u>

The Contractor shall study the feasibility of utilizing geothermal energy in agricultural areas, especially the Yuma and Hyder Valley areas, where some of the higher food and food processing crops, fruits and vegetables could be expanded. Certain practices of the Imperial and San Joaquin Valleys of California will be considered for adaption to Arizona soils and climate to mutually assist in the development of these two agricultural areas which appear to have geothermal resources.

Task 6. Coal-Fired Geothermal-Assisted Power Plant

The Contractor shall assist Arizona Public Service and other utility companies of Arizona in making engineering and economic studies on the possible benefits of utilizing geothermal energy (a) to reduce the quantity of coal that must be slurried and pumped to the plant site and (b) to reduce the total water requirements of the power plant.

During 1980 a supplemental proposal with three tasks was funded by DOE. Work on the three tasks was started immediately and some of the findings included in 1980 reports. These three tasks will be completed during 1981 and include the following:

Task 1. District Cooling/Heating of a Satellite Community

The Contractor shall investigate the feasibility of a district absorption cooling and space heating system in a satellite community or new growth area with geothermal potential. Cooling and heating loads and equipment necessary to meet these needs will be defined. Important community factors will also be defined. A cost study, possibly with the assistance of New Mexico Energy Institute (NMEI), will be done. The resulting product will be an informational packet detailing cost-effectiveness, feasibility, energy saved, and financial incentives.

Task 2. Space Cooling/Heating of a Large Industrial or Commercial Facility

The Contractor shall interact with owners of large industrial and commercial facilities in Phoenix and Tucson in order to define a system using geothermal energy to meet their cooling and heating loads. Of particular interest are large facilities in the electronics, computer, and solid state industry. A cost study, possibly with the assistance of NMEI, will be done. The resulting product will be an informational packet detailing cost-effectiveness, feasibility, and energy saved.

Task 3. Alcohol Production for Gasohol

The Contractor shall interact with persons interested in the production of alcohol to provide technical assistance in evaluating the use of geothermal energy as a major energy source in the distillation process. Energy balance and cost studies shall be performed for a specific site in Arizona. The final product shall be a package of information on the legal, institutional, financial, and engineering aspects of gasohol production using geothermal energy.

As previously mentioned, the Arizona Geothermal Team plans to modify their scope of work for 1981 by adding an additional four tasks. These tasks are seen as a natural ongoing progression of work performed during 1980 but more specific in nature. The four additional tasks are detailed in Figure 2-1 and include the following: (1) Legislative and Institutional Program; (2) Cities Program; (3) Geothermal Applications Utilization Technology Program; and (4) an Outreach Program.

2.1 Legislative and Institutional Program

During the past two years, the Arizona Geothermal Commercialization Team has completed an in-depth study of state and local rules and regulations relating to geothermal development in Arizona. It is clearly evident that some of these rules and regulations on the state level will act to deter geothermal development. Examples of these include how the royalty rate is calculated for leased state land, unitization, lack of tax incentives for geothermal development, lack of municipality bonding authority, lack of state funding and most important, the conflict between groundwater

- **LEGISLATIVE and INSTITUTIONAL**
  - Participation in Senate Subcommittee
  - Coordinate with NCSL
  - Suggest legislative changes
  - Funding programs
- **CITIES PROGRAM**
  - NMEI (cash)
  - M. Pasqualetti work w/Scottsdale and Chandler
  - HUD Grants
  - Organize local expertise
    - Community education
- **UTILIZATION TECHNOLOGY**
  - NMEI (7 site specifics)
  - Technical Assistance
    - Cottonseed oil
    - Ready-Mix Concrete
    - Soft Drinks
    - Animal Feeds
  - Existing Technology
    - Greenhouses
    - Aquaculture
    - Alcohol/Feedlot
    - Space Heating
  - Technological Research
    - Mining Applications
    - Space Cooling
    - Geothermal Power Plant
    - Industries for San Bernardino Valley
    - Food Processing/Irrigation Pumping/Biosalinity Agriculture
- **OUTREACH**
  - Newsletter Publication
  - Information Dissemination
  - Energy Fairs

Figure 2-1: Arizona Geothermal Program for 1981 laws and geothermal development laws.

Inasmuch as the Geothermal Commercialization Team will not exist next year, it is imperative that the Arizona State Legislature be made aware of these barriers in legislation. Therefore, work for CY 1981 will consist of participating with the newly established ad hoc Senate Subcommittee on Geothermal Energy. The Arizona Geothermal Team in conjunction with the National Conference of State Legislatures will suggest legislative changes and possible types of funding programs (similar to other western states) to help pave the way for geothermal development in Arizona.

2.2 Cities Program

During 1980, the Arizona Geothermal Team supported Dr. Mike Pasqualetti of Arizona State University and his work in collecting data on how geothermal energy might be utilized in certain areas of Arizona. According to Dr. Pasqualetti, it would be counterproductive and unnecessary to allow land use to add to the burden faced by developers of geothermal energy. The aim should be at removing as many land use barriers as possible. Early land use planning can be a relatively inexpensive step, especially when compared to the benefits. As his methodology, Dr. Pasqualetti used Scottsdale as a model city type in order to determine the land use factors involved in geothermal development.

During 1981, the Arizona Geothermal Team will continue to support Dr. Pasqualetti's work on land use planning. In addition, the Geothermal Team will work to organize local geothermal expertise in other towns such as Safford, Chandler, Willcox, Clifton, Papago Farms and others by providing cost data (in conjunction with NMEI), preliminary feasibility studies, assistance in writing proposals, and planning assistance.

2.3 Geothermal Applications Utilization Technology

During 1980, a study on Arizona's industries and the potential of incorporating geothermal energy was undertaken. This was the beginning of our understanding of industry in Arizona.

During 1981, further research will be done on the cottonseed oil, ready-mix concrete, soft drink, and animal feeds industries in order to better understand how geothermal energy can be utilized for their industrial processes. Technical assistance services such as institutional and regulatory, resource, engineering, and economic expertise will be provided in order to help industry realize their geothermal potential and help them in utilizing the resource.

In addition, the geothermal team will take known technologies such as greenhousing, aquaculture, alcohol production and space heating and assist persons in better understanding how geothermal energy could be utilized. For those technologies that are not yet fully understood (mining applications, space cooling, geothermal power plants, food processing, etc.), additional planning and research on how to integrate geothermal will be done.

2.4 Outreach

During 1980, the Geothermal Team began publishing a monthly newsletter on relevant geothermal topics. With a mailing list now over 500 persons, it has proved to be a most effective means of outreach.

During 1981, the Arizona Geothermal Team will continue to publish the monthly newsletter The Geothermal Resource. In addition, the Team will continue other effective outreach activities including information dissemination and exhibiting the geothermal display at energy fairs.

3.0 Work Completed

The following work was completed under each task during the second quarter of 1981.

3.1 Hiring

During the second quarter, three new student personnel were hired for the Geothermal Team. They include a chemical engineering student, a mechanical engineering student, and a journalism student. The engineering students will continue work on the specific geothermal applications while the journalism student will edit the monthly newsletter and all technical and informational reports.

3.2 Institutional and Legislative Program

The Arizona Geothermal Commercialization Team presented a paper for the National Energy Plan III held in San Francisco on April 13, 1981. The paper addressed barriers to further geothermal development and contained policy alternatives for the federal government. Tax incentives for space cooling with geothermal energy were stressed.

During the second quarter, the Arizona Geothermal Team also completed an addendum to the currently published Arizona Geothermal Institutional Handbook. The purpose of the Institutional Handbook, published in May 1980, is to assist interested persons in understanding the various institutional procedures and requirements necessary for the development of geothermal energy in Arizona. It details the key federal, state, and local agencies, and rules, regulations, and permits applicable to geothermal development. The addendum to the handbook details all the regulatory changes that have occurred since the handbook was published.

A review of the federal and state geothermal energy tax incentives was completed during the second quarter. Hypothetical economic feasibility problems are currently being worked on in order to see if these tax incentives make geothermal exploration an attractive investment. The tax incentives for geothermal exploration and development include the following:

Benefits for geothermal development begin with the exploration phase. Unlike oil and gas development, all expenses incurred during geothermal exploration and drilling may be deducted.

Development costs may be deducted during the first year of the project. Allowable deductions include all intangible costs for drilling, such as labor, supplies, fuel, and repairs.

In addition, geothermal deposits qualify for a percentage depletion allowance, as much as 27.5 percent at the state level and 20 percent at the federal level. However, the allowable federal percentage decreases by two percent a year through 1983, and thereafter becomes 15 percent.

Beyond such favorable treatment for geothermal exploration and drilling, investment tax credits and business energy credits may be claimed for investment property that has a useful life longer than three years.

A 10 percent investment tax credit applies to all capitalized items associated with a geothermal operation, and a business energy credit of 15 percent is available through 1985 for all equipment used in the production, distribution, and use of a geothermal resource.

There are several qualifications for obtaining business energy credits: (1) geothermal fluid temperatures must be at least $50^{\circ}C$ ($122^{\circ}F$); (2) equipment used in exploration and development cannot be claimed; and (3) equipment that uses both geothermal energy and energy derived from other sources do not apply, such as certain heating and cooling equipment.

Lastly, limits also apply when taking both credits. And if credits exceed the limit for one year they can be carried back three years or forward up to seven years.

Also completed during the second quarter was a land and permit acquisition survey. The methodology of the survey was to contact private sector businesses that have expressed interest in leasing land in Arizona or obtaining permits to drill geothermal wells. The Geothermal Team was interested in finding out why Arizona lags behind other western states in leasing of state land and drilling for geothermal development and whether there were any administrative or bureaucratic problems involved in obtaining the leases and drilling permits. Those businesses surveyed included Duval, Tenneco, Anshutz, Phillips, Geothermal Kinetics Systems, Union Oil, Southland Royalty, and Chevron. The results were that there generally did not seem to be any administrative or bureaucratic hold-ups to the leasing and well permitting stages. Instead, these particular businesses simply did not feel that the geothermal resources in Arizona were as attractive as other western states. It was suggested to the Arizona Geothermal Team that they continue to develop information to induce industry to look at geothermal resources on state land and that geothermal outreach go beyond the boundaries of Arizona.

The Arizona Geothermal Commercialization Team's efforts to work with the Arizona State Legislature on new geothermal legislation have been stagnant this quarter. The 1981 legislative session adjourned in April without taking any action on newly proposed legislation. In addition, Sherri Valentine has resigned her position with the National Conference of State Legislatures (NCSL). She was in the process of drawing up geothermal legislative options for the Legislature. Jerry Sherk has taken over her position and is currently familiarizing himself with the specifics of Arizona geothermal law. Efforts will be made to meet further with the Senate Subcommittee on Geothermal Energy during the legislative interim.

Lastly, the Arizona Geothermal Commercialization Team received the Arizona Department of Health Services draft regulations on the new Underground Injection Control Program. The draft regulations will be studied and comments will be made to the Department.

3.3 Maryvale Terrace

During the second quarter of 1981, work was completed and reviewed on a report detailing a district heating/cooling system for a new growth area with geothermal potential. The John F. Long Realty Company of Phoenix, Arizona, supplied information regarding Maryvale Terrace, a development in west Phoenix which began construction in the fall of 1980. In the report, cooling and heating loads and equipment necessary to meet the demands were defined. Also defined were important community factors involved in such a system.

Results of the Maryvale Terrace study looked pessimistic because of the following:

1. low energy use density made distribution costly;
2. too many production wells were required;
3. too many reinjection wells were required; and
4. the depth to resource made drilling costs prohibitively expensive.

It must be noted, however, that the system was not optimized. If the system in the study had been optimized, the results may have been more optimistic. An economic analysis will be done on the Maryvale Terrace during the third quarter.

3.4 Mining Applications

Work continued during the second quarter on the mining applications. The Geothermal Team is developing some new concepts to integrate geothermal energy in the copper dump leaching process, the in-situ mining process, and the flotation process of copper recovery. The results of the mining applications study will be reported in the third quarterly report.

3.5 District Heating/Cooling

Clifton

A meeting between the Arizona Geothermal Team and the Clifton City Manager was held during the second quarter of 1981. The meeting, to discuss geothermal district heating of Clifton, was held because every indication is that the city is colocated with a good geothermal resource (an existing well in downtown Clifton has been confirmed at $50^{o}C$ ($122^{o}F$) at a depth of 25 m (80 ft)).

In preparation for the meeting, a study of the environmental regulations and permits relevant to such a project and a study of the land ownership of Clifton and surrounding areas was completed. Results of the land ownership study indicated that there is primarily private land owned by Phelps Dodge Corporation surrounding Clifton, but a large portion of it has federally held mineral rights. There are also portions of state land and federal land surrounding Clifton. The environmental study for a district heating system in Clifton detailed the major federal regulations involved, those being the Prevention of Significant Deterioration Program and the Underground Injection Control Program. Arizona environmental regulations regarding reinjection, well drilling, noise abatement, water quality, disposal of brines, solid wastes and hazardous wastes were also detailed.

There appeared to be no additional environmental regulations at the Greenlee County level.

During the meeting, it was found that Clifton has some major problems and other priorities that would act to impede the development of a district heating system. These include the following:

1. confusion over who owns what land and mineral rights;
2. concerns of too many EPA regulations and requirements;
3. concerns of too much federal intervention;
4. new road being built by Phelps Dodge that would cut off one half of the city;
5. no city money;
6. no bonding authority;
7. existing natural gas service from an investor-owned utility; and
8. location in a flood zone. Clifton has experienced seven floods in the past ten years.

Efforts will be made to keep in touch with Clifton in case any of the above situations change, thus making for a more positive environment for geothermal development.

3.6 Irrigation Pumping

Since 1972, the Sperry Research Center has been actively engaged in the development of a down-hole pumping system for liquid-dominated geothermal resources. During the second quarter, work began on studying and summarizing the Sperry information in order to determine the applicability of a modified down-hole pumping system for irrigation pumping in Arizona. The design for the Sperry pump relies on bottom hole temperatures of at least 121°C (250°F). In the study, the Geothermal Team is trying to determine what would happen to the efficiency of the pump if lower temperatures were used. To date, work has involved further meetings with Sperry in order to obtain additional information necessary to complete the study. Results will be reported at the end of the third quarter.

3.7 District Heating - Safford Downtown District

With the assistance of the New Mexico Energy Institute (NMEI), a preliminary feasibility study was performed for a downtown commercial heating district for Safford, Arizona. The intention of the study was to approximate capital and operating costs for the construction and operation of such a system. It should be noted that the following summary represents a rough design using estimates for annual energy use.

The Safford downtown commercial district consists of approximately 167 commercial buildings in an area one-half mile long by one-quarter mile wide. The estimated natural gas demand for heating and hot water for the buildings is 62,425 x 10^6 Btu/yr. By correcting for efficiency losses in natural gas use, the actual heating and hot water demand is 43.7 x 10^9 Btu/yr. Peak demand for all the buildings, based on the relationship of average annual demand divided by average peak demand, is 38.5 x 10^6 Btu/hr. The average user peak demand is 230,550 Btu/hr. In meeting the heating and hot water demand with a 30°F temperature drop, 2,565 gallons per minute (gpm) of 60°C (140°F) geothermal water is required.

In order to meet the heating and hot water demand, three production wells will be needed, each flowing at 1,000 gpm. Each well will be drilled to approximately 3,500 feet and is to be sited in the downtown area. In addition to three production wells, one injection well would be drilled to a depth of 2,000 feet.

In addition to production and injection wells, 2.5 miles of distribution pipe and .25 miles of transmission pipe will be needed. Also, the design incorporates three well pumps, heat exchanger, controls, circulation pump and retrofit and hookup equipment. Table 3-1 presents a cost summary of equipment required for the system.

Table 3-1: COST SUMMARY - SAFFORD HEATING DISTRICT

Wells	$1,170,000
Heat Exchanger	120,000
Piping	694,000
Well Pumps	160,000
Controls	20,000
Circulation Pump	1,109,715
	$3,286,000

In addition to capital costs necessary to install the system, operating costs were also estimated for maintenance and electricity consumption. Operating costs for electricity to power the system were estimated to be $83,960 per year based on 6.5¢ per kilowatt hour of electricity. Also, maintenance costs were estimated to be $32,860 per year or one percent of capital costs. Table 3-2 summarizes operating and maintenance costs.

Table 3-2: OPERATING AND MAINTENANCE COSTS - SAFFORD HEATING DISTRICT	
Well pumps (1360 hp)	1015 kw
Circulating pump (165 hp)	123 kw
Total	1138 kw
Hours of operation (per year)	1135
Annual electric cost ($.065/kwh)	$83,956
Maintenance costs (per year)	$32,860
Conventional fuel cost (1979)	$249,600

The following assumptions were used in order to analyze the economics of a district heating system. It was assumed that the project life was 20 years, the cost of money was two percent above inflation, electricity prices would increase at three percent per year above inflation, and natural gas prices would increase at five percent per year above inflation. Table 3-3 presents a summary of economic results using the net present value investment technique.

Table 3-3: ECONOMIC ANALYSIS -SAFFORD DISTRICT HEATING PROJECT

	Nominal	Present Value
Capital Cost	$3,286,000	$3,286,000
Annual Operating Cost (20 years)	83,960	1,845,192
Annual Maintenance Cost (20 years)	32,860	548,054
TOTAL		$5,679,246
Annual Conventional Fuel Cost (20 years)	249,600	6,666,859
Net Present Value		$ 987,613
Percentage of Savings		15%

Although the district heating system economic analysis shows a positive savings over 20 years, the commercial energy users will still pay 85 percent of the conventional fuel cost. It is concluded that a 15 percent savings over 20 years would not justify the capital expense required for this project.

3.8 Geothermal Greenhouse Heating/Biosalinity Agriculture - Environmental Research Laboratory, University of Arizona

Proposed work under this task will involve the cooperation of the Arizona Geothermal Commercialization Team, the Arizona Resource Assessment Team, the Office of Arid Land Studies, and the Environmental Research Laboratory, all affiliated with the University of Arizona. The overall task encompases three distinct phases, with the final goal being a cascaded utilization of low-temperature geothermal energy for greenhouse heating and a source of saline water for growing salt-water crops and algae.

The first phase of the project involves the utilization of geothermal waters as a medium for growing halophytes and algae. The Office of Arid Land Studies and the Environmental Research Laboratory have been experimenting with alternative forms of agriculture and are now recognized leaders in the field. Because water is scarce in Arizona, new crops will be needed to replace current water-intensive agriculture within the state. Experimentation with growing crops and algae in salt water has proved to be one possible future solution to the irrigation and groundwater situation in Arizona. With the assistance of a $5,000 grant from the Arizona Solar Energy Commission, work has been initiated to determine if geothermal waters in Arizona would be suitable for irrigation of new strains of crops. In addition, deleterious minerals present in the geothermal waters collected from around the state and resource areas suitable for irrigation will be identified. The final results will demonstrate whether geothermal waters represent a new groundwater source for irrigation.

The second phase of the project involves the design and analysis of using low-temperature geothermal waters for space heating for seven acres of greenhouse at the University of Arizona. During the past five years, fuel costs for heating the greenhouses have averaged about $120,000 per year. In addition, wells drilled within five miles of the greenhouse site have recorded temperatures of 50°C (122°F) or better at 762 m (2500 ft). The Commercialization Team will evaluate the feasibility of this low-temperature application.

The third phase of the project involves a resource assessment of the area by the Resource Assessment Team. The Tucson Basin is a planned study area for CY 1981. Special attention will be paid to the greenhouse site and suggestions will be made for additional resource assessment based on the local geology.

By year-end a package containing information on local geothermal resource characteristics, engineering and economic feasibility and suitability of using spent geothermal water for experimental agriculture will be combined. The package will then be presented to the University of Arizona for funding. It is anticipated that the final product will demonstrate economic feasibility, will reduce disposal costs, and will turn otherwise wasted geothermal water into a productive asset. Additional details and background as well as progress reports will be presented at the end of the third quarter.

3.9 New Mexico Energy Institute Results

Contract work with New Mexico Energy Institute has been completed and analyzed. Cost runs for all Arizona cities colocated with geothermal resources were received and reported on in the first quarterly report of 1981. Results indicate that 13 cities, including four communities near Phoenix (Goodyear, Chandler, Mesa, Avondale), appear to have economically useable resources suitable for immediate development.

In addition to these general results, six potential resource areas were chosen for further study and analysis. The areas include Goodyear/Avondale, Litchfield Park, Alpine, Springerville and Clifton. Each of these areas is believed to contain low-temperature resources useful for space heating but not cooling. In several instances, existing wells in the areas are currently available for use. The following summarizes the results for each area.

Goodyear/Avondale

Goodyear and Avondale are two communities located 16 miles west of Phoenix. The two cities, located beside each other, have combined populations of approximately 11,000 people. Both communities grew at a compound annual rate of approximately 2.5 percent per year through the 1970s. However, future growth projections suggest that the communities will grow at annual rates of 10-20 percent through the year 2000. Clearly, both areas exhibit high growth potential for the future.

New growth in Goodyear and Avondale over the next twenty years will present many situations for geothermal development. Geothermal development will be most economic for new growth situations rather than for retrofit situations. In addition, the existence of low-temperature geothermal resources is quite evident in the area. To date, over 30 existing wells in the area exhibit either temperatures greater than 50°C (122°F) or have calculated temperature gradients greater than 50°C/km (3.7°F/100 ft). Three of these wells have discharge temperatures of 50°C (122°F) with flow rates greater than 2270 l/min (600 gpm) at depths less than 500 m (1640 ft).

The analysis which follows assumes that a private developer would be able to get the rights to one of the wells currently flowing at 50°C (122°F). The developer would then construct a new commercial facility, possibly a shopping plaza or a mall, at the well site. The developer would use the existing geothermal well to provide heat and hot water for the shopping center. Heat demand for the building was calculated based on a new building heating load of 33.3 Btu/hr/ft^2.

For purposes of this analysis, two building sizes were chosen in order to measure the affect of size on the economics of such a project. It was assumed that one building would be 55,000 ft^2 and the second building would be 280,000 ft^2. The peak heat demand for the smaller facility would be 1,830,000 Btu/hr and 9,250,000 Btu/hr for the larger facility. As will become clear, size is a critical factor in making a geothermal heating project economic.

For the two different sized facilities, all other assumptions necessary for the analysis were held constant. Those necessary assumptions are summarized in Table 3-4.

Using the outlined assumptions in the table (plus others), a life cycle cost for the geothermal energy was calculated and compared to the price of natural gas. For the smaller facility, the price of geothermal energy per million Btu was found to be $4.94, which given an increasing price for

Table 3-4: Assumptions for Geothermal Heating for Commercial Buildings

Variable	Assumed Value
Resource Temperature	50°C (122°F)
Depth	457 m (1500 ft)
Well Status	existing
Flow Rate	2271 l/min (600 gpm)
Industrial Heat Demand	0
Bond Rate (above inflation)	2%
Equity Capital	10%
Sales Tax Rate	5%
State Income Tax Rate	15%
Natural Gas Price (per MBtu)	$2.50
Real Fuel Price Increase per year to 1990	6.6%
Real Fuel Price Increase per year beyond 1990	5.0%
Project Life	20 years

natural gas would be competitive in 1993. For the larger facility, the price of geothermal energy was calculated at $2.55 per million Btu, implying that it would be comparable in price to natural gas today. Net savings over the life of the projects would be $12,000 for the smaller facility and $262,000 for the larger facility. Table 3-5 presents an itemized cost summary for the two facilities.

In addition to capital costs there are also operating costs, which include maintenance and electricity to run the pumps and fans for the system. These costs are assumed to be 2.5 percent of the cumulative investment per year. Operating costs are not a separate line item. Rather they are reflected in the final price per million Btu. Further, for each case considered, the developer receives a 20 percent real rate of return for each of the first 15 years of the project and a 12 percent real return after that.

Table 3-5: Cost Comparison and Summary
Geothermal Space Heating for Commercial Facilities - Goodyear/Avondale

	Present Value Capital Costs	
Category	280,000 ft^2	55,000 ft^2
Design	$ 19,007	$ 4,306
Wells*	25,939	18,715
Commercial Conversion	108,324	17,130
Heat Exchangers	63,356	11,236
TOTALS	$216,626	$51,387

*Well cost includes costs for pumps and lease payments. In this case, drilling is not required.

Although these data are most useful in comparing the relative savings from using geothermal in two different sized buildings, they also indicate that using existing geothermal wells is an economic alternative to other conventional energy sources for providing space heating and hot water. It is also clear that size plays a significant role in determining the economic savings possible from utilizing geothermal energy. With future growth anticipated for the Goodyear-Avondale area of Maricopa County, the use of geothermal energy could aid in reducing future energy costs.

Litchfield Park

Litchfield Park is another community located in Maricopa County, approximately 16 miles west of Phoenix and north of Goodyear and Avondale. Litchfield Park has evolved as a planned community with emphasis on development of self-sufficient villages having their own stores, post offices, businesses and recreational facilities. The 1980 population of Litchfield Park is estimated to be 3,500 people. During the decade of the 1970s, Litchfield Park grew at an annual compound rate of 7.5 percent and future projections suggest the trend will continue to the year 2000.

The previous analysis of a commercial facility in Goodyear or Avondale would also be applicable for Litchfield Park. As was the case in Goodyear and Avondale, Litchfield Park is also located in an area where numerous warm wells are known to exist. One of these known wells has a discharge temperature greater than 50°C (122°F) with a flow rate of 4390 l/min (1160 gpm) at a depth of 600 m (1970 ft).

As was the case with the previous analysis, it is assumed that a developer could acquire the rights to such a well. In this case it is further assumed that the developer is interested in building residential housing and in using geothermal energy to provide heating and hot water for the complex. For this analysis two development types are considered. The first consists of 500 apartments capable of housing 1500 people and the second consists of 375 houses and 125 apartments capable of housing 1500 people. In both cases, no commercial or industrial energy users are considered.

The heating system was designed based on average heating values for homes and apartments based on outside temperature. Heat demand for the apartments was assumed to be 300 Btu/hr/Δ°F and heat demand for the houses was assumed to be 750 Btu/hr/Δ°F. Litchfield Park has an average outside low temperature of 2°C (36°F). Peak heating loads are calculated to be 10,800 Btu/hr for the apartments and 27,000 Btu/hr for the homes, respectively. Total peak demand for the 500 apartments is 5,400,000 Btu/hr and total peak demand for the combination of 75 percent homes and 25 percent apartments is 11,475,000 Btu/hr.

For the two different developments, all other necessary assumptions were held constant. The analysis provides a comparison of the economic effect of heating density for residential applications of geothermal energy. Table 3-6 summarizes the significant assumptions.

Table 3-6: Assumptions for Residential Geothermal Heating

Variable	Assumed Value
Resource Temperature	50°C (122°F)
Depth	600 m (1970 ft)
Well Status	existing
Flow Rate	4390 l/min (1160 gpm)
Industrial Heat Demand	0
Commercial Heat Demand	0
Well Distance	1 mile
Bond Rate (above inflation)	2%
Equity Capital	10%
Sales Tax Rate	5%
State Income Tax Rate	15%
Natural Gas Price (per MBtu)	$3.25
Real Fuel Price Increase Per Year to 1990	6.6%
Real Fuel Price Increase Per Year, 1990-2000	5.0%
Project Life	20 years

Using the above outlined assumptions, a life cycle cost for geothermal was calculated and compared to the current price of natural gas. For the development consisting of all apartments, the price of geothermal energy was found to be $3.48 per MBtu, which, given the assumptions on natural gas price increases, would make geothermal energy the least-cost alternative in 1984. For the development consisting of both homes and apartments, the geothermal price was $4.80 per MBtu and economic in 1989. Net fuel cost savings over the life of the two projects would be $1,808,000 for the apartment complex and $1,115,000 for the combined development. Table 3-7 presents an itemized cost summary for the two facilities.

Table 3-7: Cost Comparison and Summary
Geothermal Space Heating for the Residential Sector - Litchfield Park

	Present Value of Capital Costs	
Category	Apartment Complex	Houses and Apartments
Design	$150,880	$199,114
Wells*	25,939	22,125
Transmission	136,516	139,968
Heat Exchangers	59,117	71,093
Central System	1,294,782	1,763,643
TOTALS	$1,667,234	$2,195,943

*Well costs include leasing and pump costs. Well was assumed to exist.

In addition to capital costs there are also operating costs which include maintenance and electricity costs to run the pumps and fans for the system. These costs are assumed to be 2.5 percent of the cumulative investment per year. Operating costs are not a separate line item. Rather they are reflected in the final price per million Btu. Further, for each case considered the developer receives a 20 percent real return on investment for each of the first 15 years of the project and a 12 percent real return after that.

A point worth noting which becomes evident in this analysis is the required flow rate to meet the peak demand versus the amount of flow available. For the all-apartment complex only 1070 l/min (282 gpm) are required, leaving 75 percent of the flow unused. Expanding the system to include 2000 apartments would improve the economics of the system. Similarly, the combined complex of houses and apartments requires 2286 l/min (604 gpm), leaving 48 percent of the heat energy available for use. Expansion of this system would also improve the system economics.

A second comment regarding the significant cost factors also seems appropriate. Based on local well drilling costs, if the developer had to drill a well, the final price per million Btu for the all-apartment complex would increase by 9.6 percent or to $3.81/MBtu. It is clear that the cost of a single well (excluding reinjection wells) would not seriously impact on the final price of geothermal energy. Rather, the most significant cost factor is the distribution system necessary to deliver the heat. Because a smaller and less extensive distribution system is required for the apartment complex, the overall system economics appear more favorable.

Alpine

The community of Alpine is a small town located in the White Mountains of east-central Arizona approximately 25 miles south of Springerville, Arizona. The community has a population of 500 people and has historically experienced very slow growth. Future growth is expected to be only one percent per year during the next 20 years. Because the community is isolated, utility services are not available. Most people heat their homes with purchased diesel oil or propane. In addition, the mountain location results in severe winters of much longer duration than is the case in southern Arizona. For comparison, heating degree days for Alpine are 7500 versus 1500 in Phoenix. These circumstances make Alpine a possible candidate for a geothermal heating system.

Preliminary studies on the potential existence of geothermal energy resources in the Alpine and Springerville area have been completed by the Arizona Bureau of Geology and Mineral Technology, Geothermal Group. Although the conclusions of the study are far from definitive, several comments are worth noting. First, the study concludes that "a relatively shallow heat source of unknown character and dimension exists, probably beneath the area between

Springerville and Alpine. Second, ground water supplying the eastern half of the area is positively affected by this heat source." In addition to these conclusions, a shallow bore hole has been drilled just north of Alpine. The hole had a temperature of 33°C (91°F) at a depth of 357 m (1170 ft). The estimated temperature gradient was 75°C/km (5°F/100 ft). The economic analysis which follows assumes the existence of a geothermal resource with the above characteristics.

The following analysis concerns the economic factors necessary to develop a geothermal heating district in Alpine. Two cases are considered. The first case assumes that the City of Alpine establish a local public service company responsible for the development, distribution and management of the heating district. The intent of the utility would be to provide hot water for domestic and commercial space heating and hot water needs while earning a modest profit. The second case assumes that a private (investor-owned) utility would be responsible for development, distribution and management of the district heating system. The intent of the utility would be to earn a profit on its operations. Both options are considered feasible methods for geothermal development.

The geothermal heating district for Alpine would consist of 167 residential houses as well as commercial buildings. It is assumed that commercial heat demand is equal to residential heat demand. Estimated residential peak demand for the community is 7,516,000 Btu/hr. The developer would be required to drill wells necessary for the system. It is assumed that 60°C (140°F) geothermal water could be discovered at 914 m (3000 ft) at a distance of one mile from Alpine. It is further assumed that the flow rate would be 1890 l/min (500 gpm). Lastly, people living in Alpine must purchase fuel oil or propane for use in heating houses and businesses. It is assumed that the price of purchased energy is $7.00/MBtu. Table 3-8 presents a summary of assumptions for the two cases considered.

Table 3-8: Assumptions for Geothermal Heating District in Alpine, Arizona

Variable	City Development	Private Development
Resource Temperature	60°C (140°F)	60°C (140°F)
Depth	914 m (3000 ft)	914 m (3000 ft)
Flow Rate	1890 l/min (500 gpm)	1890 l/min (500 gpm)
Distance	1609 m (1 mile)	1609 m (1 mile)
Bond rate (above inflation)	1%	2%
Equity Capital	10%	10%
Sales Tax Rate	0%	5%
State Tax Rate	0%	15%
Federal Tax Rate	0%	46%
Geothermal Tax Credit	0%	15%
Minimum Tax Rate	0%	15%
Property Tax Rate	0%	1%
Regular Investment Tax Credit	0%	10%
Required Rate of Return (above inflation)	1%	20%
Conventional Fuel Price (MBtu)	$7.00	$7.00
Real Fuel Price Growth (per year)	2%	2%
Project Life (years)	20	20

Using the above-outlined assumptions, a life cycle cost for geothermal energy was calculated and compared to the price of propane. The price of geothermal energy was found to be $4.55 under private development and $4.33 under city development. In both cases, geothermal energy can be supplied at a price less than the price of currently available fuel. Net fuel cost savings over the life of the project total $3,693,000 under city development and $2,795,000 under private development. Table 3-9 presents an itemized cost summary for the two cases considered.

Table 3-9: Geothermal Heating System Cost Summary - Alpine

Category	Present Value of Capital Costs: City Development	Present Value of Capital Costs: Private Development
Research Investment[(1)]	$ 461,291	$ 453,062
Design	179,684	159,915
Wells[(2)]	325,269	271,468
Transmission	195,967	178,770
Distribution Costs:		
Resid. Retrofit	362,570	330,753
Resid. Hookup	125,892	114,845
Commercial Conversion	255,309	232,905
Heat Exchangers	75,963	69,297
Central System	925,280	844,084
TOTALS	$2,907,225	$2,655,099

(1) Research Investment includes the cost of the first well, leases, and pumps.
(2) Well cost is the present value of a well drilled 10 years later to provide for system expansion and necessary leases, pumps and injection wells.

In addition to capital costs there are also operating costs which include maintenance and electricity costs to run the pumps and fans for the system. These costs are assumed to be 2.5 percent of the cumulative investment per year. Operating costs are not a separate line item. Rather they are reflected in the final price per million Btu.

Of most interest in the above analysis is the difference in the price of geothermal energy depending on the type of developer. The advantages of city development include a lower cost of capital, a lower required rate of return and exemption from state and federal taxes. However, because a private developer can take advantage of geothermal tax credits and regular investment tax credits, the private developer is able to offset some of the advantages of a city developer.

Springerville

Springerville, Arizona, along with the adjacent community of Eagar, is located about 220 miles northeast of Phoenix in the White Mountains of Apache County. Historically, Springerville has been an agricultural community relying heavily on cattle and sheep grazing. Today, the largest employment sector is the lumber industry followed by the construction industry. Currently, two large coal-fired power plants are under construction in the area. The population of the Springerville area is estimated to be 5,600 people and the annual compound growth rate during the past 10 years was 5.8 percent. Future population projections suggest a growth rate of 4.2 percent per year over the next 20 years. As was the case with Alpine, Springerville experiences long winters and very mild summers. Heating degree days exceed 6000 for the Springerville area, making it a good candidate for district-heating using geothermal energy.

The economic analysis which follows assumes the existence of a geothermal resource. As was the case with the Alpine analysis, only preliminary studies on the local geothermal resource potential have been performed. The reader should refer back to the Alpine section for resource information.

In this analysis, the economics of a geothermal district heating system are compared for two cases. The first case assumes that the district heating system is established for existing residential and commercial buildings. The second case assumes that a new subdevelopment would be constructed with the intention of using geothermal energy to provide space heating and hot water. In both cases it is assumed that a city utility develops the district heating system. It is also assumed that current energy users consume electricity for their space heat and hot water needs.

For both cases considered, the geothermal district heating system would consist of 250 residential houses as well as commercial buildings. It is assumed that total commercial demand is equal to 10 percent of residential demand. Estimated total peak demand for the system is calculated to be 10,518,750 Btu/hr. It is assumed that 60°C (140°F) geothermal water could be discovered at 914 m (3000 ft) at a distance of one mile from the site. It is further assumed that the flow rate would be 3780 l/min (1000 gpm). Table 3-10 presents a summary of assumptions for the analysis.

Table 3-10: Summary of Common Assumptions for Springerville District Heating System

Variable	Assumed Value
Resource Temperature	60°C (140°F)
Depth	914 m (3000 ft)
Flow Rate	3780 l/m (1000 gpm)
Distance	1690 m (1 mile)
Bond Rate (above inflation)	1%
Equity Capital	10%
Taxes (Federal and State)	0
Tax Credits	0
Population	750
Rate of Return (above inflation)	1%
Price of Conventional Fuel (per MBtu)	$10
Project Life (years)	20

Using the above assumptions, two life cycle costs for geothermal energy were calculated. If the development of a geothermal district heating system involved retrofiting existing homes and commercial buildings, the life cycle price of geothermal energy was calculated to be $5.53 per million Btu. This price includes the costs for hookup and conversion of each structure to be heated. If a new development were built and designated to use geothermal heat, the price of geothermal energy would be $3.96 per million Btu. In addition, each home would require $1,250 worth of hookup and heating equipment. In both cases, the geothermal price compares quite favorably with local costs for both electricity and propane. In the retrofit case, total fuel cost savings over 20 years equal $2,618,000 and in the new growth case total fuel cost savings equal $3,538,000. Table 3-11 presents an itemized cost summary for the two cases considered.

Table 3-11: Geothermal Heating System Cost Summary - Springerville

	Present Value of Capital Costs	
Category	Retrofit Case	New Growth Case
Design	$ 238,011	$ 168,810
Wells*	515,983	515,983
Transmission	146,707	146,707
Distribution:		
Residential Retrofit	466,917	0
Residential Hookup	162,124	0
Commercial Conversion	32,879	0
Heat Exchangers	47,158	47,158
Central System	935,924	935,924
TOTALS	$2,545,701	$1,814,582

*Well cost includes production wells, injection wells, pumps and lease costs.

In addition to capital costs, operating costs are estimated to be 2.5 percent of the total cumulative investment in each year. These costs are reflected in the total price of the energy.

It is obvious from the above analysis that new growth situations are preferable to retrofit situations for establishing geothermal district heating systems. However, in the new growth situation, energy users must pay for the equipment installed in each home. The effect would be to increase the price of each home or commercial building although the price of the heating equipment is comparable to prices for current furnace units. A second point worth noting is that the system analyzed contains significant excess capacity. Expansion of the heating district to 750 homes would be possible without incurring additional drilling costs.

Clifton/Morenci

Clifton and Morenci are two communities located in Greenlee County about 170 miles northeast of Tucson. Clifton is an incorporated community and county seat and Morenci is not incorporated and is the site of a large Phelps-Dodge copper mining operation. Approximately two-thirds of all employed persons work for the local mine. The total area population is estimated at 9,000 people and has traditionally been a slow growth community. Population projections suggest less than one percent growth per year over the next 20 years.

In Section 3.5 of this report, a brief discusssion is included which discusses problems currently faced by the Town of Clifton. Despite the fact that Clifton (population 1475) has one of the most obvious and best understood geothermal resources in Arizona, the town has many other more serious concerns regarding its future. For a number of reasons, near-term geothermal development is unrealistic. Despite the problems currently faced by Clifton, the following economic analysis presents general results for establishing a geothermal district heating system in Clifton.

Assumptions necessary for the analysis are presented in Table 3-12. The analysis assumes private development rather than city development.

Table 3-12: Assumptions for Clifton District Heating System

Variable	Value
Population	1475
Population Growth	0
Resource Temperature	60°C (140°F)
Depth	30 m (100 ft)
Flow Rate	1890 l/min (500 gpm)
Distance	1609 m (1 mile)
Heating Degree Days	3431
Peak Residential Heat Demand	14,750,000 Btu/hr
Peak Commercial Heat Demand	11,062,500 Btu/hr
Bond Rate (above inflation)	2%
Return on Investment (10%)	10%
Price of Natural Gas (per MBtu)	$3.30

Results of the analysis indicate that even though the depth to the resource is only 30 m (100 ft), the life cycle cost of geothermal energy is not competitive with natural gas until 1988. The calculated geothermal price is $5.74 per million Btu. The majority of the cost is associated with the residential retrofit, commercial conversion and central system components. Central system costs are directly related to energy use density, which in this example is very low. Table 3-13 presents an itemized cost summary.

Although a district heating system appears unfavorable from an economic point of view, the time will come when geothermal energy will be the best energy alternative for the community. The future savings available by replacing natural gas with geothermal energy are $4,647,000 through the year 2000. However, it is unlikely that the current situation will foster the development of the local resource for district heating purposes.

Table 3-13: Cost Summary for District Heating System - Clifton, AZ

Category	Present Value of Capital Cost
Research Investment[1]	$ 18,022
Design	362,426
Wells[2]	26,874
Transmission	162,369
Distribution:	
Residential Retrofit	785,634
Residential Hookup	272,790
Commercial Conversion	414,913
Heat Exchangers	99,607
Central System	1,870,825
TOTAL	$4,013,459

(1) Research Investment includes the cost of the first production well, injection well and pumps.

(2) Wells include cost of a second production and injection well, pumps and lease payments.

In conclusion, the results of the above six analyses indicate that geothermal energy utilization for space heating within Arizona may be an attractive alternative today. It should be noted that the conclusions drawn are general in nature and do not represent final engineering studies. Rather, it is hoped that the above analysis highlights the key factors involved in assessing the merits of geothermal systems. Comparisons have included such factors as building size, number of homes versus apartments, city versus private development and new growth versus retrofit. Further, significant geothermal resource areas have been highlighted and used as examples. All of the areas and ideas presented here are felt to deserve further attention.

3.10 Outreach

Several speaking engagements were fulfilled by the Commercialization Team. Groups spoken to included the Tucson Optimist Club and a university engineering class. In addition, several newspaper articles on the activities of the Commercialization Team and the Scottsdale work appeared in local newspapers.

Also as a function of outreach, the Arizona Commercialization Team exhibited their geothermal display in the Greater Southern Arizona Home Improvement and Energy Expo, which was held May 7-11. More than 300 alternative energy companies displayed their wares.

Members of the Arizona Geothermal Commercialization Team and Resource Assessment Team attended a Region IX contractor's meeting and a geothermal producer's meeting in El Centro, California, June 3-5. Potential development in Region IX was discussed as well as the future of the geothermal effort in Arizona.

In addition to these outreach activities, the monthly newsletter, The Geothermal Resource, was mailed to approximately 500 persons in both the public and private sectors in Arizona and other states. This newsletter serves to keep interested persons abreast of all current geothermal issues in Arizona. During the second quarter of 1981, major articles detailed the following: (1) the future of geothermal energy in Arizona; (2) the monthly Arizona geothermal highlights; (3) the Arizona Geothermal Institutional Handbook: a most valuable asset; (4) Arizona cities with potential for geothermal development (5) city planning for geothermal use; and (6) the Williams Air Force Base geothermal project. A monthly series on the steps to geothermal use was started during the first quarter and continued during the second quarter with articles on (1) exploration and siting; (2) drilling; and (3) testing plans.

Due to an Executive Order by President Reagan regarding information dissemination, it is unsure at this time whether The Geothermal Resource will be distributed in the future. The Commercialization Team must gain approval to distribute the newsletter from Washington D.C. before any more issues are sent out.

Finally, during the second quarter, efforts have been made to clean up the project in anticipation of closing it out in December. The Commercialization Team plans to publish all past work in individual reports that would be available to the public after the project is closed out. The following information will be contained in individual reports: (1) Area Development Plans; (2) Arizona Geothermal Institutional Handbook; (3) Geothermal resources and their relationship to Arizona water laws; (4) A report on industrial process temperatures; (5) land use planning; and (6) the individual specific geothermal applications and technologies. Work was begun on putting together and editing these reports.