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MULTI-PURPOSE UTILIZATION OF HYDROTHERMAL
RESOURCES WITHIN THE CITY OF EL CENTRO

Final Report

By
P. B. Sherwood
S. G. Province
R. N. Yamasaki
K. L. Newman

April 1979
Date Published

Work Performed Under Contract No. ET-78-C-03-1741

WESTEC Services, Inc.
San Diego, California

U. S. DEPARTMENT OF ENERGY Geothermal Energy

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P. B. Sherwood
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UNDER DOE CONTRACT EG-78-C-03-1741

PREPARED FOR
THE DEPARTMENT OF ENERGY
DIVISION OF GEOTHERMAL ENERGY
and
THE CITY OF EL CENTRO, CALIFORNIA

WESTEC Services, Inc.
3211 Fifth Avenue
San Diego, California 92103

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 an engineering survey of present conventional energy utilization within the City to identify and evaluate those end uses which could potentially utilize geothermal heat as a substitute for fossil fuel or electrically produced heating and cooling. A general engineering and economic evaluation of heat and cold delivery alternatives followed including evaluations of geothermal fluid transmission options, alternative refrigeration techniques, heat and cold transmission media options, probable systems interfaces, materials evaluations, projected conventional energy costs, life cycle costs for existing conventional systems, projected pricing requirements for privately and municipally developed geothermal resources, the relative distribution costs of heat delivery options, and estimated residential and commercial retrofit costs. 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-effective plan for large-scale utilization of geothermal energy in El Centro for district heating/cooling and industrial applications was developed from this evaluation and preliminary conclusions drawn.

Institutional barriers and environmental impacts associated with geothermal development in the City were also evaluated. Options available to the City in the areas of utility formation, utility financing and resource development; and potential impacts in the areas of economic incentives, competing utility services, subsidence, induced seismicity, water availability, water pollution, socioeconomics, reallocation of land and public facilities, and biological resources were evaluated. As a result of this analysis, potentially adverse impacts were identified along with mitigating measures that should either completely eliminate or reduce these adverse effects to levels of insignificance.

For comparison, several specific geothermal utilization schemes within the residential, commercial, and industrial sectors of the El Centro community were evaluated for detailed engineering and economics to determine the life cycle cost savings of systems modified for geothermal applications. Final conclusions and recommendations were drawn based on these detailed life cycle cost evaluations.

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
1	INTRODUCTION	1
1.1	Statement of Objective	1
1.2	Summary	2
1.3	Conclusions and Recommendations	3
1.4	Background	6
1.5	History of the Heber KGRA	9
1.6	Resource Availability from the Heber KGRA	11
1.7	Reservoir Characteristics	20
1.8	Energy Utilization Survey	23
1.9	Detailed Energy Evaluation	32
2	GENERAL ENGINEERING EVALUATION	39
2.1	Introduction	39
2.2	Weather Analysis	39
2.3	Geothermal Heat Extraction	42
2.4	Refrigeration Techniques	46
2.5	Heat Delivery Methods	50
2.6	System Interface	55
2.7	Materials Evaluation	58
2.8	Computer Modelling	64
2.9	Summary	67
2.10	Conclusions and Recommendations	68

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
3	GENERAL ECONOMIC EVALUATION	69
3.1	Introduction	69
3.2	Conventional Energy Costs	69
3.3	Life Cycle Costs for Conventional Systems	71
3.4	Geothermal Fluid Pricing	71
3.5	Heat Delivery Options	74
3.6	Retrofit Costs	76
3.7	Geothermal Capital Cost Models	77
3.8	Preliminary Economic Feasibility	80
3.9	Sensitivity Studies	85
3.10	Final Economic Feasibility	88
3.11	Summary and Conclusions	99
4	INSTITUTIONAL BARRIERS ASSESSMENT	101
4.1	Introduction	101
4.2	Background	101
4.3	Developing the Resource	102
4.4	Available Utility Options	105
4.5	Incentives for Utilization of Geothermal Energy	116
4.6	Interface with Existing Utility Systems	123
4.7	Proposed Industrial Park	125
4.8	Summary and Conclusions	127

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
5	ENVIRONMENTAL ASSESSMENT	137
5.1	Introduction	137
5.2	Project Description	137
5.3	Project Characteristics	139
5.4	Description of the Environmental Setting	143
5.5	Potential Environmental Impacts	145
5.6	Unavoidable Adverse Environmental Impacts	162
5.7	Alternatives to the Proposed Project	163
6	SPECIFIC ENGINEERING AND ECONOMIC EVALUATIONS	167
6.1	Introduction	167
6.2	Residential/Commercial Application - El Centro Community Center	167
6.3	Industrial Applications - American Linen Supply	174
6.4	Geothermal Industrial Park Concept	178
6.5	Summary and Conclusions	182
	BIBLIOGRAPHY	185

LIST OF FIGURES

<u>Number</u>	<u>Title</u>	<u>Page</u>
1-1	Heber KGRA	10
1-2	Existing Rights-of-Way	14
1-3	Existing Generalized Land Use	32

TABLE OF CONTENTS

LIST OF FIGURES (Continued)

<u>Number</u>	<u>Title</u>	<u>Page</u>
2-1	El Centro Temperature Distribution - 1945-1960	40
2-2	Cumulative Temperature Distribution for El Centro, California	41
2-3	Load Duration - July, 1945-1960 - El Centro, California	43
2-4	Load Duration - January, 1945-1960 - El Centro, California	44
2-5	Piping and Instrument Diagram for Production, Surface and Reinjection Facilities	45
2-6	Schematic of the Ammonium-Nitrate/Water Refrigeration Process	49
2-7	Chilled Water System	54
2-8	Central Plant System	56
2-9	Modular System	57
2-10	Geothermal System Interface	59
2-11	District Heating/Cooling System Computer Model	65
3-1	Constant Dollar Fuel Cost (December 1977)	70
3-2	Residential and Commercial Districts for "GEOCITY" Computer Model	78
3-3	Piping Main Distribution Network for "GEOCITY" Computer Model	79
3-4	High Energy Density Residential and Commercial Districts for "GEOCITY" Computer Model	90
4-1	City of El Centro Redevelopment Project Area	121
5-1	Proposed Site Layout	140
5-2	Proposed Drilling Site Locations	144

TABLE OF CONTENTS

LIST OF FIGURES (Continued)

<u>Number</u>	<u>Title</u>	<u>Page</u>
5-3	A-Weighted Sound Levels for Various Project Activities as Functions of Distance From Source	155
5-4	Community Noise Levels for Various Project Activities as Functions of Distance from Source	157
5-5	Parcel Boundary Noise Spectra for Each Phase of Project Development and Operation	159
6-1	Community Center Master Plan	168
6-2	Community Center Site Elevations	170
6-3	American Linen Existing System	176
6-4	American Linen Modified System	177
C-1	House - 1287 square feet	C-4
C-2	House - 1100 square feet	C-5
C-3	House - 1354 square feet	C-6
C-4	Apartment - 638 square feet	C-7

LIST OF TABLES

<u>Number</u>	<u>Title</u>	<u>Page</u>
1-1	Comparative Value of Imperial Valley Agricultural Products	8
1-2	Chemical Quality of Water, Heber Geothermal Reservoir	21
1-3	Reservoir Characteristics	22
1-4	Residential Energy Consumption by End Use for City of El Centro	24
1-5	Residential Energy Consumption for the City of El Centro by Energy Source	24

TABLE OF CONTENTS
LIST OF TABLES (Continued)

<u>Number</u>	<u>Title</u>	<u>Page</u>
1-6	Commercial Energy Consumption by End Use for City of El Centro	26
1-7	Commercial Energy Consumption for the City of El Centro by Energy Source	26
1-8	Energy Consumption for the City of El Centro by Sector	29
1-9	Total Energy Consumption by End Use for City of El Centro	29
1-10	Geothermal Heat Required for the City of El Centro	31
1-11	Geothermal Residential Districts	34
1-12	Annual Residential Energy Use Breakdown	35
1-13	Residential Energy Consumption by Residential Type	37
2-1	Geothermal Air Conditioning/Refrigeration Processes	47
2-2	Heat Delivery Mediums	52
2-3	Piping Materials	61
2-4	Summary of Computer Output for "GEOCITY"	66
3-1	30-Year Life Cycle Costs for Conventional Space Conditioning/Water Heating Systems	72
3-2	30-Year Life Cycle Costs for Conventional Space Conditioning/Water Heating, Combinations	74
3-3	Geothermal Pipe System Comparisons	75
3-4	Computer Program Input Data Parameters	81
3-5	Preliminary Economic Feasibility	83
3-6	Combined City-wide Modular System and Industrial Park Concept	92
3-7	Combined High Energy Density Modular System and Industrial Park Concept	93

TABLE OF CONTENTS

LIST OF TABLES (Continued)

<u>Number</u>	<u>Title</u>	<u>Page</u>
3-8	Incremental Cash Flow (Commercial)	96
3-9	Incremental Cash Flow (Residential)	97
5-1	Analysis of Colorado River Water	150
5-2	Existing Noise Levels	153
5-3	Octave Band Sound Pressure Levels at 100 Feet for Various Phases of the Project	156
5-4	Estimated Community Noise Levels at Nearest Residence	158
6-1	El Centro Community Center Square Footage	169
6-2	El Centro Community Center Existing Space Conditioning Equipment	172
6-3	El Centro Community Center 30-Year Life Cycle Costs	173
6-4	American Linen Supply 30-Year Life Cycle Costs	179
A-1	Levelized Unit Fuel Costs	A-2

APPENDICES

<u>Letter</u>	<u>Title</u>	<u>Page</u>
A	Levelized Unit Fuel Cost	A-1
B	Retrofit Costs	B-1
C	Heat Flux Calculations	C-1

SECTION 1

INTRODUCTION

1.1 STATEMENT OF OBJECTIVE

1.1.1 Overall Objective

The overall objective of this study was to determine the engineering and economic feasibility of the utilization of low and moderate temperature geothermal heat in the City of El Centro including space cooling and heating for commercial/government buildings, business complexes and residences; process heat for industry located in the city or that would be desirable to attract to the city; and agribusiness. A secondary objective was the development of engineering techniques in the non-electric application of geothermal energy in anticipation that these techniques could be translated to other geothermal resource areas and applications.

1.1.2 Specific Objectives

The specific objectives of this study were as follows:

- (1) Conduct a technical review of the DOE sponsored engineering and economic studies in the non-electric field and other DOE/Industry sponsored work in the open literature. Identify those applications which merit further investigation for application in El Centro.
- (2) Identify those additional geothermal application areas that appear attractive for El Centro but have inadequate data base. Develop heat conversion methods for translating geothermal heat to application heat for those functions compatible with the city.
- (3) Determine feasible approaches for transporting Heber reservoir geothermal heat to the City of El Centro and for distribution within the city.
- (4) Assess identified geothermal applications and heat transportation approaches for economic feasibility individually and collectively as part of an "El Centro Geothermal Loop." Include other potential users adjacent to the Loop between the city and the wellhead distribution point.
- (5) Assess the environmental impact of identified geothermal applications and heat transportation approaches.
- (6) Assess institutional barriers in relation to the establishment of an El Centro Geothermal Loop.

- (7) Determine the specific benefits of heat utilization from an El Centro Geothermal Loop in terms of reduced fossil fuel and electricity consumption and associated reduced energy costs.
- (8) Develop a geothermal utilization plan for the City of El Centro focused on the near term commercialization by the private sector of Heber geothermal resources.
- (9) Provide a final report which addresses the feasibility of multiple use applications of geothermal energy in El Centro. If it is determined feasible, provide a plan for pilot experiments and/or demonstrations required to accomplish this objective.

1.1.2.1 Relationship to Similar DOE Sponsored Work

This multipurpose geothermal application study differs in concept and potential pay off from previous DOE sponsored work in that an El Centro Geothermal Loop would provide space cooling/heating to a relatively large populated area and industrial energy to meet viable private sector business requirements. The volume of the potential demand and variety of existing and potential applications indicates a high probability that such a concept will be economically attractive.

1.2 SUMMARY

This report provides the engineering and economic evaluations of geothermal energy alternatives to space heating/cooling and water heating for domestic and industrial process applications within the City of El Centro. Initially, an engineering survey of present conventional energy utilization within the city was conducted to identify and evaluate those end uses which could potentially utilize geothermal heat as a substitute for fossil fuel or electrically produced heating or cooling.

A general engineering evaluation of alternative methods of heat and cold delivery followed including evaluations of geothermal fluid transmission options, alternative refrigeration techniques, heat and cold transmission media options, probable systems interfaces, and materials evaluations. This engineering 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 general economic evaluation of heat and cold delivery alternatives followed including the calculation of projected conventional energy costs, life cycle costs for existing conventional systems, projected pricing requirements for privately and municipally developed geothermal resources, the relative distribution costs of heat delivery options, and estimated residential and commercial retrofit costs. This economic evaluation work was performed with the use of the "GEOCITY" computer program to define a large scale district heating and cooling model for detailed economic evaluation.

The initial results of the preliminary economic model were not favorable, therefore a series of refinements were made to the economic model based on

alternatives identified in the general engineering and economic evaluations. A cost-effective plan for large scale utilization of geothermal energy in El Centro for district heat/cooling and industrial applications was developed from this evaluation and preliminary conclusions drawn.

Institutional barriers associated with geothermal development in the City of El Centro were evaluated. Options available to the City in the areas of utility formation, financing, and resource development were analyzed in detail. Economic incentives to geothermal development within the City were identified along with the potential impacts from competing utilities providing standby services. The concept of a geothermal energy industrial park was also evaluated. Based on these evaluations potential institutional barriers to geothermal development within the City were identified and specific conclusions and recommendations were drawn.

The potential environmental effects resulting from geothermal development activities in the City of El Centro were evaluated. Following the example of the Final Environmental Impact Report to the Imperial County Geothermal Element the environmental assessment focused on the potential impacts identified as relevant to geothermal operations in the Imperial County. These include subsidence, induced seismicity, water availability, water pollution, socioeconomic impacts, reallocation of land and public facilities, and impacts on biological resources. As a result of this analysis, potentially adverse environmental impacts were identified along with mitigating measures that should either completely eliminate or reduce these adverse effects to levels of insignificance.

For comparison, several specific geothermal utilization schemes within the residential, commercial and industrial sectors of the El Centro community were evaluated for detailed engineering and economics to determine the life cycle cost savings of systems modified for geothermal applications over conventional systems. The three specific applications chosen for detailed evaluation were space conditioning and water heating at the El Centro Community Center, process heating at the American Linen Supply Company laundry, and process heating for a conceptual industrial park containing an onion dehydrating and alfalfa drying facility. Final conclusions and recommendations were drawn based on these detailed life cycle cost evaluations.

1.3 CONCLUSIONS AND RECOMMENDATIONS

The conclusions resulting from this engineering and economic feasibility study of utilizing geothermal heat from the Heber KGRA for space conditioning, and domestic and industrial water heating in the El Centro community are summarized below.

- Uncertainties associated with plans for electric production from the center of the Heber KGRA have tentatively precluded these higher temperature resources from consideration as the primary resource for nonelectric applications within the City of El Centro. Moderate temperature geothermal resources which are believed to exist beneath the city may offer the potential for municipal development of the resource at potentially lower costs per delivered BTU.

- A geothermal heat gradient of 2.0F per 100 feet of depth prevails below a depth of 1000 feet within the El Centro city limits. Therefore, unless geothermal anomalies are encountered, 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.
- Flow tests and core and log analyses indicate that a well drilled within the City and completed in 1000 feet of sand at 8500 feet would be capable of producing 585,000 lb/hr of geothermal fluid using a downhole pump with a setting depth of 1000 feet.
- An energy utilization survey of the present energy uses within the City shows that approximately 78 percent of the present energy consumed is potentially replaceable by geothermal heat processes. Of the energy uses within the City, space heating and cooling comprise over half of the total energy consumed with the space cooling approximately twice that of the space heating load.
- Industrial applications of geothermal process heat have the highest probability of economic success within the City of El Centro because of their large concentrated load requirements, resulting in minimized distribution costs. Any economically viable district heating and cooling systems will have to follow the industrial development of geothermal energy within the City and engage in energy cascading techniques with industry.
- Modular geothermal district heating and cooling systems utilizing energy cascading techniques with industrial processes will be economically feasible on a retrofit basis. Also, it is apparent that, for new construction, modular geothermal energy systems will be economically viable, without the requirement for energy cascading, if well production capacity is utilized effectively.
- The municipal utility and non-profit corporation options for utility formation and financing offer the most economic and institutional advantages to the City.
- The public utilities currently serving El Centro are potential institutional barriers to geothermal utilization within the City. Cuts in natural gas and electric service could result in higher charges for conventional energy by the utilities, due to the requirement for standby or peak shaving service.
- Geothermal development within the City of El Centro could potentially result in adverse environmental effects which could, however, be easily mitigated by measures included in development plans. These measures would either completely eliminate or reduce these adverse effects to levels of insignificance. Such measures would lie primarily in the areas of water quality, air quality, noise, and water consumption.

As a result of the El Centro engineering and economic feasibility analysis, it is recommended that the following work be continued or initiated:

- Provide, as a proof-of-concept geothermal field experiment, a district heating and cooling utility core which can establish the necessary foundation for the industrial utilization of the resource beneath the City. The primary objective of this field experiment would be to obtain reliable, objective, and definitive technical, economic, institutional, and environmental data under field operating conditions. This data would facilitate decisions on the utilization of geothermal energy by prospective users. Estimated three year project costs for such an experiment utilizing the El Centro Community Center, would be \$2 million.
- Utilize the El Centro Utility Core Field Experiment as a test bed for evaluating engineering variables essential to the design of cost effective hot and chilled water distribution systems. Various piping arrangements and control schemes can be tested along with the evaluation of the effect on system performance of modifying various operating parameters.
- Utilize the cost data developed by the El Centro Utility Core Field Experiment to check assumptions made in this study and re-evaluate the economic viability of large scale district heating and cooling systems for El Centro.
- Begin more detailed reservoir survey and analysis work to verify the extent of the resources beneath the City and to identify the location of potential "hot spots" and candidate drill sites within the City. Utilize core samples taken during drilling operations for the proposed field experiment to evaluate reservoir properties.
- Perform a preliminary survey of industries requiring process heat in the temperature range predicted for El Centro to determine the compatibility of their energy, raw material, water, transportation, labor, and space requirements with the resources available in the City of El Centro.
- Perform a detailed energy use survey of the City particularly concentrating on the downtown high density commercial area which appears to have the highest probability of economically viable near term utilization by the residential/commercial sector.
- Begin detailed discussions with the local utilities serving El Centro to more clearly define the potential impacts of nonelectric geothermal development within the City on the rates paid for conventional energy.
- Begin detailed investigations into the options available to the City for municipal or non-profit utility formation and financing.

- Begin development of new refrigeration technology that may prove to be more economically viable for operation with low to moderate temperature heat sources, such as those geothermal resources identified as being suitable for direct heat use only and those found on the periphery of existing geothermal resources designated for electric production.

1.4 BACKGROUND

1.4.1 General

The City of El Centro, California, is located in the heart of the vast Imperial Valley agriculture zone, lying approximately 100 miles east of San Diego and 90 miles south of Indio. 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. Sited on what has been called the "richest land on earth," the City's 23,000 residents are acutely aware of their unique geographic position to benefit from the development of geothermal energy resources in the Imperial Valley. The El Centro City Council has passed a formal resolution in which they have expressed a strong desire to participate in a study of multiple use applications of geothermal energy within the City including the application of geothermal heat relating to:

- Space heating and cooling and water heating for commercial/government buildings, business complexes and residences.
- Process heat for industry located in the City or that would be desirable to attract to an industrial park including agricultural product cleaning, drying, canning and freezing.
- Space/water heating for agribusiness such as greenhouses and fish farming.

Accordingly, WESTEC Services, Inc. teamed with the City of El Centro to conduct a study of the engineering, economic and institutional factors associated with the nonelectric utilization of the Heber KGRA hydrothermal resources in the City with an overall goal of early implementation of those approaches found to have positive impact on the economic base of the community and the quality of life in El Centro.

The study utilized the data base available from the Department of Energy (DOE) sponsored engineering and economic studies in the nonelectric field and other DOE/Industry sponsored work in the open literature. The additional application techniques required to orchestrate a viable plan for the near term commercialization by the private sector of low to moderate temperature resources were developed.

Imperial County is the test bed for development of hydrothermal resources in the United States. Community acceptance of geothermal projects presupposes an environment in which agricultural and geothermal activities complement each other and provide positive social and economic effects.

1.4.2 Community Analysis for the City of El Centro

1.4.2.1 Population

The total population of Imperial County, California, stood at 86,900 as of 1976. Population growth for the County was very limited between 1960 and 1970, totaling only 2,387. This is less than one-fourth the rate of growth recorded for the County during the previous decade (1950-1960), reflecting the essential stability and lack of strong continuing growth pressures in the region's agriculturally based economy.

The City of El Centro increased its population total to 22,660 in 1976, growing between 1960 and 1976 at a rate slightly above that recorded for the County as a whole. This factor indicates a continuance of the modest trend of population moving from the rural areas of the County to its several small cities, including El Centro. Today, one of every four persons living in Imperial County resides in the City of El Centro. Twenty years ago, in 1950, this ratio was about one in every five.

Based on its continued functions as County seat and major shipping-service center for the stable agribusiness economy of Imperial County, El Centro will continue to experience modest population growth. Geothermal development, tourism, and resort-recreation activities will add to the population growth pressures of the El Centro area.

In this context it is projected that the population of the City of El Centro will increase by between 10,000 and 17,000 by the year 2000.

1.4.2.2 Climatic Conditions

The climate of El Centro is dry, with hot summers and pleasant winters. There is very little variation in climate within the County, except for higher humidity levels in the irrigated areas and local differences in winds. Imperial County is subject to mild prevailing westerly winds. Average rainfall is approximately 3 inches per year; about half falls in high intensity summer showers and about half in gentle winter rains. Day temperatures rise to 105-120F almost every day from May through October making building and residence cooling a major energy user, while dropping to the low 60's at night. Winter temperatures are moderate, in the 50's and 60's predominantly, thus permitting year around crop cultivation. Because of its inland location, the Imperial Valley is almost entirely free of low cloud cover which affects more marine influenced climates.

1.4.2.3 Employment

The employment base of the El Centro Community Labor Market Area, which includes the City of El Centro as well as that portion of Imperial County immediately surrounding the community, recorded strong growth over the past ten years. In 1976 about 26,700 persons were employed in this labor market area in non-agricultural employment categories in contrast to a total of 8,625 persons in the same categories in 1960. This represents a gain of over 18,000 jobs in the past 16 years.

Gains occurred in all categories of non-agricultural employment. The classification of wholesale-retail trade and government recorded the largest individual numerical increases.

El Centro's role as County seat and as a principal shopping-service center for Imperial County can be identified as the major factor stimulating this rate of non-agricultural employment growth which has been well above the pace of population growth during the past decade in the El Centro area.

A large number of people commute into El Centro for employment from places of residence elsewhere in the County, outside the incorporated boundaries of the City of El Centro.

1.4.2.4 Economic Base

Intense, large-scale agriculture is practiced in the irrigated areas adjacent to El Centro. General field crops include cotton, alfalfa, wheat, barley, sugar beets, and grain sorghum; major horticultural crops include asparagus, cantaloupes, lettuce, onions, and carrots. The cattle-feeding industry is very extensive, consuming more grain than is produced locally. In 1975, the value of Imperial County agricultural products exceeded \$500,000,000, an increase of almost \$170,000,000 over 1972 crop values. Table 1-1 documents the continued growth of agricultural crop values from 1975 to 1978, the last year for which figures are available.

Table 1-1

COMPARATIVE VALUE OF IMPERIAL VALLEY AGRICULTURAL PRODUCTS

	<u>1975</u>	<u>1978</u>
Field Crops	\$215,967,000	\$240,876,000
Vegetable Crops	142,288,000	148,835,000
Livestock & Dairy	127,204,000	177,571,000
Fruit & Nut Crops	2,896,000	4,848,000
Seed & Nursery Crops	10,780,000	10,971,000
Apiary	<u>1,047,000</u>	<u>1,313,000</u>
TOTAL	\$500,182,000	\$584,414,000

As can be seen by Table 1-1 above, cattle raising continues to be a major segment of the County's agricultural economy, but has declined in relative importance compared to field crops and vegetable crops. Because the rising cost of feeding cattle has not been compensated by increased wholesale cattle prices, cattle raising firms have been cutting back on production, such that most feed lots in the County are currently operating well under capacity.

Since 1969, the economy of Imperial County has undergone a degree of diversification. Non-agricultural employment showed steady gains to 1973; since that time, however, this growth has leveled off. At present there are nine industries near El Centro, employing approximately 1,400 persons.

Over the same time period, agricultural employment has dropped steadily, in part because of increasing farm mechanization.

Potential industrial applications of geothermal energy in the El Centro area include:

- Product freezing
- Product chilling
- Product drying
- Canning
- Seed processing
- Agricultural chemical production
- Plaster board production
- Commercial laundry
- Lactose production
- Beet sugar refining
- Aquaculture

There are 570 acres in the City limits zoned for medium and heavy industry; about 50 percent is vacant and available ranging in size from one to sixty acres.

1.4.2.5 City General Plan Goals

Four goals from the El Centro General Plan are pertinent to this study:

- Preserve and protect agricultural uses and the natural resources within the City's area of influence in the Imperial Valley.
- Protect desirable residential areas by proper improvements to provide for the various human life styles.
- Foster the continued growth of the civic and financial center combining all levels of public service and attendant private services.
- Support the revitalization of older commercial areas and the maintenance of newer commercial areas.

1.5 HISTORY OF THE HEBER KGRA

1.5.1 Introduction

The geothermal reservoir which is the energy source for this study is embodied in a 13.5 square mile area known as the Heber Known Geothermal Resource Area (KGRA) in the Imperial Valley. The area of maximum temperature gradient is centered around the township of Heber which is approximately $4\frac{1}{2}$ miles south of the City of El Centro. The southeast corner of the City of El Centro is within the boundary of the Heber KGRA, as designated by the U.S. Geological Survey. Figure 1-1 depicts the Heber KGRA and indicates the location of the City of El Centro with relation to the temperature gradient contours of the Heber geothermal anomaly.

Figure 1-1. HEBER KGRA

The land within the Heber KGRA is under private ownership and is principally devoted to intensive agricultural utilization. Other land uses include urban and industrial developments. Portions of the City of El Centro are included in the northern area of the KGRA and the entire Township of Heber is included in the central area.

Geothermal development in the Heber KGRA has been due primarily to the efforts of the Chevron Resources Company, Magma Power and associated organizations. This area has been considered a potential heat anomaly since 1945 when an oil and gas test well was drilled just west of the Heber townsite. Well logs indicated a higher-than-normal heat gradient. In 1963, Chevron confirmed the Heber geothermal anomaly by drilling a shallow test hole and measuring the heat gradient. In 1971, Chevron initiated a geophysical program to more fully evaluate the geothermal potential of the area.

Early in 1972, Magma Energy, Inc., in conjunction with Chevron Resources Company, drilled the Holtz Well #1 to a depth of 5,148 feet in an area approximately one mile southwest of Heber Township. Well conditions were encouraging and prompted Magma to drill a second well nearby. In the fall of 1972, Chevron drilled its first well, Nowlin #1 to a depth of 5,030 feet in an area due east of the Magma wells.

In 1973, Chevron, New Albion Resources Company (a subsidiary of San Diego Gas & Electric Company) and Magma agreed to a joint venture at Heber to test and evaluate the geothermal potential indicated in the earlier wells. Chevron was designated as operator for the joint venture. The test project began in late 1973 and was completed in mid-December 1974. The objective of this program was to determine production and injection capability of the Heber reservoir. Chevron's Nowlin #1 and Magma's Holtz #1 wells were produced and reservoir fluids were injected into Magma's Holtz well #2. Results of these tests encouraged the drilling of three additional wells, two by the Chevron-New Albion-Magma joint venture and one by Chevron on its own behalf.

In 1975, a major effort was funded by the Electric Power Research Institute (EPRI) which, inter alia, was to determine the feasibility of constructing and operating a 50 MWe electric generating demonstration plant utilizing the hydrothermal resources of the Heber KGRA. As a result, Southern California Edison Company has plans to construct a geothermal flash steam power plant at Heber, which directly impacts on the potential for resource utilization by the City of El Centro. For this reason, we have established technical communications channels with Chevron Resources Company, as the major geothermal leaseholder, to assure a reasonable assumption for brine availability to the City of El Centro.

1.6 RESOURCE AVAILABILITY FROM THE HEBER KGRA

1.6.1 Introduction

Developments relating to the utilization of geothermal resources from the center of the Heber KGRA have been in a continuous state of flux in recent times; however, one fact has become clear. Until definite decisions are made whether or not to proceed with plans for electric production, leaseholders have stated that they are not

in a position to make additional commitments for geothermal fluid supply from the center of the reservoir.

However, since one of the specific objectives of this study is to determine feasible approaches for transporting geothermal heat from the Heber KGRA to the City of El Centro, several potential rights-of-way were selected for detailed investigation. The following analysis, conclusions, and recommendations concerning potential rights-of-way were predicated on (1) policy statements and goals outlined in the Geothermal Element to the Imperial County General Plan (2) the related Environmental Impact Report (EIR) for the Geothermal Element to the Imperial County General Plan; (3) an assumption that geothermal brine would be supplied by wells in the vicinity of the Heber anomaly, presently being developed by Chevron Resources and others; and (4) a worst-case engineering estimate calling for at least two pipe lines (production and injection) to provide the heat requirements of an absorption chiller sized for the peak city-wide cooling demand, each pipeline being 36 to 48 inches in diameter and the total right-of-way occupying a width of approximately eight to ten feet.

This estimate was used to screen potential rights-of-way and in no way reflects the final pipe sizes resulting from the feasibility study.

1.6.2 Brine Transmission Corridors

1.6.2.1 Background

Two major concerns regarding brine transmission voiced by Imperial County and analyzed in the EIR are its potential effect on the environment and on agricultural operations. Imperial County has recommended that brine pipe lines be located along existing rights-of-way and above ground. This latter recommendation is based upon the lower costs associated with the above ground construction of pipe lines and the greater ability to monitor leaks above the surface. The County favors pipe line placement in concrete conduits covered, for example, with a concrete cover or removable grating. Reducing the visibility of the lines in this manner would improve the aesthetics and would minimize safety hazards.

Adoption of the Geothermal Element on November 22, 1977, by the Imperial County Board of Supervisors has removed some of the uncertainty of local government's reaction to proposed routes. While the regulations themselves have not yet been drafted, it was assumed that there would be consistency with the recommendations made in the Geothermal Element. Thus, initially the task of defining the right-of-way problem shifted from an institutional question to the question of where the actual transmission corridor would begin.

As a part of this study, Chevron Resources, the major leaseholder in the Heber area, informally agreed to provide pricing information for purposes of the economic evaluation. Since Chevron Resources would also be the likely supplier of geothermal brine if supplied from outside the El Centro city limits, a preliminary identification of its existing wells in the Heber area was made. The premise was that these wells might also define the suitable area for future drilling. Most of the drilling activity to date has occurred in the area west to southwest of the City of Heber, where resources of a temperature high enough to support electric generation have been found.

This area serves as a convenient starting point for our evaluation of potential brine transmission corridors.

The final problem, prior to the analysis and selection of actual available routes, was to consider the restrictions imposed by the size of the pipe and the number of lines needed for efficient brine transportation. To transport the brine from the wells to a distribution point within the city, the worst-case engineering estimate of 36 to 48 inch pipe offered the necessary order of magnitude for evaluating existing rights-of-way, yet initially eliminated from consideration rights-of-way too narrow to accommodate these lines. It is certainly conceivable that more than two lines will be required, particularly if industry participates in the utilization of geothermal energy. Additional lines would necessitate additional space, demanding wider or multiple rights-of-way. While so many options remain unexplored, a requirement for two 36 to 48 inch pipe lines was considered a realistic appraisal of the current situation.

1.6.2.2 Discussion

In view of the foregoing constraints, four potential north-south corridors were identified and investigated. Several east-west routes, intended to function perhaps as secondary corridors, were then reviewed (Figure 1-2). A brief description of the north-south corridors with the attendant advantages and disadvantages of each follows:

1.6.2.2.1 Southern Pacific Railroad

The right-of-way owned in fee, that is, owned outright by the railroad, is uniformly 100 feet in width, except in El Centro and Heber where the station grounds are much wider. The tracks and gravel embankment occupy a relatively small portion of this 100 feet.

Permission to encroach upon Southern Pacific's land would be evidenced by a written lease for a term covering the life of the project at an annual rent based upon the appraisal value of the property to be occupied.

The railroad right-of-way offers the advantage of being wide enough to accommodate the large diameter pipe required for this project. A Southern Pacific spokesman indicated that the railroad lease makes no mention of the specific width to be granted, only that which is reasonably needed for the project and which will not interfere with existing utilities. Because there are currently no utilities along this segment of track, the City of El Centro would not incur any of the usual costs associated with the relocation of utilities.

An additional advantage is the route's proximity to that area, outside the city limits, suitable as a site for an industrial energy park. This designation would be in conformity with the Land Use Element of the City of El Centro's General Plan. Finally, several existing businesses near the tracks offer opportunities for non-electric applications.

A major drawback to the railroad right-of-way is Southern Pacific's requirement that any pipe line be buried at least three feet below the surface and

LEGEND

- RAILROAD
- CITY LIMITS
- CANAL
- LATERAL
- DRAIN

Figure 1-2. EXISTING RIGHTS-OF-WAY

covered. This requirement raises a major obstacle to use of this right-of-way, assuming Imperial County promulgates regulations following the recommendations for an above ground pipe line. The railroad sees no above ground construction as providing adequate safeguards against rail car derailments. To date, no satisfactory compromise or alternative has been presented.

The width and accessibility of this right-of-way make it otherwise preferable to the options discussed below. Therefore, should it become apparent that future drilling will occur near the railroad, further efforts to reconcile the differing requirements of Southern Pacific and Imperial County will be undertaken.

1.6.2.2.2 State Highway 86

State Highway 86 is recorded as a standard forty foot road with two twelve foot lanes and two eight foot shoulders. However, a physical inspection reveals that there are no road shoulders and that there is a steady stream of traffic in both directions. A narrow road drainage ditch and telephone lines parallel the highway on the west side along the north-south segment. Realistically speaking, relocation of the utility lines will be costly, and elimination of the road ditch will leave no collector for water runoff from the road. An Imperial Irrigation District (IID or the District, hereafter) lateral and drain are located along portions of the east side and north side outside Heber. The possibility of locating between the road right-of-way and IID looks equally unpromising for an above ground pipe line, since the District utilizes available space as maintenance and delivery roads.

State right-of-way maps indicate that most of State Highway 86 is occupied by prescriptive easement, the notable exceptions being segments adjacent to the Cities of Heber and El Centro and that segment forming a right angle west of Heber. Under prescriptive rights, the State acquires use of only that land which it visibly maintains. Along Highway 86, the State occupies almost all that space which it maintains. Other segments of the highway under discussion are secured by a deed for a specified width from 30 to 85 feet. This distinction between deeded rights and prescriptive rights is important if the City of El Centro must rely on existing rights-of-way. Along portions held by prescription, there would be insufficient space for the City to construct any pipe line.

Assuming the State Highway 86 right-of-way were sufficiently wide, El Centro would secure a longitudinal encroachment permit from the California Department of Transportation (DOT) prior to construction. A longitudinal encroachment permit allows the applicant to encroach along, rather than merely across, the permitting authority's right-of-way. To secure approval, DOT regulations provide that any pipe line be buried a minimum of 30 inches below the surface. However, the Department's permit engineers indicated that a concrete-lined trench with a removable cover would most likely be acceptable. Special permission must be obtained for any excavation closer than 10 feet from the pavement. The State's concern is that there be sufficient room for maintenance work on the highway. Recent concern over the environment has engendered a proposal to require a State EIR prior to approval of any encroachment permit. This additional requirement raises the possibility of further delay, if State Highway 86 were selected as the transmission corridor.

To summarize, the following findings militate against use of State Highway 86 as a feasible approach: (1) the right-of-way is often narrow and its dimensions fluctuate from tract to tract; (2) there is near maximum utilization of available space on both sides of the highway; (3) "visual pollution" and hazards to safety appear to be genuine concerns along this busy route; (4) further delays during the permitting stage would occur if an EIR were first required.

This route should be shelved as a suitable approach. Utilization of isolated segments may be viable where use of farmland is the only practical alternative.

1.6.2.2.3 The Imperial County Road System

Imperial County roads are typically two lane roads, 22 feet wide, with 14 foot shoulders on either side. Like the State, land occupied by the Imperial County road network is secured in one of three ways: (1) by a right-of-way deed which grants the County outright ownership of a strip, usually 60 feet wide; (2) by right-of-way easement, wherein the property owner has expressly sanctioned the use of a specified portion, usually 60 feet in width; or (3) by prescriptive easement whereby the property owner has sanctioned by implication the use of that portion of the road which the County has visibly maintained over a period of years.

An application to encroach upon Imperial County's existing right-of-way is routinely granted, if the County concludes that the use will not interfere with the use of the road nor injure abutting property. Whether permission would be granted for construction above the surface along the berms, or shoulders, is less certain. As with State Highway 86, safety considerations will probably foreclose using these shoulders.

Should the City of El Centro locate its pipe line along Imperial County roads, it must first secure a longitudinal encroachment permit from the County. This permit, like the one mandated by the State, grants the applicant the right to encroach upon the road right-of-way. It is utilized in lieu of a written lease such as that required by Southern Pacific Railroad.

Since Imperial County has only the use, rather than outright ownership, of much of the land for road purposes, it can be argued that only the true property owner can convey to the City of El Centro that use of the right-of-way which is not in conflict with the County's existing use. As a governmental entity, Imperial County could acquire outright ownership of these rights-of-way under the doctrine of eminent domain or condemnation, whereby private property is expropriated for public use. Such a measure has apparently been unnecessary, since Imperial County desires only the use of the land for its roads. Nor apparently have the property owners along these roadways felt it necessary to challenge the encroachment permitting procedure as being beyond Imperial County's authority, obviously recognizing that in doing so they would be risking eventual loss of ownership by condemnation. As a practical matter, the City of El Centro, or any company supplying brine via pipe line to the City, can be assured that receipt of a longitudinal encroachment permit provides the necessary authorization to use the County right-of-way.

In the absence of such authorization, it is possible that the City of El Centro could also acquire ownership of a strip of land for its pipe line by condemnation,

even though this strip were outside the City's limits or jurisdiction. The City might argue that it needed such land for a municipal utility, the formation of which would be a proper exercise of powers granted to municipalities by State statutes. In view of the excellent cooperation shown by Imperial County personnel in discussing the right-of-way problem, there is little likelihood that such a step will ever be necessary.

Once the foregoing information was gathered, it was necessary to identify those roads in the proposed area which might be acceptable as a pipe line right-of-way.

1.6.2.2.4 North-South Imperial County Roads

Initially, all County roads running in a north-south direction in the area of the Heber anomaly were examined. They are (1) Dogwood; (2) Farnsworth; (3) Clark; and (4) La Brucherie.

1. Dogwood Road

Imperial County is the record owner of a 60 foot right-of-way for the entire segment of road running from El Centro to Heber. The road is situated near the existing well site to the south and is near existing businesses and the proposed industrial energy park to the north. A canal, telephone lines, and gas line run along the eastern side of the road. The only existing utility on the western side is a short buried gas feeder line from El Centro to the Valley Nitrogen Producers Plant. From an inspection of the road, there appears to be approximately 15 to 25 feet available on the western edge for the entire corridor under consideration; farmlands and business front the road.

2. Farnsworth Road

This road runs only from Danenburg Road to McCabe Road. An IID drain occupies the eastern side for approximately half the distance, then crosses under the pavement to the western side for the remaining distance. There are several houses in the area; otherwise interference is minimal. Imperial County occupies this right-of-way under prescriptive rights except for a short segment which has been deeded to the County. However, it is unclear what the County actually maintains as its easement.

3. Clark Road

Again, Imperial County occupies the land by prescription for all but a segment of a 60 foot right-of-way between McCabe and Heber Roads. District (IID) laterals and drains line the eastern edge; to the west, buried utility lines and cables crowd the area.

While the road is farther removed from the existing wells, there are potential nonelectric applications to Imperial County facilities existing and under construction along Clark Road.

4. La Brucherie Road

Farthest from the well site, La Brucherie Road is lined on both sides by the IID system and by other utilities. Imperial County has recorded documents showing easements from 30 to 66 feet for the entire segment (Figure 1-2). However, since underground utilities are present over much of the area from the City of El Centro to McCabe Road, an above ground pipe line is not a sound alternative.

1.6.2.2.5 East-West Imperial County Roads

All east to west Imperial County roads were investigated secondarily as potential link-ups between major north-south rights-of-way. A brief discussion of each of these roads follows.

1. Danenburg Road

Running only from State Highway 86 to Dogwood Road, Danenburg Road occupies part of a 60 foot right-of-way held by Imperial County. Valley Nitrogen Producers borders at Dogwood Road with other businesses along Dogwood in close proximity. A District concrete-lined lateral occupies the northern site of Danenburg from Farnsworth Road to State Highway 86. Several residential lots extend to the shoulders of Danenburg Road.

2. McCabe Road

The major portion of Imperial County's easement is only that which it visibly maintains. Irrigation facilities are located on a small northern segment off the road shoulder, and, as is the case throughout much of this area, telephone lines have been erected at the edge of the berms. There appears to be minimal interference with residential dwellings, particularly on the south side of the roadway. There is some new construction occurring on the north side of McCabe Road between State Highway 86 and Dogwood Road.

3. Heber Road

This western extension of State Highway 86 is designated as a secondary or minor Imperial County road. It forms the northern boundary of the geothermal overlay zone for development of the Heber reservoir. To the north, roughly 25 feet from the edge of the pavement, there is a narrow concrete-lined irrigation ditch which is most likely privately-maintained. To the south, telephone lines and a small road drainage ditch approximately 15 feet from the pavement run parallel to the roadway. Since this segment of Heber Road is classified as an easement by prescription, that which Imperial County appears to maintain on the south side may be sufficiently wide for pipe line placement.

1.6.2.3 Summary

An investigation of possible brine transmission corridors from the center of the Heber reservoir to the City of El Centro was undertaken. In accordance with the Geothermal Element of the Imperial County General Plan, only existing rights-of-way

were considered. Rights-of-way chosen for further investigation were those along the Southern Pacific Railroad, State Highway 86, and Imperial County roads.

Initially the most suitable corridor for brine transmission appears to be the railroad right-of-way owned by Southern Pacific. The railroad strip is 100 feet wide throughout the distance between the Cities of El Centro and Heber. Currently, there are no other utilities along this segment of track. Several businesses have facilities near the tracks, particularly on the outskirts of El Centro.

To occupy any segment along this track, the City of El Centro will be required to execute a written lease for a term covering the life of the project. A condition to this lease is that the pipe line be buried at least three feet beneath the surface and be covered, which is in conflict with provisions of the Geothermal Element of the Imperial County General Plan.

The next site suitable for investigation was State Highway 86. The right-of-way occupied by this highway is of varying widths. The road itself covers a major portion of the available space. Irrigation facilities and a road ditch border the highway on either side and there is very little shoulder to the road. The State occupies a major portion of the underlying land by prescriptive right. Therefore, the right-of-way consists of only that land which the State visibly maintains.

Prior to occupation of any portion of the highway right-of-way, the State will require the City to obtain a longitudinal encroachment permit. In the future, there is a possibility that issuance of a permit will be conditioned upon State approval of an environmental impact report. No decision has been made regarding this latter requirement.

The final area of consideration was rights-of-way along the Imperial County road network. Eight roads are located within the subject area (Figure 1-2). Only two of these roads, Dogwood and La Brucherie, are entirely documented by recorded right-of-way deeds or easements, both of which specify the width conveyed to Imperial County by the property owner. The entire segment or portions of the remaining six roads are occupied under prescriptive easements, wherein Imperial County has acquired the easement by continued usage of the particular strip over a period of years. Like the State, the County has use of that land which it visibly maintains. Imperial County typically maintains not only the road and shoulders, but also any adjoining strips bordering fence lines or hedges.

There are utilities and/or irrigation facilities on one or both sides of each of the eight Imperial County roads. These utilities include Pacific Telephone Company lines and underground cables, Southern California Gas Company lines, and City of El Centro water mains and sewage lines.

1.6.2.4 Conclusions and Recommendations

Assuming pipe line placement along existing rights-of-way and below ground, the Southern Pacific Railroad easement offers the most feasible brine transportation approach. At present, however, this approach appears to be in conflict with the Geothermal Element of the Imperial County General Plan.

Assuming pipe line placement along existing rights-of-way and above ground, segments of the Imperial County road network offer the most feasible approach for brine transportation.

With respect to the selection of a suitable right-of-way, that area along the western strip of Dogwood Road offers several distinct advantages. It interferes the least with existing agricultural and residential land uses; is sufficiently wide to accommodate a large pipe line; and is proximately located to the existing well sites.

The rights-of-way along Clark and La Brucherie Roads vary from one tract of land to the next and are flanked by utilities and the Imperial Irrigation District system. Despite these drawbacks, each of these roads appears preferable to State Highway 86, which is subject to similar encroachments along its right-of-way. In addition, construction of a pipe line along State Highway 86 would aggravate existing traffic problems and would create road drainage problems.

Selected sites along the east-west Imperial County road system also present possible transmission corridors, notably the southern sides of McCabe and Heber Roads. On these sides, existing commercial and residential development is minimal, and strips of land between the road berms and fields are not being cultivated. Whether Imperial County maintains these strips as part of its easement is uncertain. If the County does not, it might still be possible to acquire an easement from the landowner. Such acquisition would not appear to conflict with Imperial County's Geothermal Element, which recommends that, where possible, agricultural land not be taken out of production for geothermal operations. Acquisition of additional land would also permit pipe installation farther away from the paved portion of the roadway.

The possibility of well sites closer to the City of El Centro and more distant from the center of the Heber anomaly has not been eliminated. Geothermal developers have expressed an interest in demonstrating the ability to either pick unique hot spots on the periphery of the reservoir, or to drill deeper to take advantage of the heat gradient, supplying smaller amounts of hot water for specific projects by drilling the well close to its intended user. Recent information has indicated the high probability of finding desirable brine temperatures in areas within the City of El Centro itself; therefore brine transmission corridors will be confined to areas within the City limits for the remainder of this study.

1.7 RESERVOIR CHARACTERISTICS

Although details of the Heber KGRA are considered proprietary, adequate information has been published to establish basic reservoir characteristics for the purposes of this study. Table 1-2 shows brine chemistry for five wells in an area of three square miles in the center of the KGRA. The City of El Centro is $4\frac{1}{2}$ miles north of the center of the KGRA, 4.2 miles north of "HULSE No. 1" and in an area where well temperature gradients should be 2 to 4 F 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 2.0-3.3 F per 100 feet of depth. This is based on data published by the U.S.G.S. and the

Table 1-2

CHEMICAL QUALITY OF WATER, HEBER GEOTHERMAL RESERVOIR
IMPERIAL VALLEY, CALIFORNIA

Parameter*	Nowlin #1	Holtz#1	Holtz#2	C.B. Jackson#1	J.D. Jackson#1
Total Dissolved Solids (TDS)	14,100	13,168	16,330	15,430	15,275
SiO ₂	120	268	187	267	268
Li	6.6	4	4.1	2.8	3.4
Na	3,600	5,500	4,720	4,688	4,563
K	360	220	231	181	197
Ca	880	1,062	1,062	891	781
Mg	2.4	5.6	23	4.7	3.8
Cl	9,000	7,420	8,242	8,320	8,076
SO ₄	100	100	148	152	150
CO ₃	4	NA	NA	NA	NA
HCO ₃	20	NA	NA	NA	NA
F	1.6	1.7	1.5	0.9	0.6
B	4.8	4.1	8	4.8	5.2
Fe	0.9	15	5	20	10
Mn	NA	0.9	0.9	1.3	1.9
Pb	0.1	1.6	0.6	0.6	0.9
Zn	0.68	0.3	0.1	0.4	0.5
Cu	0.2	0.5	0.4	0.4	0.4
Ba	NA	6	3	3	3
Sr	NA	37	42	32	36
Al	0.04	15	12	0.5	18
Ag	NA	NA	NA	NA	NA
Li	4	NA	NA	NA	NA
pH	7.1	NA	7.4	5.8	6.5

* Except pH, all parameters are in parts per million.

California Division of Mines and Geology, and data gathered by geothermal developers in the Heber area. 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, unless geothermal anomalies are encountered, it is highly probable to find 250 F brine at about 8500 feet and it is moderately probable to find that temperature at about 6500 feet.

Based on flow tests and core and log analyses done by geothermal developers at Heber, it is estimated that a well drilled within the City and completed in 1000 feet of sand at 8500 feet will have a productivity index of 110 B/D/psi. Assuming that this well will be produced by a downhole pump which can be operated at a setting depth of 500 feet, the maximum production rate is estimated at 730 gpm (365,000 lb/hr). The reservoir, however, is capable of supporting a production rate up to 1170 gpm (585,000 lb/hr) if the setting depth is 1000 feet and the pump and well casing are modified to accomplish such a rate.

With the assumption that the used brine will be reinjected into a different zone, the continuous production will result in depleting the reservoir pressure. For an assumed continuous aquifer of 5000 acres, the maximum cumulative production is estimated at 32 million barrels.

The project life, however, could be extended if the reservoir is replenished by brine encroachment from a larger aquifer or by brine imbibition from overlying and underlying strata. Reinjected brine may also help replenish the reservoir if there is any vertical communications between injection and production zones. The actual extension of project life due to one or more of these factors will depend on their continued brine volume relative to the produced volumes.

The reservoir characteristics established in Table 1-3 are based on the chemistry data in Table 1-2, discussions with the reservoir leaseholder and the assumption that properties of the brine will remain constant over the useful economic life of any geothermal applications.

Engineering calculations and preliminary system design schemes will be developed based on the following criteria which the reservoir engineers at Heber have indicated can be met on the fringes of the KGRA.

Table 1-3

RESERVOIR CHARACTERISTICS

Total Dissolved Solids (TDS)	14,000 ppm
Brine Chemistry for Thermodynamic Calculations	14,000 ppm solution of NaCl
pH	6.2
CO ₂ by weight of flashed steam	$\leq 0.3\%$

Table 1-3 (Continued)

Methane and hydrogen sulfide by weight of flashed steam	trace
Maximum supply rate per well	585,000 lb/hr per well
Downhole Brine Condition at the City	Saturated @ 250 F
Brine return temperature at the reinjection well	≥ 160 F

1.8 ENERGY UTILIZATION SURVEY

1.8.1 Introduction

An energy utilization survey of present conventional energy consumption levels within the City of El Centro was completed. This survey was used to determine the magnitude of potential geothermal energy applications to the City.

Documented sales records from the utility companies serving the El Centro area were used as the primary source of information. Supplemental data, gathered from various reports and studies done for similar desert communities, was also used.

An estimate of the total conventional energy consumption for the City of El Centro was made. This estimate was then broken down into specific end uses. Potential geothermal energy applications were identified from these end uses and relative conversion efficiencies were used to estimate the potential geothermal energy requirement for the City of El Centro.

1.8.2 Present Energy Consumption

In investigating the total energy consumption for the City of El Centro, energy sources were examined, along with end uses, for possible replacement by geothermal energy.

Major energy sources as defined for this report include: electricity, natural gas, and petroleum.

Electricity and natural gas are the two major sources of energy for the City for which consumption can be readily identified for each sector. Sectors are herein defined as Residential, Commercial, and Industrial. Electric and gas consumptions are based on sales records from the utility companies serving the El Centro area.

The use of petroleum has been consigned solely to the industrial sector.

Since there are wide areas of consumption where recorded data is lacking, a concerned effort was made to make reasonable estimates of end use consumption based on available information.

1.8.2.1 Residential Energy Consumption

The residential sector of the City is made up of roughly 8,000 dwellings comprised of houses, apartments, and mobile homes.

The residential energy consumption is estimated to be approximately 5.9×10^{11} BTU/yr which is about 60 percent of the total energy consumed in the residential and commercial sectors of the City.

The major sources of energy are electricity and natural gas. The use of petroleum in the home is considered to be non-existent.

Significant end uses were categorized as follows: air conditioning, space heating, water heating, cooking, refrigeration, and clothes drying.

A breakdown of the total residential consumption by end use is listed in Table 1-4. Table 1-5 lists a further breakdown of energy consumption by energy source.

Table 1-4

RESIDENTIAL ENERGY CONSUMPTION BY END USE FOR CITY OF EL CENTRO

	<u>%</u>	<u>BTU/yr</u>
Air Conditioning	36	2.1×10^{11}
Space Heating	20	1.2×10^{11}
Water Heating	17	1.0×10^{11}
Refrigeration	10	0.6×10^{11}
Cooking	12	0.7×10^{11}
Clothes Drying	3	0.2×10^{11}
Other*	<u>2</u>	<u>0.1×10^{11}</u>
TOTAL:	100	5.9×10^{11}

Table 1-5

RESIDENTIAL ENERGY CONSUMPTION FOR
THE CITY OF EL CENTRO BY ENERGY SOURCE

	<u>Electrical</u>	<u>Natural Gas</u>
	%	%
Air Conditioning	60	NIL
Space Heating	15	30
Water Heating	NIL	40
Refrigeration	16	NIL
Cooking	3	25
Clothes Drying	3	5
Other*	<u>3</u>	<u>NIL</u>
TOTAL:	100	100

*includes small appliances, lighting, dishwashers, televisions, etc.

1.8.2.2 Commercial Energy Consumption

The commercial sector of the City is an agglomeration of various activities. They include professional services, contractors, hotels and restaurants, wholesale and retail trade, agricultural businesses, finance companies, et al., as well as utilities, schools, churches, hospitals, and government institutions.

The commercial sector consumes approximately 3.9×10^{11} BTU/yr in energy or about 40 percent of the total energy consumed in the residential and commercial sectors of the City.

The major energy consumption for the commercial sector comes from the use of electricity and natural gas. Petroleum (such as gasoline or fuel oil for commercial transportation and commercial feedstock for asphalt or road oil) was eliminated as a major source of energy since this energy source was deemed not to be readily replaceable in the commercial sector utilizing geothermal resources. Also, the commercial use of petroleum is estimated to be too small a fraction of the total energy picture to be considered significant.

Total energy consumption figures for the commercial sector were provided by the local utilities; however, with such a wide variety of commercial activities, as described previously, it is difficult to derive energy consumption values for each type of end use. Rather than attempt to survey each and every commercial establishment in the City for end use consumption, the consumption of energy in the commercial sector was estimated based on its relationship to the consumption of energy in the residential sector. This was accomplished by investigating data gathered for similar desert communities and also from national energy consumption data.

Major end uses in the commercial sector are as follows: air conditioning, refrigeration, space heating, water heating, and cooking.

Commercial end use consumptions are listed in Tables 1-6, and 1-7.

1.8.2.3 Industrial Energy Consumption

The Bureau of the Budget has established 20 major standard industrial classification groups. These groups range from the tobacco industry to heavy machinery manufacturers.

There are only a handful of companies in El Centro which can be classified as industrial according to the Bureau of Budget standards. These include: an ice company, garment manufacturers, a newspaper, and commercial laundry.

There are no industrial level users of electricity within the city limits of El Centro according to the local utility company.

The large volume of natural gas used in the industrial sector within the city limits is mainly used by the local utility company for an electrical generating steam plant which also uses fuel oil. Geothermal applications to an existing electrical generating steam plant are not within the scope of this study. At present, the only potential industrial applications of geothermal energy within the City of El Centro is a commercial laundry. The concept of an industrial energy park within the City of El Centro is considered in detail in other sections of this report.

Table 1-6

COMMERCIAL ENERGY CONSUMPTION BY END USE FOR CITY OF EL CENTRO

	<u>%</u>	<u>BTU/yr</u>
Air Conditioning	39	1.5×10^{11}
Water Heating	15	0.6×10^{11}
Refrigeration	13	0.5×10^{11}
Space Heating	18	0.7×10^{11}
Cooking	8	0.3×10^{11}
Other*	<u>7</u>	<u>0.3×10^{11}</u>
TOTAL:	100	3.9×10^{11}

Table 1-7

COMMERCIAL ENERGY CONSUMPTION FOR
THE CITY OF EL CENTRO BY ENERGY SOURCE

	<u>Electricity</u>	<u>Natural Gas</u>
	%	%
Air Conditioning	60	NIL
Space Heating	12	28
Water Heating	NIL	43
Refrigeration	20	NIL
Cooking	0.3	22
Other*	<u>7.7</u>	<u>7</u>
TOTAL:	100.0	100

*includes lighting, elevators, escalators, office machines, etc.

1.8.2.4 End Uses

A brief examination of each of the end uses follows. The largest non-industrial end use consumption in the City is for air conditioning, as would be expected for a desert community. The majority of the air conditioners are of the vapor compression type, some using cooling water in the condenser but most using outside air. Heat pumps, used for heating as well as air conditioning, are also very popular and are increasing in numbers as new buildings are constructed. Server-gas type air conditioners were assumed to be too small in number and estimated to consume too small a fraction of the total energy to be considered in this evaluation.

Refrigeration is one of the largest consumers of energy, a necessity not only for home use but also for the important commercial agricultural business in the Imperial Valley. Refrigeration systems in the City, like the air conditioners, are mainly of the electrically-driven vapor compression type. No gas heated absorption units were assumed in use. Freezers were included under the heading of refrigeration for simplification.

Space heating comprised an estimated 18 to 20 percent of the energy consumption in both the residential and the commercial sectors of the City. This is well below the 56 percent national average, but the large energy use for air conditioners by the City makes up for this difference..

Heat pumps and natural gas are the two major types of heating systems. Electric space heaters were assumed to be of little impact on the total. Direct space heating by petroleum products was assumed to be non-existent.

Energy consumption for water heating, while making up about 16 percent of the total energy picture, is the major end use for natural gas in the residential and commercial sectors. Estimates for the percentage of natural gas used for water heating are shown in Tables 1-5 and 1-7. These estimates for water heating are somewhat overstated, but are offset by the fact that no electrical water heating was assumed.

Energy consumption for cooking makes up one of the smallest portions of the major end use consumptions. The major source of energy in this category is natural gas.

Rounding out the balance of the energy consumed is a mass of smaller energy consumption categories which include clothes drying, lighting, elevators, escalators, office machines, small appliances, etc.

1.8.3 Geothermal Applications

Given the major end uses described in the previous section (1.7.2.4), the next step is to identify those potential end uses suitable for geothermal energy application.

The main attribute of geothermal energy is heat. Therefore, geothermal energy applications to various end uses must be analyzed in terms of the economic and technical feasibility of direct and indirect heat conversion.

This study is focusing on nonelectric applications of geothermal energy, however, some electric production may be included to provide electric power for operating geothermal auxiliary equipment. This electric production would result in a geothermal energy system that is not dependent on conventional sources of electricity, and is thereby totally energy independent.

The following end uses were chosen for possible geothermal application, each based on: (1) its adaptability to using hot geothermal brine for an energy source, utilizing equipment available on the market today; (2) its significant impact on the total energy picture; and (3) its practicality for adapting to geothermal energy.

Air conditioning for both home and commercial use is adaptable to geothermal energy by use of lithium bromide-water absorption chillers. Hot geothermal brine can be used as the heat source in the absorption chilling system.

Commercial refrigeration can utilize an absorption type refrigeration system with geothermal energy providing the heat source, especially where large capacity cooling requirements make it possible to use commercially available chillers. Commercial refrigeration would require using the ammonia-water absorption process with geothermal energy providing the heat source.

Residential and commercial space heating and water heating appear to have the highest potential for direct geothermal application from a technology standpoint, since the systems for heat transfer are efficient and time proven. The utilization efficiency for direct heat application is very high (92-95%) which makes geothermal heating very efficient. Basically the heating systems used would involve heat exchange between geothermal brine and the medium to be heated, namely air or water.

New industrial processes also have the potential for geothermal energy application as direct heat uses and can be tailored to provide the opportunity for energy cascading to improve overall heat utilization.

1.8.4 Summary

The energy utilization survey has 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 1-8. 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, however, the one industrial natural gas user is addressed in some detail in Section 6.3.

Electrical and natural gas energy usage has been converted to BTU's. This results in a total of 9.8×10^{11} BTU/yr consumed by the City. The ratio between electrical energy consumption and natural gas energy consumption is almost 2 to 1. Nationwide surveys show that the use of natural gas energy is about two to three times that of electrical energy. The reason that El Centro figures differ so drastically is twofold: (1) the wide use of electrical air conditioning which makes up over one-third of the total energy used; and (2) the exclusion of industrial gas users from the consumption figures as explained previously.

Table 1-9 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.

1.8.5 Conclusions

Approximately 78 percent of the total energy consumed in the residential and commercial sectors of the City is potentially replaceable by geothermal energy. As shown in Table 1-10, the geothermal energy required to replace 78 percent of the present energy consumed is estimated at 16.98×10^{11} BTU/yr compared to the present level of 7.6×10^{11} BTU/yr.

In Table 1-10, utilization efficiencies shown in column 2 are COP's (coefficient of performance) for air conditioning and refrigeration and natural gas combustion efficiencies for space heating and water heating. Column 3 shows the actual heating/cooling loads for the individual end uses. Column 4 lists the geothermal utilization efficiencies based on COP's for absorption chillers (for air conditioning and refrigeration) and direct heat efficiencies (for space heating and water heating). The result in column 5 shows the geothermal heat energy required to replace the conventional energy source.

Table 1-8

ENERGY CONSUMPTION FOR THE CITY OF EL CENTRO BY SECTOR

	<u>Electricity</u>		<u>Natural Gas</u>	
	<u>(KWH/yr)</u>	<u>(BTU/yr)</u>	<u>(Cu.Ft./yr)</u>	<u>(Btu/yr)</u>
Residential	104,279,960	3.56×10^{11}	233,521,500	2.34×10^{11}
Commercial	<u>75,364,079</u>	<u>2.57×10^{11}</u>	<u>135,962,700</u>	<u>1.36×10^{11}</u>
TOTAL:	179,644,039	6.13×10^{11}	369,484,200	3.70×10^{11}
Total = 9.8×10^{11} BTU/yr				

Table 1-9

TOTAL ENERGY CONSUMPTION BY END USE FOR CITY OF EL CENTRO

	<u>%</u>	<u>BTU/yr</u>
Air Conditioning	37	3.6×10^{11}
Water Heating	16	1.6×10^{11}
Space Heating	19	1.9×10^{11}
Commercial Refrigeration	5	0.5×10^{11}
Residential Refrigeration	6	0.6×10^{11}
Cooking	10	1.0×10^{11}
Residential Clothes Drying	2	0.2×10^{11}
Other	<u>5</u>	<u>0.4×10^{11}</u>
TOTAL:	100	9.8×10^{11}

Table 1-10

GEOTHERMAL HEAT REQUIRED FOR THE CITY
OF EL CENTRO

	<u>Energy Consumed (10¹¹ BTU/yr)</u>		<u>Utilization Efficiency</u>		<u>Actual Heating/Cooling Load (10¹¹ BTU/yr)</u>		<u>Geothermal Utilization Efficiency</u>		<u>Geothermal Heat Required (10¹¹ BTU/yr)</u>
Air Conditioning (E)	3.6	x	2.0	=	7.2	÷	0.63	=	11.43
Water Heating (NG)	1.6	x	0.64	=	1.02	÷	0.92	=	1.11
Space Heating (NG)	1.08	x	0.75	=	0.81	÷	0.95	=	0.85
(E)	0.84	x	2.0	=	1.68	÷	0.95	=	1.77
Commercial Refrigeration (E)	<u>0.5</u>	x	2.0	=	1.0	÷	0.55	=	<u>1.82</u>
TOTAL:	7.6								16.98

(E) Electrical

(NG) Natural Gas

1.9 DETAILED ENERGY EVALUATION

1.9.1 Introduction

The analysis of the application of geothermal energy to the City of El Centro must not only include a detailed analysis of the overall energy requirements of the city, but must also include a geographical breakdown of the energy requirements. This analysis will aid in developing a model of a geothermal heating and cooling distribution system as well as providing a data base for the calculation of the repayment of capital expenditures through energy savings.

This section explores the residential sector of the City of El Centro, and will serve as a model for the analysis of the commercial sector. Figure 1-3 gives an overview of the City and the geographical locations of the residential, commercial/industrial, and school/park sectors. This also displays the need for an organization of the City's energy consumption by district, for as with any slowly developed area, the City has grown tract by tract, each with its own characteristics.

1.9.2 Energy Use Modelling

1.9.2.1 Residence Type Analysis

The residential sector was divided into districts based on age, size, and homogeneity of the residences. The breakdown is shown in Table 1-11. The City's residences were separated into six categories: mobile homes, high-density apartments (more than 10 dwelling units per acre), low-density apartments, houses of 900 to 1,000 square feet, houses of 1,000 to 1,200 square feet, and houses of 1,200 to 1,400 square feet. A minority of individual residences do not fit into these categories, but they have been averaged with residences in the same district. The categories were designed to fit the residential breakdown instead of attempting to fit the residences to randomly chosen categories. The analysis of the residential sector was accomplished on a microscopic basis using the City Assessor records, without regard to the overall totals of the breakdown. Therefore, a comparison of the total number of dwellings and the population of each with a census of the City should be similar to support the validity of the residential sector breakdown. In fact, the estimated population from the detailed breakdown (24,210) is slightly higher than that of the January 1977 Census (22,660). This would be supported by the fact that there are residences in the City which are second homes for winter residents. The impact of this situation on the City's energy consumption, however, is not considered significant.

1.9.2.2 Residential Energy Use

An analysis of overall energy consumption was undertaken to break down the consumed energy by end use. Two forms of energy are supplied to the residences in El Centro as in most other areas of the nation: electricity and natural gas. There are small, localized exceptions (all electric homes) which will be accounted for in the analysis. Table 1-12 displays a residential energy utilization breakdown by type of

EXISTING GENERALIZED LAND USE EL CENTRO, CALIFORNIA

LEGEND

RESIDENTIAL		TRAILER PARK	INDUSTRIAL	PUBLIC USES & FACILITIES			
SINGLE FAMILY		COMMERCIAL	INDUSTRIAL	CH	CITY HALL	E	ELEM. SCHOOL
TWO FAMILY		COMMERCIAL	INSTITUTIONAL	P	POLICE STATION	J	JR. HIGH SCHOOL
THREE & FOUR FAMILY		HOTEL, MOTEL	CHURCH & SCHOOL	F	FIRE STATION	H	HIGH SCHOOL
FIVE OR MORE FAMILY		PARKING		HOSP	HOSPITAL		PARKS

FIGURE 1 - 3

Table 1-11

GEOTHERMAL RESIDENTIAL DISTRICTS

<u>DISTRICT #</u>	<u>D.U./ACRE</u>	<u>TOTAL ACRES</u>	<u># OF DWELLINGS</u>	<u>SQUARE FOOTAGE</u>	<u>POPULATION</u>
1	1.26	56.87	72 Mobile Homes	1,400	216
2	20.69	14.69	304 Apt. Units	680	1,150
3	3.5	57.62	201 Houses	1,240	563
4	9.94	30.07	299 Mobile Homes	1,080	593
5a	35.68	4.82	172 Elderly Apts. (pl.)		*258
5b	16.99	13.65	232 Condos (under const)		*580
5c	18.25	2.41	44 Apts.		110
6	3.68	263.05	969 Houses	1,330	3,876
7	2.75	211.83	583 Houses	1,020	2,332
8	3.24	149.21	323 Houses	1,300	1,233
9	4.97	204.17	805 Houses		
			210 Apt. Units	950	3,384
10	5.92	35.08	208 Mobile Homes	240	415
11	5.87	202.49	780 Houses		
			409 Apt. Units	1,050	2,593
12	3.99	238.15	762 Houses		
			189 Apt. Units	1,200	3,048
13a	18.12	6.42	116 Apt. Units		(406)
13b	12.79	6.8	87 Elderly Apts.	650	*269
14a	9.98	5.11	51 Apt. Units	1,200	128
14b		13.00	Vacant Land & Church	---	---
15	8.20	11.82	97 Apt. Units	730	234
16a	----	5.8	Commercial	---	---
16b	13.06	15.0	196 Apt. Units	900	352
17	3.21	197.04	583 Houses		
			50 Apt. Units	1,000	2,623
18	3.44	42.14	142 Houses		
			3 Apt. Units	980	685
<u>TOTAL:</u>		1,787.24	7,887		24,210

*Projected Population

Table 1-12

ANNUAL RESIDENTIAL ENERGY USE BREAKDOWN (PRELIMINARY)

RESIDENCE TYPE	BASELOAD		HEATING LOAD		COOLING LOAD		WATER HEAT		TOTAL	
	(KWH)	(THERMS)	(KWH)	(THERMS)	(KWH)	(THERMS)	(KWH)	(THERMS)	(KWH)	(THERMS)
Mobile Home	3,930 ²	46 ²	510	199 ^{2*}	6,570 ^{4*}	----	1,210	76 ²	12,250	321
(All Electric)	4,260 ²	---	2,050 ^{1*}	---	6,570 ^{4*}	----	3,970 ^{3**}	---	16,850	---
High-Density Apt.	4,090 ²	46 ²	287	38 ^{2*}	5,320 ^{4*}	----	780	65 ²	10,477	149
(All Electric)	4,420 ²	---	570 ^{1*}	---	5,320 ^{4*}	----	2,600 ^{3**}	---	8,910	---
Low-Density Apt.	4,240 ²	46 ²	190	74 ^{2*}	7,250 ⁴	----	1,300	108 ²	12,980	228
(All Electric)	4,570 ²	---	775 ^{1*}	---	7,250 ⁴	----	4,340 ^{3**}	---	16,935	---
House - 900-1,000 ft. ²	3,930 ^{1**}	46 ³	510	199 ^{3*}	6,570 ^{1*}	----	1,210	76 ^{2**}	12,250	321
(All Electric)	4,260 ^{1**}	---	2,050 ^{1*}	---	6,570 ^{1*}	----	3,970 ^{3**}	---	16,850	---
House - 1,000-1,200 ft. ²	4,480 ^{1**}	46 ³	560	218 ^{3*}	7,250 ^{1*}	----	1,310	99 ^{2**}	13,600	363
(All Electric)	4,810 ^{1**}	---	2,760 ^{1*}	---	7,250 ^{1*}	----	4,370 ^{3**}	---	18,690	---
House - 1,200-1,400 ft. ²	5,210 ^{1**}	46 ³	637	243 ^{3*}	8,100 ^{1*}	----	1,460	121 ^{2**}	15,407	410
(All Electric)	5,540 ^{1**}	---	2,530 ^{1*}	---	8,100 ^{1*}	----	4,880 ³	---	21,050	---

*Proportioned based on wall & ceiling area, for heating and cooling, based on projected population density (average) for water heat.

**Proportioned assuming base consumption is directly proportional to floor area.

¹Source: Southern California Edison (see References).

²Source: Department of Housing and Urban Development (see References).

³Source: Arizona Public Service (see References).

⁴Low Density apartment assumed similar in cooling demand to a mid-size house (1,000-1,200 ft.²). High density apartment and small house considered similar in all energy demand areas.

residence as outlined in Section 1.9.2.1. The energy consumption due to space heating, space cooling, and water heating have been broken out because of the obvious potential for their conversion to geothermal energy while energy source conversion for cooking purposes, for example, is not considered feasible.

The data listed in Table 1-12 has been labeled "preliminary" because of the bases from which it has been derived. The base loads calculated include cooking, lighting, clothes washing and drying, and the loads due to all of the various appliances present in the house. The source of the data for the calculation of the base loads was a computer simulation for a residence in Blythe, California (similar ambient conditions) provided by Southern California Edison Company and from a Department of Housing and Urban Development (HUD) study of multi-family dwellings in the East Coast area prepared by Hillman Associates. The heating and cooling load calculations were based mainly on the Blythe computer simulation, and also to a large degree on data gathered from Arizona Public Service. In some instances, calculation techniques were taken from the previously mentioned HUD study. The energy demands for domestic water heating were in some instances estimated based on the most reliable consumption figures available for similar situations.

1.9.2.3 Commercial Energy Use

As described previously, the commercial sector encompasses a wide variety of activities. It is for this reason that a breakdown of the commercial energy consumption by end use is rather difficult to determine, even for a small community such as El Centro. A brief survey of the commercial sector indicates that there are no extraordinary end uses for natural gas or electricity consumption. Most members of the commercial sector are small businesses utilizing conventional energy for space cooling, space heating, water heating, and lighting. Therefore instead of attempting to identify all of the various types of businesses present in the City, along with each type of end use consumption value, an average energy consumption value was taken for each business in the commercial sector. Total consumption values for each end use category were derived as described in Section 1.8.2.2.

It has been estimated that there are approximately 950 members of the commercial/institutional sector within the city limits of El Centro with an average consumption of 79,000 KWH/yr and 1430 therms/yr per each member. Approximately 84 percent of this energy is potentially replaceable by geothermal energy.

1.9.3 Geothermal Applications

1.9.3.1 "Replaceable" Energy

In a previous section (1.9.2) the residential sector of the City of El Centro was divided into districts and the residences in each of those districts were categorized. The energy consumption for each category of residence was then estimated by type of consumption. Table 1-13 lists the total estimated consumption for each category of residence and also lists the part of that total which can be most readily replaced by geothermal energy. The quantities of electricity and natural gas which potentially can be replaced with geothermal energy in the residential sector amount to 75 percent and 70 percent, respectively. This is quite obviously an impressive portion of the energy consumed in the residential sector.

Table 1-13

RESIDENTIAL ENERGY CONSUMPTION BY RESIDENCE TYPE (ANNUAL)

<u>RESIDENCE TYPE</u>	<u>NUMBER</u>	<u>CONSUMPTION</u>		<u>REPLACEABLE ENERGY</u>	
		<u>KWH</u>	<u>THERMS*</u>	<u>KWH</u>	<u>THERMS*</u>
Mobile Homes	579	7,100,000	186,000	5,370,000	130,000
High Density Apartments	1,151	12,100,000	172,000	8,280,000	98,000
(All Electric)	97	900,000	-----	900,000	-----
Low Density Apartments	912	11,800,000	208,000	8,950,000	136,000
Houses - 900 to 1,000 ft. ²	1,530	18,700,000	491,000	14,212,000	346,000
Houses - 1,000 to 1,200 ft. ²	2,125	28,900,000	771,000	21,710,000	554,000
Houses - 1,200 to 1,400 ft. ²	1,237	19,100,000	507,000	14,100,000	370,000
(All Electric)	256	5,400,000	-----	4,478,000	-----
TOTAL:	7,887	104,000,000	2,335,000	78,000,000	1,634,000
(BTU/yr)		(3.55 x 10 ¹¹)	(2.34 x 10 ¹¹)	(2.66 x 10 ¹¹)	(1.63 x 10 ¹¹)
RESIDENCE AVERAGE:		13,200	296	9,890	207
(BTU/yr)		(45.0 x 10 ⁶)	(29.6 x 10 ⁶)	(33.7 x 10 ⁶)	(20.7 x 10 ⁶)
PERCENT REPLACEABLE:				75%	70%

* One therm = 10⁵ BTU = 100 cubic feet of natural gas (@ 1000 BTU/CF)

1.9.3.2 Geothermal Energy Requirements

The total amount of geothermal energy that would be required in the residential and the commercial sectors to potentially satisfy all the space conditioning and water heating needs can be estimated using the energy conversion efficiencies for natural gas, electricity, and geothermal energy as illustrated by the calculations in the preceding Table 1-10. The amount of energy annually required by this geothermal system is estimated to be 9.0×10^{11} BTU/yr, to replace 4.29×10^{11} BTU/yr presently consumed in the residential sector. For the commercial sector, 8.0×10^{11} BTU/yr of geothermal energy would be required to replace 3.32×10^{11} BTU/yr presently consumed.

1.9.4 Summary

A detailed energy analysis of the residential sector of the City of El Centro has been performed and has resulted in the defining of districts for the City's residences and preliminary calculations of the total and itemized residential and commercial energy consumptions. The resultant amount of heat energy which must be supplied by the geothermal system is estimated at 194 million BTU/hr annual average. A more precise calculation of the potential geothermal energy requirements of the residential sector is included in the computer analysis work to follow.

SECTION 2

GENERAL ENGINEERING EVALUATION

2.1 INTRODUCTION

A preliminary evaluation of the practical methods of geothermal heat extraction, transmission, storage, 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. Specific end uses which appear to have the greatest potential for geothermal applications are space heating and cooling, water heating, commercial refrigeration and industrial process heat.

2.2 WEATHER ANALYSIS

Space heating and cooling comprise over half of the total energy consumed in the City of El Centro (0.36×10^{12} BTU/yr space cooling, 0.19×10^{12} BTU/yr space heating). These two end uses have the greatest potential for geothermal applications and have the greatest affect on the economic feasibility of using geothermal energy. Since these two end uses are weather dependent, a look at the weather history of El Centro is in order.

Weather data has been compiled on a month-by-month basis for individual years by the Imperial Irrigation District to as far back as 1914. Also, the Naval Weather Service Command has compiled weather data for El Centro over a 16-year period on a month-by-month basis including a 16-year summary.

The climate of the Imperial Valley is definitely a desert product. Space heating may be necessary from late October to mid-April, with occasional overnight frosts. The Valley has a rainy season from the first of November through March averaging a little more than three hours a month with average yearly rainfall of 2.81 inches. The only recorded snowfall of any consequence occurred in 1932, $2\frac{1}{2}$ inches were recorded over a nine-hour period.

Figure 2-1 shows the temperature distribution for the period 1945-1960. The temperature ranges from a maximum of 120F to a minimum of 25F. The average mean dry-bulb temperature for this period was 74F, wet-bulb temperature 57F, corresponding to a relative humidity of 34 percent. Assuming a normal distribution curve, this means that 95 percent of the time the temperature in El Centro is between 39F and 109F.

El Centro has 1,216 heating degree days and 3,794 cooling degree days, based on the traditional 65F base temperature. It can be seen that three times as much cooling is required as heating. As a matter of comparison, San Francisco, California has 3,042 heating degree days and 108 cooling degree days.

Figure 2-2 shows the cumulative percent of total hours versus dry bulb temperature. This shows that approximately 35 percent of the 8760 hours in a typical year the temperature is 65F or less, or 65 percent of the time the temperature is above 65F.

Figure 2-1

Figure 2-2. CUMULATIVE TEMPERATURE DISTRIBUTION FOR EL CENTRO, CALIFORNIA

Naval weather data has shown the hottest months in El Centro to be May, June, July, August, September, and October, with July being the hottest at an average temperature of 93F. The coldest months are December, January, and February with January being the coldest at an average temperature of 55F. November, March, and April are interim months averaging a comfortable 67F.

Looking at a composite load-duration curve for the month of July over the period 1945-1960 shows that for a typical day the average temperature is 93F with temperatures ranging from a low of 65F to a high of 120F (see Figures 2-3 and 2-4). It can be seen that space heating is not required during July. The other summer months bear similar curves with very little to no space heating required.

A composite load-duration curve for the month of January shows that for a typical day the average temperature is 55F with a temperature ranging from a low of 25F to a high of 86F. The required amount of space cooling during January averages out to about one hour per day. Other winter months are similar.

With knowledge of the foregoing weather data, a unique set of factors is defined for district energy systems within the City of El Centro. Unlike most communities lying on or adjacent to a KGRA which utilize geothermal energy for direct heating purposes, El Centro would benefit more from the conversion of geothermal energy to space cooling than heating. Therefore, efforts are being made in developing concepts for district cooling systems using geothermal energy as well as utilizing existing concepts for district heating systems.

2.3 GEOHERMAL HEAT EXTRACTION

The geothermal energy required to replace 78 percent of the present energy consumed in the City of El Centro is estimated at 16.98×10^{11} BTU/yr. This does not include the potential new industrial geothermal applications.

The Heber KGRA geothermal reservoir is the energy source for this study. The area of maximum temperature gradient is centered around the township of Heber which is approximately $4\frac{1}{2}$ miles south of the City of El Centro. As described in Section 1.6 various brine transmission corridors were evaluated from the center of the KGRA to the City. But since recent information has indicated the high probability of finding desirable brine temperatures in areas within the City, brine transmission corridors will be confined to within the City limits.

2.3.1 Geothermal Fluid Production/Reinjection

The piping and instrumentation diagram for a typical production, surface, and reinjection facility is shown in Figure 2-5. A cement-cased production well would be drilled to a depth of 7,000 feet. If required, the hole could extend to a depth of 10,000 feet to provide core samples for geological analysis and temperature gradient readings. These readings would form a data base on which to assess the technical and economic viability of developing geothermal resources from deeper horizons using normal area temperature gradients for nonelectric process heat.

A totally submersible electric driven downhole pump, with a setting depth of 500 feet, would pressurize the production system to prevent brine flashing. A sand

Figure 2-3

Figure 2-4

PIPING & INSTRUMENT DIAGRAM
PRODUCTION, SURFACE & REINJECTION FACILITIES

Figure 2-5

separator would eliminate entrained solids further downstream. The present design incorporates a counterflow shell and tube heat exchanger to provide the interface between the geothermal fluid and the secondary fluid distribution system.

A centrifugal reinjection pump would pressurize the reinjection system to provide adequate flow through the cement cased reinjection well, which would extend to a depth of 4,000 feet. All process piping and equipment would be properly insulated.

Production brine temperature is expected to be around 250F with reinjection temperature above 160F. Brine production flows of around 365,000 lb/hr per well are expected. Production flows of 585,000 lb/hr are possible with a downhole pump setting depth of 1000 feet and some modifications to the well casing to accommodate this high flow rate.

Temperature, pressure, and flow recorders would provide a permanent record of geothermal fluid production rates and well flow characteristics.

2.4 REFRIGERATION TECHNIQUES

A preliminary comparison of available refrigeration technology was completed to determine the most realistic design parameters for large scale geothermal air conditioning applications within the City of El Centro. Table 2-1 summarizes the results of this evaluation.

Four refrigeration cycles were considered for comparison, one organic Rankine compression cycle and three absorption refrigeration cycles. The organic Rankine compression cycle is one proposed and tested by Barber Nichols Engineering Company utilizing R-11 as the rankine cycle working fluid and R-11 also as the refrigerant. This cycle has been tested in a prototype 77 ton York Open Turbopak Centrifugal Chilling Unit built for a solar cooling demonstration at the Los Alamos Scientific Laboratory National Security and Resources Study Center. Test results were used as the basis for calculating performance parameters for geothermal application at a resource temperature anticipated to be found in the City of El Centro.

The three absorption processes considered consist of two proven cycles utilizing lithium-bromide/water and ammonia/water and one yet unproven process proposed by WESTEC Services, Inc. involving an ammonium-nitrate and water cycle. The performance data for lithium-bromide/water absorption was based on commercially available chiller units which can operate on hot water resources. Performance data was calculated using standard performance curves provided by manufacturers such as Trane and Arkla.

The ammonia/water absorption process performance data was provided by Lewis Refrigeration. At present ammonia/water absorption units are not being mass produced, but must be custom fabricated.

The ammonium-nitrate/water process proposed by WESTEC Services, Inc. is a new concept which has been proven in batch mode operation but has yet to be tested in continuous operation.

Table 2-1

Geothermal Air Conditioning/Refrigeration Processes

	R-11/R-11 Rankine Compression	Lithium Bromide Absorption	Ammonia Absorption	Ammonium Nitrate Absorption
Reservoir Temperature	250F	250F	250F	250F
Inlet Temperature	215F	200F	200F	150F
Outlet Temperature	163F	180F	180F	135F
Condensing Temperature	95F	95F	95F	95F
Evaporator Temperature	42F	42F	42F	42F
Brine Heat Flow	79 $\frac{\text{BTU}}{\text{lb}}$	62 $\frac{\text{BTU}}{\text{lb}}$	62 $\frac{\text{BTU}}{\text{lb}}$	90 $\frac{\text{BTU}}{\text{lb}}$
Refrigeration Efficiency	0.33	0.36	0.20	0.73
COP	0.63	0.63 ²	0.35 ⁴	0.75 ⁵
RTU	0.0041 $\frac{\text{ton-hr}}{\text{lb}}$	0.0033 $\frac{\text{ton-hr}}{\text{lb}}$	0.0018 $\frac{\text{ton-hr}}{\text{lb}}$	0.0056 $\frac{\text{ton-hr}}{\text{lb}}$
Capital Cost (1977 \$'s)	\$196/ton ¹	\$409/ton ³	\$420/ton	\$431/ton ¹

1. Based on mass production of prototype equipment presently designed for solar/geothermal application.

2. Based on a commercially available single-stage system.

3. Assumes derated capacity at 45 percent of rated capacity.

4. Based on a commercially available two-stage system.

5. Based on the conceptual design of a prototype ten effect unit.

The ammonium-nitrate/water absorption process shown in Figure 2-6 differs from the other two absorption processes considered in that it is based on a solid -- liquid endothermic reaction rather than a liquid -- liquid exothermic process. In other words, the strong liquor out of the generator (a multiple effect distillation unit in this case) is purposely cooled to the point where crystallization takes place. The solid crystals are then recombined with the cooled distillate (water in this case) resulting in an endothermic cooling effect. A tremendous uptake of heat takes place in this dissolving process because of the phase change from solid to liquid as compared to a smaller heat uptake when diluting a strong liquor of the same substance to form a weak liquor.

Performance data for the ammonium-nitrate/water cycle was excerpted from data developed for the conceptualization of a low temperature waste heat absorption air conditioning system proposed by WESTEC Services, Inc. The capital costs associated with mass producing such a system are unknown at this time since special process equipment from the chemical and pharmaceutical industries may have to be adapted to handle the continuous crystallization and subsequent dissolving of the ammonium-nitrate. An estimated capital cost, however, is included in Table 2-1 for comparison.

A comparison of the performance characteristics of the lithium bromide and ammonia absorption processes shows that the lithium bromide process can far out perform the ammonia process at the assumed resource temperature. This fact coupled with the high toxicity of ammonia and the lack of mass produced units for commercial and residential application leads us to eliminate the ammonia absorption process from further consideration.

A comparison of the lithium bromide absorption and the organic Rankine compression (ORC) cycle performance characteristics shows that both processes have almost identical overall coefficients of performance (COP), however, the organic Rankine compression process has a higher brine heat utilization resulting in a higher refrigeration thermal utilization (RTU). This fact combined with the lower projected initial capital cost for ORC cycles and the lower thermal inertia associated with the Rankine compression process makes it a prime candidate for geothermal refrigeration in the City of El Centro. Unfortunately, the initial capital cost for ORC Systems is presently only a projection based on a few prototype units built for solar cooling demonstrations. At present, no one is mass producing these units for either solar or geothermal applications.

An organic Rankine compression and ammonium nitrate absorption process performance characteristics comparison shows that the ammonium nitrate absorption process has the potential to out perform the ORC process through higher brine utilization, higher COP, and higher refrigeration thermal utilization. In addition, the ammonium nitrate absorption process has the potential of operating at low inlet temperatures and low source-sink temperature differences where the ORC cycle cannot function efficiently and where ORC cycle equipment sizes become unwieldy. This feature would allow the use of high grade geothermal heat for industrial uses, while cascading the rejected low grade heat to the absorption chiller for residential/commercial air conditioning, a potentially more cost effective approach. Unfortunately, this endothermic absorption concept has not been tested in a continuous process nor have detailed capital cost projections been made as yet to be conclusive about its potential benefits over the organic Rankine compression and lithium bromide processes.

Figure 2-6 SCHEMATIC OF THE AMMONIUM-NITRATE/WATER REFRIGERATION PROCESS

Since the charter of this section is to determine the most realistic design parameters for large scale geothermal air conditioning applications within the City of El Centro, it becomes obvious that a conservative approach requires the use of the lithium bromide absorption process as the basis for a realistic engineering and economic evaluation. It is also concluded, however, that the organic Rankine compression and ammonium nitrate absorption processes have great potential and that they be considered in the final analysis.

2.5 HEAT DELIVERY METHODS

There are various methods described in the open literature that can be utilized to extract and/or deliver heat from point to point. The district heating and cooling system has been widely analyzed and has been found to have many significant advantages:

1. Less space is used with a central heating/cooling system than with unitary systems at each end use point.
2. Heating/cooling equipment is less expensive per unit output with a central system.
 - a. Lower cost of energy required (\$/unit energy)
 - b. Large units are more durable
 - c. Large units are more efficient
 - d. Total effect of one unit shut down in a central plant containing several partial capacity units will be less than the effect of the failure of one end point unit, from the users viewpoint.
3. Concentration of maintenance to one area is more economical.
4. Better safety is expected in a central plant.

The main disadvantage of the district heating/cooling scheme, and a limiting factor to the economic feasibility of the system, is the large and thus expensive distribution network that is required to supply and return the thermal transport medium from producer to consumer.

Therefore, in order to maximize all of the benefits of a central system and minimize the cost, especially the distribution system cost, an economic sensitivity analysis was made of district heating and cooling systems for the City of El Centro. The computer model used in this analysis is described in Section 2.8.

2.5.1 Heat Delivery Mediums

In conjunction with a district heating and cooling system there are various heat transfer mediums possible for use. These mediums will be investigated along with

four types of piping systems for delivery of these mediums to the consumer. Table 2-2 describes some of these mediums with a brief description of the advantages and disadvantages of each.

Hot water and chilled water are the common denominators of all of the geothermal replaceable heating and cooling requirements of the City. By supplying the appropriate amount of hot water and chilled water to the consumer, requirements for space heating and cooling, water heating, commercial refrigeration and process heat can all be satisfied with the proper interface equipment. A brief discussion of the advantages of hot and chilled water systems follows:

HOT WATER SYSTEM: Hot water can be easily provided utilizing geothermal heat by the use of a heat exchanger at the well site, whereby hot brine would exchange heat with clean city water. The heated clean (or treated) water would be used directly by the consumer for space heating, water heating, and commercial refrigeration (absorption chiller).

The transporting of hot clean water, as opposed to hot brine, has the distinct advantage of eliminating potential scaling problems as well as potentially harmful environmental problems. As a result of these facts, the transmission pipe can be safely buried underground. Although an intermediate heat exchanger would be required in using clean water, the cost savings in pipe and equipment maintenance would more than offset this capital cost.

CHILLED WATER SYSTEM: Clean chilled water can be obtained utilizing absorption chillers heated by hot clean water derived from hot geothermal brine. Chilled water plants would be either centrally located or distributed throughout the City. Chilled water would be pumped to the consumer for space cooling purposes.

The transporting of chilled water from central chilled water plants has the technical advantages as mentioned in Section 2.5 for a district cooling system as well as the environmental advantage of limiting the number of cooling towers that would be required for each district.

2.5.2 Piping Systems

An evaluation was made of the various types of piping systems that may be utilized for district heating and cooling. The systems can be designated as four types: one-pipe, two-pipe, three-pipe, and four-pipe systems.

a. **One-Pipe System** - The one-pipe system consists of one supply pipe with no return pipe. Therefore, from a material standpoint, it is the most inexpensive of the four types. This system would transport hot water during the winter and chilled water during the summer. The fluid, once used, would have to be disposed of, most likely through the sewage system. A disadvantage to the system is that only hot water or chilled water would be available at one time from the central plant. Since water is a valuable commodity in this heavily irrigated agricultural community and energy has been expensed to either raise or lower the temperature of the water to the point where effective heat transfer can take place, disposal of the heat transfer medium to sewage is not a favorable alternative.

Table 2-2
HEAT DELIVERY MEDIUMS

<u>MEDIUM</u>	<u>USE</u>	<u>ADVANTAGES</u>	<u>DISADVANTAGES</u>
1. Hot Water	<ul style="list-style-type: none"> - Space Heating - Water Heating - Absorption Chillers - Industrial Process 	<ul style="list-style-type: none"> - No scaling problems - Can bury pipe - Can use in one, two, or three pipe system 	<ul style="list-style-type: none"> - Use of clean hot water mandates need for intermediate heat exchanger and associated piping - Loss of some thermal efficiency
2. Hot Steam	<ul style="list-style-type: none"> - Same as hot water 	<ul style="list-style-type: none"> - Lower pumping costs - More BTU's per pound 	<ul style="list-style-type: none"> - Live steam if pipe breaks
3. Hot Brine	<ul style="list-style-type: none"> - Same as hot water 	<ul style="list-style-type: none"> - Direct heat use most efficient 	<ul style="list-style-type: none"> - Scaling a problem when flashed, thus expensive maintenance costs - Requires above ground piping - Higher friction losses in transmission - Must use four pipe system if using chilled clean water for cooling - Need special interface to run through chillers
4. Chilled Water	<ul style="list-style-type: none"> - Space Cooling 	<ul style="list-style-type: none"> - No scaling problems - Can bury pipe - Use of central chilled plant allows higher efficiencies, lower cost per BTU cooling - Can use in one, two, or three pipe system 	<ul style="list-style-type: none"> - Requires absorption chillers at source point - Loss of some thermal efficiency - May experience large ground heat gains on chilled lines
5. Chilled Brine Solution	<ul style="list-style-type: none"> - Space Cooling - Refrigeration 	<ul style="list-style-type: none"> - Use of central chilled water plant allows higher efficiencies, lower cost per BTU cooling 	<ul style="list-style-type: none"> - Possible scale problems - Requires use of four pipe system if using hot clean water for heating - Higher friction losses in transmission
6. Ammonia	<ul style="list-style-type: none"> - Space Cooling - Refrigeration 	<ul style="list-style-type: none"> - Use of central chilled plant allows higher efficiencies, lower cost per BTU cooling - Lower pumping cost 	<ul style="list-style-type: none"> - Toxic, flammable, explosive - Requires use of an installation of expansion valve and safety devices at user point
7. Hot Air	<ul style="list-style-type: none"> - Space Heating 	<ul style="list-style-type: none"> - Lower friction losses - Can easily interface with existing equipment 	<ul style="list-style-type: none"> - Requires large supply pipe - Requires large surface heat exchange - Requires intermediate heat exchanger and associated piping between the two phases (brine-air)
8. Chilled Air	<ul style="list-style-type: none"> - Space Cooling 	<ul style="list-style-type: none"> - Same as hot air 	<ul style="list-style-type: none"> - Same as hot air plus - May experience large ground heat gains on chilled air lines

b. Two-Pipe System - The two pipe system employs both a supply pipe and a return pipe. Like the one pipe system either hot water or chilled water is circulated depending upon the seasonal demands. Since the system is a closed loop, the same water can be recirculated, thereby recovering a large amount of heat as well as the fluid itself. This heat recovery (cold recovery for the cooling scheme) reduces the amount of required geothermal heat input. The two-pipe system can also be used as two supply lines providing both hot water and chilled water at the same time. This would fulfill the needs of each individual user but would require the disposal of the water to sewage. Like the one-pipe system, disposal of precious water and energy to sewage would be unfavorable.

c. Three-Pipe System - The three-pipe system utilizes two pipes for supply and one pipe for return. The two supply pipes can be hot and chilled water (or hot water or chilled water of two different flow rates) with one common return pipe. The three pipe system is versatile in that hot water and chilled water can be supplied to the consumer in any quantities necessary for proper air conditioning control. Since hot water and chilled water return are mixed together in the same return pipe, recovery of hot and cold water would be less effective than with the two-pipe or four-pipe systems.

d. Four-Pipe System - The four-pipe system utilizes two independent loops. One loop is used for hot water and the other for chilled water. This allows flexibility, through controls, to meet the entire range of thermal energy demand for both heating and cooling. Because of the complete separation of hot and cold fluids, heat recovery (or cold recovery) would be far greater than with the three-pipe scheme. This means less geothermal heat required for heating hot water and chiller units; but because of the increase in piping required, expenses could be higher overall.

The piping systems described above are all technically feasible. The economic feasibility will be the determining factor as to which system will be recommended. Section 3.5 gives an in-depth view into the economics of the various piping schemes.

2.5.3 Storage

For the El Centro district heating and cooling system, storage tanks for hot and chilled water would be required to handle load fluctuations on a day-to-day basis. Storage tanks would be located throughout the City at chilled water plant sites and hot water distribution points. Each chilled water plant and distribution point would supply water to a particular district.

In the chilled water plant system, accumulators would provide storage for minor flow fluctuations. Added tanks would store chilled water in readiness for heavy load conditions.

Chillers would be sized to handle the normal load by circulating the fluid through the circuit shown in Figure 2-7 from the chillers to the consumer and back to the chillers again. As the load increases during the day, a larger amount of chilled fluid would be required; thus fluid from the storage tanks would be drawn as needed, first from tank No. 1, then No. 2, etc. As the load decreases in the evening, chilled water would be diverted back to storage until, during low load periods, the entire stored

Figure 2-7 CHILLED WATER SYSTEM

chilled water capacity would be replenished for the next day's use. By utilizing this method, the chillers are always operating at their most efficient point - design capacity.

The hot water supply system would be similar, except that the storage capacity for hot water would be expected to be much less than for chilled water because of the smaller amounts of hot water required for the relatively mild winters experienced in El Centro.

2.5.4 Modular System

The modular system concept combines the aspects of (1) the decentralization of the one plant concept to reduce the size of pipe mains, while still maintaining (2) the concept of a central chilled water/hot water district system; and (3) storage for peak load shaving.

Figures 2-8 and 2-9 show the basic concepts involved in a central chilled water/hot water plant and a modular system.

The central plant concept has the benefit of better efficiency or lower cost per unit output, but has the disadvantage of a large and expensive pipe network. The 24-inch pipe main shown in Figure 2-8 was sized according to the chilled water required for District 1 during the summer cooling season. An 8F temperature difference between the supply and return temperatures was used for the sizing. The chiller plant/hot water distribution point is located at the well site. This one central plant serves the entire City. Thus, it can be concluded that pipe mains emanating from this one plant would be very large (see Figure 3-3).

By the use of a modular system, such as shown in Figure 2-9, the one plant concept is decentralized into many smaller plants located throughout the City. The modular system emphasizes the distribution of hot water to the modular unit sites. Distribution of hot water to District 1 yields a 20F temperature difference between supply and return temperatures resulting in the requirement of only a 16-inch pipe main. Another advantage of the system is that, since each modular system serves a small number of units, it is more sensitive to demand fluctuations.

The extreme modular system case would be for each building to become a modular plant which would result in only hot water being distributed to each building. The economics of the modular system concept is detailed in Section 3.10.2.

2.6 SYSTEM INTERFACE

Section 1.8 described the various end uses which have the highest potential for geothermal energy applications. Energy consumed for air-conditioning, space heating, water heating and commercial refrigeration make up over 75 percent of the total energy consumed in the City. If geothermal energy is to become a viable energy replacement for existing energy sources, there must be proper interface or energy conversion equipment between the geothermal energy source and the consumer.

Figure 2-8 CENTRAL PLANT SYSTEM

Figure 2-9 MODULAR SYSTEM

The major types of heating and cooling equipment presently in use in the City are: vapor compression air conditioners (including heat pumps), natural gas forced-air heating, natural gas water heating, and vapor compression refrigeration.

An evaluation was made as to the various types of interface schemes possible for replacing or supplementing the above listed equipment with equipment for use with a district heating and cooling system.

Geothermal space heating systems have been in existence for a number of years. By the use of a simple heat exchanger or fan-coil unit, geothermal energy can be directly used for space heating requirements. A fan-coil unit is the prime candidate for the interface at the consumer point in the system. This choice was made over other forms of heating equipment (baseboard heating, heat pipes, etc.) because a fan-coil unit can be used for both heating and cooling. Space cooling is the major source of energy consumption in the City, therefore the viability of the geothermal system is highly dependent on its ability to provide space cooling as well as heating.

In most cases, it would be possible to retrofit existing buildings with fan-coil units in the existing air-conditioning ductwork. With the proper size fan, a coil can be placed in the ductwork for use with either hot water or chilled water. The existing heating and cooling equipment could be used during peak demand periods to take part of the load or at any time as a backup means. On those residences that have window units and thus no ductwork, it is assumed that free-standing fan-coil units can be placed next to the window with minimal ductwork.

Since geothermal fluid from the Heber Reservoir is not clean enough to be used directly in the home for domestic use, an intermediate loop would be required between the brine wells and the consumer. Thus an interface between hot brine and clean city water would be made by a heat exchanger at the well site. See Figure 2-10. For the cooling mode an additional loop would be required. Hot geothermally heated city water would be used to generate chilled water by use of a lithium bromide/water absorption chiller. The cold water loop would provide chilled water to the fan-coil units for space cooling.

Commercial refrigeration would require a chiller unit of the ammonia/water type.

Domestic water heating using geothermal energy would be accomplished by the use of a preheater tank which is simply a heat exchanger. This would be used in addition to the existing hot water tank, therefore allowing the use of natural gas or electricity as a backup.

2.7 MATERIALS EVALUATION

2.7.1 Pipe Materials

A preliminary investigation into the different types of pipe construction, pipe materials, and pipe insulation uncovers quite a wide variety of combinations from which to choose. The basic criteria in choosing the best combination would be: 1) the pipe must meet the requirements of the heat transfer medium, i.e., the pipe must not

Figure 2-10 GEOTHERMAL SYSTEM INTERFACE

be adversely affected by the medium's temperature, pressure, or chemistry; 2) the insulation must properly limit thermal losses or gains; 3) some form of encasement must protect the pipe and insulation from external loads and the underground environment; 4) the cost-benefit ratio for the pipe-insulation-conduit combination must be examined in relation to the medium being transferred.

There are, of course, many other factors to be considered such as heat transfer characteristics, thermal expansion, creep strength, corrosion protection, etc.

Some of the different types of pipe materials are listed in Table 2-3, giving a brief description of the characteristics of each. Mild steel is the most commonly used material in prefabricated pipe and conduit casings, but experience in the El Centro area has shown that steel pipes have deteriorated due to the corrosive nature of the soils.

It appears that asbestos cement or fiberglass reinforced plastic (FRP) would be suitable for the El Centro district heating and cooling system. With proper insulation, these pipes can be used for both low temperature hot water as well as chilled water. They are lightweight yet can give acceptable strength when supported properly.

Further investigation was made into the economic advantages as well as the technical feasibility of using preinsulated piping systems as a cost cutting measure to reduce the expense of the distribution network.

Preinsulated pipe, very simply, is a prefabricated pipe usually from 10 ft to 13 ft in length which contains an inner core (copper, asbestos-cement, steel, or PVC), insulating material around the inner core (polyurethane foam or calcium silicate), and an outer casing (asbestos-cement or PVC). Because all of the components are packaged into a pipe spool at the factory, the cost per unit length is relatively inexpensive. Besides this main advantage, the prefabricated system is fast and easy to install.

To satisfy the needs of the El Centro distribution system a preinsulated pipe was selected from one of the many lines of pipe offered by a major manufacturer. This pipe has an epoxy lined asbestos-cement inner core with polyurethane foam insulation and an asbestos-cement outer casing. The polyurethane foam insulation is bonded between a lined casing and core, and capped at both ends with water and heat resistant end seals to ensure complete encasement. The material makeup of this pipe precludes any corrosion problems. The conductivity of the pipe-insulation-casing combination is listed by the manufacturer at 0.16 BTU-in/sq ft-hr-F @ 150F.

Because this pipe has a liquid temperature handling range of 32-200F, both chilled water (42F) and hot water (195F) can be transported through this pipe. Pipe operating pressure is limited to 130 psig for pipe sizes 3 inches through 10 inches and 150 psig for pipe 12 inches and larger; thus, the use of this pipe limits the size of a distribution network such that the pressure in any segment of pipe is within the specified operating pressure. Large pressure drops and the resulting large pump head requirements must be avoided with this type of piping material.

Piping for the brine transmission system presents different problems in material selection. Since the previously described preinsulated pipe has a maximum operating temperature of 200F, it cannot be used for brine transmission at 250F. There

Table 2-3

PIPING MATERIALS

FERROUS METALS

Cast Iron	-	Widely used in water and sewer lines
	-	High resistance to atmospheric and soil corrosion
	-	Are comparatively brittle but have acceptable strength
Wrought Iron	-	Highly corrosion resistant
	-	Expensive
Low Carbon Steel	-	Widely used in various applications
	-	Good for low and medium pressure steam & water
	-	Rather economical
	-	Easy to weld
	-	Low corrosion resistance
Stainless Steel	-	Highly corrosion resistant
	-	Very expensive

NON-FERROUS METALS

Note: The use of these materials is confined to within buildings. They are not used extensively in underground mains for thermal conveyance systems.

Copper	-	Widely used for indoor plumbing
	-	Good corrosion resistance
	-	Highly expensive
Aluminum	-	Lightweight
	-	Good corrosion resistance
Brass, Bronze	-	Suitable for low and medium temperature service

NON-METALLIC MATERIALS

Asbestos-cement	-	Often used in water lines
	-	High resistance to corrosion
	-	Low friction losses
	-	Good strength
	-	Highly brittle
	-	Sizes up to 36 in., pressures up to 200 psi, temperatures up to 200F
Concrete	-	Used for large water mains and sewer lines
	-	High flow coefficient
	-	Corrosion resistant
	-	Can withstand significant external loads
Fiberglass Reinforced Plastic (FRP)	-	Temperatures up to 300F
	-	Corrosion resistant
	-	Low friction losses
	-	Lightweight
	-	Easy to install
	-	Good strength
Thermoplastics	-	Temperatures up to 200F
	-	Pressures up to 100 psia
	-	Relatively low strength
Thermosetting Resins	-	Can be used as liner for other pipe materials
	-	Good corrosion resistance
	-	Good for low temperature water service

are preinsulated pipes which can withstand temperatures to 450F but are limited to diameters 12 inches and smaller. This type of pipe has a carbon steel core and an asbestos-cement casing. Transmission pipe sizes in the brine loop network are expected to vary from 3 inches to 18 inches in diameter.

Since the brine will be kept in liquid phase, i.e. no flashing, plain carbon steel should suffice for the brine transmission pipe. Pipe scaling can be kept to a minimum if no flashing occurs. The brine transmission and reinjection piping will be routed above ground so there will be no ground soil corrosive action nor any concern for ground load on the pipe. El Centro's rainy season is very short and humidity is relatively low which should help keep corrosion due to moisture to a minimum.

A pipe material combination which has been used successfully in the past is carbon steel pipe, calcium-silicate insulation, and a sheetmetal aluminum casing. This combination, using fiberglass insulation in place of the calcium-silicate, is another viable solution for the brine transmission pipe.

2.7.2 Insulation

An ideal material for insulation service should be: 1) capable of withstanding repeated wetting and drying without serious deterioration; 2) non-corrosive to pipe materials when wet; 3) a nonconductor of electricity; 4) vermin proof; 5) chemically and physically stable at operating temperatures.

There are a variety of insulation types on the market, the most conventional being fibrous glass, calcium silicate, and polyurethane foam. Physical forms of insulation can be loose-fill, flexible, rigid, reflective, and formed in place.

Ground temperatures in the Imperial Valley range from 66F in the winter to 87F in the summer at depths from 2 to 10 feet. Although in the same underground environment greater heat loss would occur from the hot water line (250F-66F=184F) than that gained by the chilled water line (87F-42F=45F) assuming the same flow rate, pipe size, etc. the heat gained by the chilled water line is of major concern. This is because: 1) chilled water is more expensive to generate than hot water; 2) chilled water has higher demand than hot water in El Centro; 3) the only areas requiring hot water above 195F would be for the chilled water plants, commercial refrigeration, and industrial process heat. Insulation for buried chilled water piping must provide a positive protection against moisture, since with chilled water there is no internal heat to drive out moisture. The insulation must have low permeance and low water absorptivity. A polyurethane foam is a good choice for this use. Since temperatures are relatively low, polyurethane foam is also a good choice for the hot water and hot brine systems.

2.7.3 Conduit

Conduit envelopes protect pipe and insulation against wetness, corrosive soils, and mechanical loads. Conduits break down basically into two types: 1) poured field constructed type; 2) prefabricated type; both types can be either pressure tight or non-pressure tight. Many of the poured envelopes incorporate a combination cement-insulation or insulating cement which is poured around the pipes. Others use a

hydrocarbon envelope of a natural granular asphaltic material of high resin content, or asphalt contained in a metal jacket surrounding the pipe.

U.S. Department of Agriculture data has shown the water table for the El Centro area varying from 5½ feet to more than 9 feet. In some areas close to the irrigation canals, the table may vary from 3 feet to 10 feet.

Because field constructed conduits are more costly than factory prefabricated conduit sections, which can be easily assembled at the site, a look at some of the prefabricated conduit types is in order.

Prefabricated pressure tight steel conduit can be made of either smooth or corrugated steel. The pipe is surrounded with preformed insulation and then the conduit is placed around it with a drain space in between. A coupling is welded to join two sections of conduit; a protective coating, enamel or mastic is used to seal the joints. Sealed asbestos-cement conduits are similar in configuration to the prefabricated steel type except asbestos-cement is used for both the pipe and outer casing. Joints are made with compression type couplings and O-rings for sealing. Epoxy lining and polyurethane foam insulation is also used.

Also similar to this configuration is fiber-reinforced plastic conduit using FRP pipe with polyurethane insulation. Joining sections is by use of a bonding cement or mastic.

2.7.4 Heat Exchanger Materials

The well site heat exchanger(s) would be called upon to transfer heat between Heber reservoir brine (@ 250F) and El Centro city water taken from the Colorado River (@ 70F). The brine characteristics were previously described in Section 1.7. The Colorado River water characteristics are described in Table 5-1.

There is a wide variety of materials for heat exchangers. Tube materials range from mild steel and copper alloys, to expensive titanium. Mechanically, these materials have high strength combined with excellent ductility so that they can be handled with reasonable care without bending, kinking, becoming dented or otherwise damaged.

Tests have been conducted on heat exchanger tube materials under experimental conditions at a Heber Reservoir site. Results taken from tests at Heber's Nowlin #1 Well have shown that carbon steel or titanium tubes can be considered for service at Heber if proper precautions are taken to prevent excessive exposure to air (oxygen) during start-up, shutdown, and maintenance operations. Tests performed at an East Mesa geothermal well site have also shown positive results utilizing carbon steel tubes. After formation of a tenacious layer of magnetic iron oxide, corrosion appeared to have ceased. No signs of pitting or flaking of the oxide were apparent. Copper nickel (90:10) proved to function satisfactorily in lower temperatures but in hotter temperatures corrosive attack was excessive. Titanium tubes showed no signs of corrosion or other damage.

2.8 COMPUTER MODELLING

2.8.1 Introduction

The viability of the El Centro geothermal district heating and cooling system depends upon the technical and economic feasibility of replacing the present system with a geothermal system. An analysis was made of the technical requirements and of the potential capital costs involved in the geothermal system by using a computer model of the district system.

2.8.2 "Geocity"

The computer model "GEOCITY" was a major aid to the technical and economic analysis. This model was developed by Battelle Pacific Northwest Laboratories for calculating costs of district heating using geothermal resources. "GEOCITY" utilizes factors of climate, demography, heat demand of the city, geothermal resource conditions, well drilling costs, type of distribution system, tax rates, and financial factors to determine potential capital and operating costs.

The program provides the flexibility to individually or collectively evaluate the impact of different economic and technical parameters, assumptions, and uncertainties on the cost of providing district heating from a geothermal resource.

"GEOCITY" consists of two major parts: the geothermal reservoir submodel and the distribution network submodel.

The geothermal reservoir submodel calculates the unit cost of energy by simulating the exploration, development, and operation of a geothermal reservoir. The submodels include exploration and development, drilling, reservoir operation, and fluid transmission and disposal.

Figure 2-11 shows the district heating/cooling system model used by the "GEOCITY" computer program. The transmission system constitutes that portion of the system from the brine wells up to the heat exchanger. The distribution system includes that portion of the system from the heat exchanger (and including the heat exchanger itself) to the consumer. The absorption chillers and associated equipment is not a part of the "GEOCITY" computer program, but was included as a part of the distribution system in hand calculations to supplement the computer runs.

The wells in the reservoir network are located at the vertices of equilateral triangles (nodes in a triangular lattice) as shown in Figure 2-11, with pipe runs parallel to the horizontal X-axis. The fluid transmission system has a manifold pipeline for transmitting the geothermal fluid from all rows of wells to the distribution center.

The computer program "GEOCITY" calculates the number of producing, non-producing, and injection wells based on the total geothermal fluid flow rate required by the distribution system. Subroutines calculate the well spacing, pipe size and length required, number of valves and fittings required, thickness of insulation and total cost. Table 2-4 gives a summary of the computer output from "GEOCITY".

Figure 2-11 DISTRICT HEATING/COOLING SYSTEM COMPUTER MODEL

Table 2-4

SUMMARY OF COMPUTER OUTPUT FROM "GEOCITY"

Distribution System Demand and Fluid Transmission Iteration History (Final Iteration)

- Fluid Transmission Submodel Input
- Fluid Transmission Submodel Output
- Convergence Test for Distribution System Demand and Fluid Transmission Iteration

Distribution System Input and Output

- Definition of Districts
- District Populations
- Piping Network and Fluid Conditions for each District
- Capital Costs and Material Requirements of Piping Network for each District
- Main Network and Fluid Conditions for each District
- Total Capital Costs, Material Requirements, and Total Operating Expenses of the Distribution System Summed Over all Districts
- Summary of District Heating Requirements and Capital Costs and City Climatic Characteristics

Reservoir Technical and Economic Input and Output

- Reservoir Characteristics and Well Properties
- Reservoir Exploration, Development, and Operation Costs
- Financial and Tax Data Input
- Annual Cash Flow Statement
- Annual Tax Deductible Expense Statement
- Annual Income Statement
- Annual Payout of Investments (Capitalization)
- Cost Distribution of Energy from the Reservoir

Distribution Economic Input and Output

- Financial and Tax Data Input
- Annual Cash Flow Statement
- Annual Tax Deductible Expense Statement
- Annual Income Statement
- Annual Payout of Investments (Capitalization)
- Cost Distribution of Heat from the District Heating Distribution System

Some of the input parameters used in the reservoir and transmission model as well as the distribution submodel are listed in Table 3-4.

The distribution system submodel calculates the unit cost of heat by simulating the design, construction, and operation of a district heating distribution network. The distribution model includes submodels which (1) design a distribution system for a city by considering building densities, heat demands, and climatic data; (2) calculate heat and heat losses for the system; (3) estimate equipment and material requirements; and (4) estimate construction, operating and maintenance costs.

Capital costs, operating costs, and maintenance costs for the piping network, heat exchanger, pumps, meters, and control equipment are derived based on the distribution system design options.

Chiller plant equipment costs, absorption chillers, cooling towers, and auxiliary pumps are estimated separately by hand, as are retrofit equipment costs, and factored into the computer runs in the final analysis.

2.9 SUMMARY

Space heating and cooling comprise over half of the total energy consumed in the City of El Centro with the space cooling load approximately twice that of the heating load.

The climate of El Centro is a desert type with an average dry bulb temperature of 74F, wet bulb temperature of 57F, and a relative humidity of 34 percent. El Centro has 1216 heating degree days and 3794 cooling degree days.

A preliminary evaluation of the practical methods of geothermal heat extraction, transmission, storage, and delivery to the consumer was made. Geothermal heat extraction will be limited to areas within the City of El Centro eliminating the need for any further investigation into brine transmission corridors outside the City limits.

Brine production wells will be drilled to a depth of 7,000 feet. The production brine temperature is expected to be around 250F with reinjection temperature to be maintained above 160F. Pumped brine production flows of around 585,000 lbs/hr per well are expected for a pump setting depth of 1000 feet.

A conservative approach requires the use of a lithium bromide absorption process as the basis for a realistic engineering and economic evaluation for large scale geothermal air-conditioning applications within the City of El Centro.

The district heating and cooling system has been found to have many significant advantages, the main one being lower cost per unit output. The main disadvantage for a central system is the expensive distribution system.

There are various heat transfer media, the most feasible being clean hot water and clean chilled water.

Interface at the consumer point would be handled by a fan coil for space heating and cooling, a solar type water heater for hot water, and an absorption chiller unit for commercial refrigeration.

Preinsulated pipe is an ideal choice for the El Centro distribution system. This pipe is able to handle the 195F hot water distributed in the winter and the 42F chilled water distributed in the summer. It is relatively inexpensive and easy to install.

The computer model "GEOCITY" was used in modelling the transmission system and the distribution system for El Centro.

2.10 CONCLUSIONS AND RECOMMENDATIONS

The weather analysis has revealed that El Centro would find greater benefit in the application of geothermal energy to space cooling. Therefore efforts have been made in this report to develop concepts for district cooling systems.

It is concluded that the organic Rankine compression and the ammonium nitrate absorption processes have great potential for application to large scale geothermally energized air-conditioning requirements in the City of El Centro. It is recommended that these processes be considered in the final analysis. However, it is concluded that a conservative analysis requires that the lithium-bromide/water absorption process be assumed for the evaluation of near-term geothermal utilization for residential/commercial space cooling.

The one-pipe, two-pipe, three-pipe, and four-pipe systems have all been found to be technically feasible. The economics of each system is evaluated in Section 3.5.

The economic factors affecting the system interface/retrofit equipment is addressed in Sections 3.6 and 6.2.

The modular system concept offers advantages over the central plant system, the main one being lower capital costs due to smaller pipe mains required by distribution of hot water to modular chilled water/hot water plants throughout the City.

SECTION 3

GENERAL ECONOMIC EVALUATION

3.1 INTRODUCTION

A preliminary economic evaluation was completed to determine the overall economic feasibility of replacing conventional energy sources with geothermal energy for all residential/commercial space heating/cooling and domestic hot water for the entire City of El Centro. The evaluation was completed by calculating annual capital recovery charges in dollars per million BTU for a geothermal energy system and comparing it with levelized conventional energy charges for the same period. Capital cost estimates for geothermal energy systems were based on the "GEOCITY" computer program developed by Battelle Pacific Northwest Laboratories. Various sensitivity analyses were conducted to uncover the most favorable scheme for geothermal implementation within the City of El Centro.

3.2 CONVENTIONAL ENERGY COSTS

In any study of alternative energy cost effectiveness, it is essential to establish a model of conventional energy costs during the study period. Although political and economic ramifications concerning foreign oil make any energy cost prediction highly uncertain, conservative estimates were made in determining the following constant dollar fuel costs. Each of the conventional energy sources available to the consumer was evaluated for constant dollar cost escalations over the study period (based on reports published by the Electric Power Research Institute (EPRI) and price forecasts reported to the California Public Utilities Commission by San Diego Gas & Electric Company) and appears in Figure 3-1. The following assumptions were made in determining the constant dollar fuel costs:

1. Purchased electricity from the local utility for the residential/commercial sectors will increase 26 percent overall between 1977 and 1985. This 26 percent increase over an eight-year period is equivalent to a 2.9 percent escalation rate per year. Between 1985 and 2012 purchased electricity real costs will be practically constant (less than 0.2 percent rise per year).

Purchased electricity from the local utility for the industrial sector will increase at a rate of 3.8 percent escalation per year between 1977 and 1985. This reflects an overall 35 percent increase for this period. Beyond 1985 to the year 2012 the cost for purchased electricity will rise about 10 percent overall.

2. Residential/commercial natural gas prices will take an early 55 percent increase over the period 1977 to 1983. Prices will then rise at a constant 2.2 percent per year over the remaining years.

Industrial sector natural gas prices will double from 1977 to 1985. A 2.5 percent per year escalation over the remaining years will more than triple the 1977 price by the year 2012.

3. Commercial distillate fuel oil will increase approximately 32 percent from 1977 to 1995. Prices then will rise at a 2.2 percent rate per year paralleling the residential/commercial natural gas prices over the remaining years.

Figure 3-1

3.3

LIFE CYCLE COSTS FOR CONVENTIONAL SYSTEMS

Life cycle costs for space heating and cooling with conventional systems were calculated for the period 1983 to 2012 on a 1977 constant dollar basis. Results are shown in Table 3-1. On a 30-year levelized cost basis, the costs range from a high of \$21.92/10⁶ BTU for residential electric space heating to a low of \$9.75/10⁶ BTU for commercial air conditioning.

Table 3-2 lists various scenarios for space conditioning combinations for the City's residential and commercial sectors. The most economical combination, from a life cycle point of view, would be a standard natural gas water heater, natural gas furnace, and vapor-compression air conditioner. The life cycle cost for this combination will be \$12.57/10⁶ BTU in the residential sector and \$10.18/10⁶ BTU in the commercial sector. Assuming the entire City's heating/cooling systems were made up of this combination (a conservative assumption) the overall life cycle cost of the combined residential and commercial sectors would be \$11.60/10⁶ BTU. A somewhat more realistic scenario for the entire City would be a mixture of 30 percent of Combination 1 with 70 percent of Combination 2 which would result in an overall life cycle value of \$11.90/10⁶ BTU.

The estimate of the life cycle cost of Combination 1 being higher than Combination 2 at first seems rather surprising, especially with all of the heat pumps in use in the City today. But this can be explained by the fact that, during the cooling mode, heat pumps and air conditioners perform on an equal basis, while during the heating mode the heat pump competes with natural gas, which is cheaper than electricity, even with conversion efficiencies included. In addition, the annualized capital cost of Combination 2 is less than that of Combination 1.

Combination 3 has the highest life cycle cost due to the electric resistance heating costs. Electric ceiling heaters, while having a long useful life and virtually no operating or maintenance costs, suffer from high energy costs per delivered BTU at \$13.58/10⁶ BTU.

3.4

GEOTHERMAL FLUID PRICING

One requirement of this economic evaluation is to predict geothermal fluid pricing on the Heber KGRA for inclusion in the geothermal energy systems costs for comparison with conventional energy costs. For this preliminary evaluation, geothermal fluid prices were calculated utilizing the "GEOCITY" program based on resource exploration and development by a major lease holder on the Heber Reservoir. The cost of brine computed reflects both the field development costs and the field operating costs incurred by the lease holder. Geothermal fluid prices were computed by calculating the annual capital recovery charges in dollars per million BTU for geothermal energy between a resource temperature of 250F and an assumed reinjection temperature of 160F. The geothermal fluid was assumed to be single-phase throughout and the energy utilization factor was assumed to be 1.0. Levelized geothermal fluid prices in constant 1977 dollars ranged from a high of 2.00 for relatively low flow rates to a low of 1.67 at flow rates above four million pounds per hour. Further work is done in the sensitivity analysis to determine the cost benefits of municipal financing of geothermal resource development within the City of El Centro as compared to issuing geothermal leases to private resource developers.

Table 3-1

30-YEAR LIFE CYCLE COSTS
FOR CONVENTIONAL SPACE CONDITIONING/WATER HEATING SYSTEMS
1983-2012

R E S I D E N T I A L					
Annual Levelized Costs (1977 \$)	Water Heater	Heat Pump	Air Conditioner	Gas Furnace	Electric Heat
O & M	\$ 20	\$ 40	\$ 40	\$ 10	NIL
Capital ¹	83	440	242	124	\$160
Energy ²	49	470	345	100	263
	<u>\$152</u>	<u>\$950</u>	<u>\$627</u>	<u>\$234</u>	<u>\$423</u>
Annual Load BTU/yr. =	8.11 x 10 ⁶	7.25 x 10 ⁷	5.32 x 10 ⁷	1.93 x 10 ⁷	1.93 x 10 ⁷
Life Cycle Cost (\$/10 ⁶ BTU) =	18.74	13.10	11.79	12.12	21.92
Capital Cost (1977 \$)	300	2,340	1,290	700	900
Useful Life (years)	5	9	9	40	40
Fuel Conversion Efficiency	0.64	2.0	2.0	0.75	0.95

¹Based on 12 percent cost of borrowed money.

²Based on \$0.044/KWH levelized cost of electricity or \$0.385/therm levelized cost of natural gas.

Table 3-1 (Continued)

C O M M E R C I A L					
Annual Levelized Costs (1977 \$)	Water Heater	Heat Pump	Air Conditioner	Gas Furnace	Electric Heat
O & M	\$ 20	\$ 50	\$ 50	\$ 20	NIL
Capital ¹	208	1,782	982	533	\$ 684
Energy ²	243	2,665	2,049	488	1,297
	<u>\$471</u>	<u>\$4,497</u>	<u>\$3,081</u>	<u>\$1,041</u>	<u>\$1,981</u>
Annual Load BTU/yr. =	4.04 x 10 ⁷	4.11 x 10 ⁸	3.16 x 10 ⁸	9.50 x 10 ⁷	9.50 x 10 ⁷
Life Cycle Cost (\$/10 ⁶ BTU) =	11.66	10.94	9.75	10.96	20.85
Capital Cost (1977 \$)	750	9,495	5,230	2,840	3,645
Useful Life (years)	5	9	9	40	40
Fuel Conversion Efficiency	0.64	2.0	2.0	0.75	0.95

¹Based on 12 percent cost of borrowed money.

²Based on \$0.044/KWH levelized cost of electricity or \$0.385/therm levelized cost of natural gas.

Table 3-2

**30-YEAR LIFE CYCLE COSTS FOR CONVENTIONAL
SPACE CONDITIONING/WATER HEATING COMBINATIONS
FOR THE CITY OF EL CENTRO**

Combination	Residential \$/10 ⁶ BTU	Commercial \$/10 ⁶ BTU	Residential and Commercial \$/10 ⁶ BTU
1. Gas water heater, electric heat pump	13.67	11.00	12.59
2. Gas water heater, electric air conditioner, gas furnace	12.57	10.18	11.60
3. Gas water heater, electric air conditioner, electric resistance heating	14.91	12.26	13.84

3.5 HEAT DELIVERY OPTIONS

Section 2.5 to this study introduced three schemes of heat and/or cold delivery for technical and economic consideration: (1) supply both hot and chilled water at the same time, (2) supply hot water only or chilled water only as the season dictates, or (3) supply hot water only. The pipe arrangements implied by the foregoing schemes correspond to the following in respective order: (1) three-pipe, two-pipe (both supply), or four-pipe system, (2) one-pipe or two-pipe system, (3) one-pipe or two-pipe system.

All of the pipe systems mentioned above are technically feasible, so the matter of choosing a favorable system comes down to economic considerations. Table 3-3 gives a comparison of the capital costs per million BTUs delivered for the piping systems in question. As can be seen, the two-pipe system is the most favorable, with the three-pipe and the four-pipe systems following. The one-pipe system has been eliminated from consideration because of the need for water conservation in the Imperial Valley. The Imperial Valley, where El Centro is located, depends heavily on water for its agricultural industry. With one supply pipe and no return pipe, dumping of usable water into the sewage system would be not only economically unfavorable, but could have political and social ramifications. The same applies to the two-pipe (both supply) system.

Table 3-3

GEOTHERMAL PIPE SYSTEM COMPARISONS
FOR THE CITY OF EL CENTRO, CALIFORNIA

<u>System</u>	<u>Capital Cost Of Distribution System</u>	<u>Potential Load Capacity</u>	<u>Capital Cost/ 10⁶ BTU</u>
One pipe	Not considered		
Two pipe (Both supply)	Not considered		
Two pipe	\$49,000,000	$9.2 \times 10^{11} \frac{\text{BTU}}{\text{yr}}$	\$53.26
Three pipe	\$62,000,000	$1.08 \times 10^{12} \frac{\text{BTU}}{\text{yr}}$	\$57.41
Four pipe	\$71,000,000	$1.08 \times 10^{12} \frac{\text{BTU}}{\text{yr}}$	\$65.74

The capital costs used in the comparison are for the distribution network only. Costs of the reservoir and transmission systems were not included. If these other costs were included, it would be expected that each of the cost figures for the piping systems would increase by about the same amount leaving the relative costs between the piping systems about the same. The capital costs shown on Table 3-3 are interim values and do not reflect the final costs. These values are used for comparative purposes only.

The heat load listed is the potential capacity of the system and includes residential/commercial space heating and cooling and domestic hot water. Commercial refrigeration loads are not included.

The three-pipe and four-pipe systems each have the potential to fulfill the daily demands of the City throughout the year by supplying hot and chilled water when necessary. The two-pipe system, on the other hand, can supply only seasonal demands, hot water in the winter, chilled water in the summer. This means that with a two-pipe system, a portion of the cooling load in the winter and heating load in the summer, including domestic hot water demand in the summer, will not be fulfilled. To determine the extent of this off-season load, weather data for El Centro was analyzed (see Section 2.2).

Looking at weather data compiled by the Naval Weather Service Command shows that approximately 8 percent of the heating load occurs during the summer months and approximately 2 percent of the cooling load occurs during the winter months. This means that overall about 3 percent of the total load demanded by the City will be left unfulfilled by the two-pipe system. This loss is a minor drawback when considering the economic savings in the distribution network over the other two systems. The two-pipe system has lower potential capacity than the three or four-pipe systems but also much lower capital costs which accounts for the overall

lower cost per million BTU delivered. With the elimination of the three-pipe and four-pipe systems, along with the one-pipe and two-pipe (both supply) systems, heat delivery Scheme 1 (supply both hot water and chilled water at the same time) is also eliminated. This leaves Scheme 2 (seasonal hot or chilled water supply) which has already been discussed, and Scheme 3 (hot water only supply).

El Centro has 1216 heating degree days per year, a relatively small amount for a district heating system. Supplying hot water for only space heating and domestic hot water for El Centro will not be economically feasible due to the low energy demand per unit of area. A more practical method will be the use of distributed hot water for not only space heating and domestic hot water, but also for firing refrigeration chillers, located at each home or at modular facilities located throughout the City, to provide space cooling. In this way, hot water would be distributed year around allowing higher utilization of the brine wells, while increasing the energy demand per unit of area.

A major advantage results from distributing hot water only in that higher temperature drops per pound of fluid can be realized for hot water distribution as compared to chilled water distribution (20F drop versus 8-10F drop). This means that less mass flowrate is required with hot water distribution which results in the use of smaller diameter pipe and lower capital costs. This technique for reducing capital costs for heat distribution should be quite effective when evaluating El Centro's large cooling demand.

The foregoing discussion emphasizes decentralization of the refrigeration chiller units, possibly into each home, which may present some drawbacks, since the economic and technical benefits of a central chilled water plant are lost to a certain degree. However, it is possible to design modular units throughout the City which would combine the best of both the concepts of hot water distribution and central chiller plants. The economics of the modular system concept is further detailed in Section 3.10.

3.6 RETROFIT COSTS

Minimum retrofit costs for interfacing existing systems with a new geothermal hot and chilled water distribution system for space cooling and space and water heating were developed for two types of buildings: (1) single-family residential, and (2) commercial/institutional. The cost of retrofit for the residential sector was estimated at an average of \$1,497 per house in 1978 dollars and for the commercial sector at \$3,442 per building in 1978 dollars. Appendix B contains an itemized breakdown of the estimated retrofit costs. All buildings were assumed to have some type of existing duct-work to which a fan-coil unit or a heating/cooling coil could be added. A hot water preheater tank for geothermal hot water heating of domestic water was included in the costs.

Buildings with heat pumps and natural gas domestic hot water heating will require the addition of a heating/cooling coil (and in some cases a larger air handler), duct work modifications, control and isolation valves, extra copper pipe, thermostats for room and hot water heater control, and a hot water preheater tank. Buildings with air-conditioners and natural gas heating require similar modifications.

The single-family residential retrofit cost estimates were based on a design cooling load of 41,000 BTU/hr. These costs are conservative since the average peak

cooling load is estimated at 24,000 BTU/hr. One fan-coil unit will provide space cooling in the summer as well as space heating in the winter. Fan-coil units sized to handle the cooling load will have more than enough capacity to handle the space heating needs during the winter heating mode of operation. Domestic hot water equipment was sized based on a usage of 40 gallons of hot water per day.

Commercial and institutional buildings comprise a wide variety of sizes. An average peak cooling load of 195,000 BTU/hr was used as the basis for the retrofit costs. Domestic hot water consumption was estimated to average 190 gallons per day per building.

A comparison of the retrofit costs with the entire geothermal system costs shows that the retrofit costs make up approximately 28 percent of the total annualized capital costs for a City-wide district heating and cooling system, a significant fraction of the overall cost of delivered energy.

The initial outlay of \$1,497 per house in the residential sector or the equivalent of \$350 per year on an annualized basis does not take into account potential income tax deductions made possible by the National Energy Act of 1978. Under this Act, homeowners and renters who install geothermal energy devices would receive a tax credit of 30 percent of the first \$2,000 of outlays and 20 percent of the next \$8,000 for a maximum of \$2,200. This credit applies to new homes as well as retrofitting existing homes. The credit applies to principal residences only, vacation homes and other second homes would not qualify. Further analyses of the tax incentives for homeowners and commercial businesses is contained in Section 3.10.5.

3.7 GEOHERMAL CAPITAL COST MODELS

A capital cost model of a district heating and cooling system was made for the entire City of El Centro to determine the feasibility of replacing fossil fuel with geothermal energy. A preliminary analysis was made of the potential capital costs involved by using a computer capital cost model of the district system. The computer program was utilized in an economic sensitivity analysis to determine optimum system load capacities, distribution network sizes, and capital and life cycle costs.

The distribution system submodel to the computer program was used to define the energy requirements of the entire city by dividing the city into districts utilizing two major parameters. The first district parameter is related to demand density, i.e. a district defines a contiguous area of relatively homogeneous building heat demand density. In the preliminary analysis, two types of demand density were used: residential and commercial.

The second district parameter defines the size and location of a district. In the preliminary analysis there were eight residential and five commercial districts defined. These districts are shown in Figure 3-2.

One required input to the program is the routing of the piping mains to each of the different districts. The routing chosen for our preliminary analysis is shown on Figure 3-3. The hot and chilled water distribution point was assumed to be located close to a proposed well drilling site near the center of District 15 in the industrial section of the City.

Figure 3-2.
RESIDENTIAL AND COMMERCIAL DISTRICTS FOR "GEOCITY" COMPUTER MODEL

REVISED DECEMBER, 1975
JANUARY, 1977

Figure 3-3.
PIPING MAIN DISTRIBUTION NETWORK FOR "GEOCITY" COMPUTER MODEL

Although the computer program was designed to handle district heating systems only, modifications were made to the input data to the program in order to analyze district cooling distribution system costs. By maintaining proper temperature differences, modifying outdoor air and ground temperatures, using cooling demands in place of heating demands, and including an absorption chiller coefficient of performance it was possible to utilize the district heating distribution program for district cooling economic sensitivity analysis.

An example of some of the computer program input data parameters used for the El Centro study are shown in Table 3-4. The data presented in Table 3-4 was used during the sensitivity studies that followed the preliminary economic feasibility portion of the study. The financial scenario presented here is based on municipal financing of the resource development portion along with the distribution system construction portion of the City-wide utilization scenario.

3.8 PRELIMINARY ECONOMIC FEASIBILITY

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 of 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, as described in Section 3.7, using the modified "GEOCITY" program. The "GEOCITY" program was written as a general engineering and economic model and no attempt was made in this preliminary economic evaluation to optimize the parameters for the El Centro model. The initial financing scenario was based on resource exploration and development by a major leaseholder on the Heber Reservoir and development of 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 the base price discussed in Section 3.4 factored by the appropriate thermal conversion efficiency and utilization factor.

Table 3-5 shows the costs in dollars per million BTUs of providing residential and commercial space heating and domestic hot water utilizing geothermal energy. Table 3-5 includes the costs of home retrofit, geothermal energy, and a two-pipe centralized hot water distribution system. Geothermal energy costs were calculated to be \$7.57 per million BTU, based on a utilization factor of 0.21 (where a factor of 1.0 assumes that all of the geothermal heat energy from all of the wells between 250F and 160F is continuously utilized to recover the reservoir capital investment), which is typical for district heating in the City of El Centro. A conventional system life cycle cost is indicated for space and domestic water heating based on levelized conventional energy costs, equipment replacement costs, system operation and maintenance costs, and an appropriate thermal conversion efficiency.

A centralized hot water distribution system cost for residential/commercial space and domestic hot water heating is initially estimated at \$13.36 per million BTUs of building heat load, based on a carbon steel distribution system. It is felt that considerable reductions can be made in the distribution costs of hot water for residential/commercial use by utilizing pre-insulated asbestos-cement piping where the continuous operating temperature does not exceed 200F. However, it is apparent from

Table 3-4

COMPUTER PROGRAM
INPUT DATA PARAMETERS

1.	<u>Reservoir Characteristics and Well Properties</u>	
•	Average production life of reservoir wells	30 years
•	Maximum flowrate of the geothermal fluid from each wellhead	585,000 lbs/hr
•	Fraction of non-producing (dry) wells	0.20
•	Ratio of production wells to injection wells	2
•	Temperature of the geothermal fluid at the reservoir wellhead	250F
•	Production well drilling cost (1977 \$'s)	460,000
•	Injection well drilling cost (1977 \$'s)	270,000
2.	<u>Funding and Tax Data for Municipal Financing</u>	
•	Fraction of initial investment in bonds	1.0
•	Bond interest rate	0.06
•	Earning rate on equity after taxes	0.06
•	Federal income tax rate	zero
•	Depreciable life of reservoir wells	30 years
•	Startup year for operation	1983
•	State income tax rate	zero
•	State gross revenue tax rate	zero
•	Property tax rate	zero
•	Property insurance rate	0.0019
•	Distribution system operating life	30 years
•	Royalty payments	zero

Table 3-4 (Continued)

	●	Percent investment tax credit for the reservoir	zero
3.		<u>City Characteristics</u>	
	●	Number of districts in the City	13 (8 residential sector) (5 commercial sector)
	●	Total annual degree days	1216 (heating) 3794 (cooling)
4.		<u>District Parameters</u>	
	●	Density of buildings, buildings/sq mi	2930 (residential) 923 (commercial)
	●	Peak load demand per building, BTU/hr	16,600 (residential heating) 81,400 (commercial heating) 23,400 (residential cooling) 139,000 (commercial cooling)
	●	Daily hot water demand per building gal/day	40 (residential) 190 (commercial)
	●	Fluid temperature to the building	195F (heating) 42F (cooling)
	●	Fluid temperature out of the building	115F (heating) 50F (cooling)
5.		<u>Distribution System Parameters</u>	
	●	Thermal conductivity of pipe (preinsulated asbestos cement)	2.7 BTU-in/hr-ft ² - F
	●	Thermal conductivity of the ground	2.5 BTU-in/hr-ft ² - F
	●	Thermal conductivity of insulation (polyurethane foam)	0.13 BTU-in/hr-ft ² - F
	●	Average ground temperature	87F (summer) 66F (winter)
	●	Cost of pumping	\$0.028/kwh
	●	Absorption chiller COP	0.63

Table 3-5

PRELIMINARY ECONOMIC FEASIBILITY

	<u>District Heating</u>	<u>District Cooling</u>	<u>Combined District Cooling and Heating</u>
Reservoir Temp. °F	250	250	250
Production Wells	6	54	54
Reinjection Wells	3	23	23
Peak Fluid Demand, 10^6 lb/hr	2.071	19.581	19.581
Fluid Utilization Factor	0.21	0.08	0.10
Annual Bldg. Demand, 10^{12} BTU	0.43	0.81	1.24
Distribution System Cost, $\$/10^6$ BTU	13.36	10.32	6.75
Chiller Plant Cost, $\$/10^6$ BTU	—	0.62	0.40
Retrofit Cost, $\$/10^6$ BTU	5.40	2.86	1.87
Interim Capital Replacement, $\$/10^6$ BTU	0.85	0.60	0.39
Energy Supply Cost, $\$/10^6$ BTU	7.57	35.31	23.09
Operating Expenses, $\$/10^6$ BTU	1.22	2.92	1.91
Property Taxes and Insurance $\$/10^6$ BTU	0.50	0.35	0.23
Total Delivered Cost, $\$/10^6$ BTU	28.90	52.98	34.64
Conventional Delivered Cost, $\$/10^6$ BTU	13.14	11.32	11.90

Table 3-5 that the use of geothermal energy for residential/commercial space and water heating alone for the entire City of El Centro will not be economically feasible when using a centralized hot water distribution system. This lack of feasibility can be attributed to a combination of the limited number of degree-heating-days for El Centro (1216), and the low-density suburban housing distribution which typifies the El Centro area.

Table 3-5 also shows the costs in dollars per million BTU of providing residential/commercial space cooling for the entire City of El Centro utilizing geothermal energy. This table includes the costs of home retrofit, a centralized chiller plant, geothermal energy, and a two-pipe centralized chilled water distribution system. The cost of geothermal energy for district cooling is calculated to be \$35.31 based on a utilization factor of 0.08 (where a factor of 1.0 assumes that all of the geothermal heat energy from all of the wells between 250F and 160F is continuously utilized to recover the reservoir capital investment), which is typical for district cooling in the City of El Centro. This low utilization factor is due to the relatively high peak demand for cooling combined with the small brine temperature drop allowed to meet the minimum temperature requirements of the absorption refrigeration unit. A conventional system life cycle cost for space cooling is indicated on Table 3-5 based on levelized conventional energy costs, equipment replacement costs, system operation and maintenance costs, and an appropriate thermal conversion efficiency for air-to-air heat pumps.

A centralized chilled water distribution system cost for residential/commercial space cooling is initially estimated at \$10.32 per million BTUs of building air conditioning load, based on a carbon steel distribution system. Again, it is felt that considerable reductions can be made in the distribution costs of chilled water for residential/commercial use by utilizing pre-insulated asbestos-cement piping. However, it is apparent from Table 3-5 that the use of geothermal energy for residential/commercial space cooling alone for the entire City of El Centro will not be economically feasible when using a centralized chilled water distribution system. This lack of feasibility can be attributed to the large peak cooling demand required, and the low-density suburban housing distribution which typifies the El Centro area.

Costs for a centralized two-pipe combined hot and chilled water distribution system is also shown in Table 3-5 of this preliminary economic feasibility section. Costs for this system are very similar to costs for the space cooling system alone. In a combined hot and chilled water system, the chilled water requirements dominate the economics because of the high peak and annual cooling demand compared to the low heat demand. Geothermal energy and distribution system costs still overpower the economics to the point that the combined system is only slightly more economical than the cooling system alone.

In Section 3.10, the concept of a modular (decentralized) distribution system, which is a more cost effective means of providing geothermal district heating and cooling is discussed. In addition, the effects of varying the parameters which control the economic feasibility of district heating and cooling systems in the City of El Centro are discussed such as materials of construction, load density, brine utilization, and resource development financing. From this analysis a scenario for economically feasible geothermal energy utilization will be developed to guide the exploitation of the geothermal resources beneath the City.

3.9 SENSITIVITY STUDIES

3.9.1 Base Case

A modified version of the computer program "GEOCITY" was used extensively in the economic analysis portion of this project to model the economics of district heating and cooling systems in the City of El Centro. From the base case, described in the Preliminary Economic Feasibility Section (3.8), various parameters were modified to test their economic sensitivity. These modifications are explained further in this section.

In the base case, the geothermal system consists of a central chiller plant, utilizing lithium bromide-water absorption chillers, and central chilled and hot water distribution systems. These distribution systems serve the entire City which is broken down into 13 districts — 8 residential, 5 commercial (see Figures 3-2 and 3-3). The piping network to and from the districts is a two-pipe system consisting of carbon steel pipe, polyurethane foam insulation, and a prefabricated steel, Class A casing. Both supply and return are in a common casing. In the base case, separate two-pipe systems are provided for chilled water and for hot water distribution. In addition, the economics of combining the two systems into one two-pipe system providing both hot or chilled water was considered.

Geothermal brine is extracted from the well at a temperature of 250F and sent through a heat exchanger, to exchange heat with clean city water, before being reinjected at a temperature somewhat above 160F.

The initial case assumes resource development by a private leaseholder and distribution system development by a nonprofit or municipally owned utility.

The peak heat demand for the residential and commercial buildings as listed in Table 3-4 is based on an average heat flux of 712 BTU/hr-F-bldg for residential buildings and 3521 BTU/hr-F-bldg for commercial buildings (see Appendix C). The annual load on a typical house is 5.32×10^7 BTU/yr for cooling, and 1.92×10^7 BTU/yr for heating; and for commercial buildings is 3.16×10^8 BTU/yr for cooling, and 9.50×10^7 BTU/yr for heating. The load is based on a 65F design indoor temperature per ASHRAE standards.

Further evaluation was made of the economic feasibility of substituting geothermal energy for all or part of the residential/commercial space heating and cooling and domestic hot water for the City of El Centro.

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.

The base case yielded hot water distribution system costs for residential/commercial space and domestic hot water heating at \$13.36 per million BTUs of building heat load. Chilled water distribution system costs for residential/commercial space cooling were estimated at \$10.32 per million BTUs of building air conditioning

load. The distribution system costs account for over half of the total capital costs for the geothermal district heating/cooling system. Therefore, methods of reducing distribution system costs were investigated.

3.9.2 Municipal Utility or Non-Profit Corporation

In the base case, it was assumed that the geothermal resource developer was a publicly owned corporation. The first parameter to be modified was this assumption. A municipal utility offers many financial advantages over a publicly owned corporation as well as its broad powers to operate in the utility field. More evaluation on this subject is contained in Section 4.4.

3.9.3 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.

The preinsulated pipe chosen has a maximum operating pressure of 130 psig for 3 inch through 10 inch diameters, and 150 psig for 12 inch diameter and larger. Because these operating pressures are lower than the previously specified carbon steel pipe, pressures in the preinsulated pipe system had to be reduced. This was accomplished by reducing the flow velocity of the thermal transport medium (clean hot or chilled water) through the pipe by using larger diameter pipe in areas where the pressure was too large. The use of the larger diameter pipe resulted in only a slight decrease in savings.

3.9.4 Uninsulated Piping

The economic effects of using totally uninsulated pipe for both supply and return lines was also investigated. The benefits of using uninsulated pipe is a decrease in the capital costs (elimination of insulation costs). The penalty involved is an increased loss of heat, for the hot water system, or increased gain of heat for the chilled water system. The value of lost heat or lost chilled water cooling capacity is estimated at \$2.00/10⁶ BTU and \$10.60/10⁶ BTU, respectively.

The average ground temperatures for the El Centro area vary from 66F in the winter to 87F in the summer. This results in a delta T (difference between ground temperature and thermal fluid temperature) of 129F for hot water transport and 45F for the chilled water transport. The larger of the two differences is for the heating system. Because the heating load is so much smaller than the cooling load for the City, it was hoped that the lack of insulation and the ensuing loss of heat would have minimal effect on the overall financial picture.

The result of this analysis showed that, although the capital costs dropped 25 percent on a dollar per million BTU basis for the distribution system, the operating expenses jumped 113 percent. Because there was no insulation on the pipes, the computer program compensated by increasing the flow velocity through the pipe to reduce heat loss. The program accomplished this by designating smaller diameter pipe.

This reduced the pipe costs but meant an increased pumping horsepower was required because of the higher pressure drops through the smaller diameter pipe. This resulted in an overwhelming cost increase in operating expenses.

Further analyses along these lines were abandoned because (1) there was an overall increase in cost due to the increased pumping requirements, and (2) if uninsulated pipe were to be used, larger diameter pipe would have to be used to reduce the pressure. This larger diameter pipe would mean a further increase in cost.

3.9.5 Reduced Load Demand

Further 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, i.e. the cost per delivered BTU (heating or cooling) would be at its lowest point. In order to find that design point, the geothermal load demand was varied from 100 percent to 80 percent of the total City demand.

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. As the load is decreased, both the capital costs for the distribution system and the amount of annual delivered BTU's drop as expected, however, the amount of delivered BTU's drops faster than the capital costs resulting in an increase in the cost of annual delivered BTUs. Therefore, at approximately 91 percent of the total load (for both heating and cooling), optimum use of the distribution system is obtained. Capital costs for the distribution system dropped 17 percent for the cooling case and 8 percent for the heating case with a cost per million BTU drop of about 9 percent and 3 percent, respectively, in going from 100 percent to 91 percent of the annual geothermal cooling and heating loads.

3.9.6 Peak Load Shaving

Methods of peak load shaving using conventional fuels and storage means were investigated. Assuming a geothermal load of 91 percent of the total annual cooling load for the City, an analysis was made of the tradeoffs of using conventional fuels and stored energy versus geothermally energized absorption machines. The benefits of shaving the peak geothermal load with alternate methods is a reduction in the size of the geothermal equipment, more efficient use of the geothermal equipment, and a reduction in capital costs. On the other hand, there is the cost of the peak load shaving equipment to consider, whether it be heat pumps or storage tanks, and the cost of conventional energy sources to be paid.

It was felt that by using storage tanks to store hot or chilled water a reduction in the absorption machine capacity could be realized. Stored energy would be tapped during peak loads and replenished during off-peak hours.

Based on the month of July (the hottest month in El Centro), preliminary analysis has shown that maximum economic benefit could be obtained by substituting approximately 9 percent of the geothermal load with stored energy reducing the capital cost expenditures for refrigeration equipment by 13 percent. The storage system would

include a steel storage tank with proper insulation. No instrumentation or extra pumps were included in the analysis.

A similar type of analysis substituting electrical heat pumps for part of the load proved to be economically unacceptable due to the high cost per unit output of the heat pumps compared to stored energy.

3.9.7 Conclusion

The result of the aforementioned 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 Section 3.10.

3.10 FINAL ECONOMIC FEASIBILITY

3.10.1 Central Plant Concept

Section 3.9 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 3.9.7, the total delivered costs for the district heating system and for the district cooling system now become \$9.91/10⁶ BTU and \$14.06/10⁶ BTU, respectively.

Combining the district heating system and the district cooling system into a single two-pipe system, and adding in the costs for building interface equipment retrofit and the costs of absorption refrigeration equipment, results in an overall cost of \$13.79/10⁶ BTU. This cost can now be compared with the conventional energy life cycle cost of \$11.90/10⁶ BTU derived in Section 3.3. 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.

3.10.2 Modular Concept

The technical aspects of a modular system concept are described in Section 2.5.4. This concept entails the decentralization of the chiller facilities into modular units serving approximately one hundred buildings per module. This concept results in the large scale distribution of hot water to the modular units and the distribution of chilled water only to the area served by each module. This concept eliminates large scale chilled water distribution from one central chiller plant. The main advantage of this system is the cost savings associated with 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 as the central plant is modularized into smaller plants, the economic advantages of a central plant are lost, due to the increased number of cooling towers, auxiliary pumps, etc.

The economic effects of going from a central plant to modular units are as follows: the distribution system capital costs are reduced; the energy supply costs (well costs, transmission system costs, field development costs, etc.) are reduced, the operating expenses are reduced, the chiller plant equipment costs increase, the hot water distribution equipment costs increase, and home retrofit equipment costs remain unchanged. 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 \$10.04/10⁶ BTU. Although it is not apparent yet from this calculation whether geothermal energy systems represent an economically viable investment, on a retrofit basis, for large scale district heating and cooling; it is apparent that, for new construction, modular geothermal energy systems serving increments of approximately 1535 tons of peak cooling capacity per well are economically feasible. Assuming a peak geothermal system cooling capacity of 73 percent of the building cooling capacity (equivalent to 91 percent of the annual cooling load) and a diversity factor of 72 percent, this represents a building peak cooling capacity of approximately 2920 tons per well.

3.10.3 High Energy Density Concept

Another approach was taken to reduce the geothermal system cost per delivered BTU. Areas within El Centro were searched for high energy density. It was hoped that a more concentrated load would 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 along Main Street between the Southern Pacific Railroad and Imperial Avenue. A high density computer model was established with the districts, as shown on Figure 3-4. Four residential districts and three commercial districts were chosen for this model. These districts were chosen for their energy density characteristics and their location in relation to the proposed well site. These districts cover about half the area of the City. The central plant high energy density case resulted in a total capital cost of 33 million dollars, while the modular high energy density case required 27 million dollars. Each cost includes approximately 5 million dollars for residential and commercial retrofit.

The high energy density central plant case resulted in a figure of \$12.06/10⁶ BTU as compared to \$13.79/10⁶ BTU for the central plant system for combined heating and cooling in the entire City. Applying the modular system techniques to this high energy density model reduced the cost of district heating and cooling to \$9.79/10⁶ BTU. This is 17 percent lower than the present conventional system life cycle cost of \$11.90/10⁶ BTU for combined heating and cooling in the City, however, this may still not be enough of a difference to make geothermal systems economically viable on a retrofit basis. As mentioned in the previous Section 3.10.2, the application of the modular concept to new residential and commercial construction is economically viable

Figure 3-4.
HIGH ENERGY DENSITY RESIDENTIAL AND COMMERCIAL DISTRICTS
FOR "GEOCITY" COMPUTER MODEL

when done in large enough increments to utilize the well capacity effectively. The use of high energy density design concepts in planning new construction will improve the economic viability of geothermal district heating and cooling systems.

3.10.4 Industrial Park Concept

Up to this point the number of geothermal production wells has been based upon the peak capacity requirements for district heating and cooling of the residential and commercial sectors of the City. The utilization of geothermal energy by the residential and commercial sectors is highly weather dependent, which varies from season to season. The fact that the City of El Centro requires such a small heating load during the winter and such a high cooling load in the summer has resulted in only a 20 percent annual load factor for combined heating and cooling. Therefore greater utilization of the production wells would certainly enhance the overall economic feasibility.

Energy cascading through industrial process use of geothermal energy can bring about greater utilization of the geothermal resource. Industrial use of geothermal heat on a constant, year around, high volume basis can bring about greater economical 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.

The effects of increasing the geothermal industrial load requirements is tabulated in Tables 3-6 and 3-7 for three industrial park cases. These tables show the effects an industrial park utilizing cascaded energy would have on the overall cost of delivered heat/cold and the utilization efficiency. In Table 3-6 line A is the annual cost for a citywide heating and cooling system. This figure includes the cost to locate the resource, extract the heat, convert the heat to chilled water for cooling, and deliver the energy (heat/cold) to the consumer. Costs of the chiller plants located throughout the City and costs of retrofit equipment located in each building are also included. Line B is the sum of the annual BTU's of heat and the annual tons of cooling converted to BTU's and delivered to the citywide system. Line C is the cost per delivered BTU (heating and cooling) for the same system. Line D, is the annual utilization efficiency of the geothermal production wells when used for district heating and cooling only.

Three energy park cases were chosen for sensitivity analysis. The three cases chosen depict varying levels of industrial involvement in geothermal energy use. The annual energy consumption for Case I, for example, is typical of a dehydration plant sized to handle alfalfa drying and onion dehydrating for a typical annual crop yield in the Imperial County.

The data listed in Tables 3-6 and 3-7 under the Industrial Park Concept assumes that an Industrial Park is developed independent of other uses within the City and does not include any energy cascading. The annual cost listed includes resource identification and development, and heat extraction and delivery. Heat delivery to the industrial park would be in the form of hot City water (heated at the well head). Heat would be extracted by the industrial user in his facilities and the cooled water would be delivered back to the well site to be reheated, forming a continuous loop.

Table 3-6

COMBINED CITYWIDE MODULAR SYSTEM AND INDUSTRIAL PARK CONCEPT

Residential/Commercial Citywide Modular System

A.	Annual Cost	\$ 9.78x10 ⁶
B.	Annual BTU's Delivered	0.98x10 ¹² BTU/yr
C.	Cost per 10 ⁶ BTU's (A/B)	\$10.04
D.	Utilization Efficiency	20%

Industrial Park Concept

		<u>Case I</u>	<u>Case II</u>	<u>Case III</u>
E.	Annual Cost	\$ 0.30x10 ⁶	\$0.42x10 ⁶	\$0.73x10 ⁶
F.	Annual BTU's Delivered	0.23x10 ¹² BTU/yr	0.46x10 ¹² BTU/yr	0.92x10 ¹² BTU/yr
G.	Cost per 10 ⁶ BTU's (E/F)	\$ 1.31	\$0.92	\$0.79
H.	Utilization Efficiency	76%	76%	76%

Combined City Model and Industrial Park

I.	Incremental Annual Cost	\$ 0.15x10 ⁶	\$0.16x10 ⁶	\$0.19x10 ⁶
J.	Total Annual Cost (A + I)	\$ 9.93x10 ⁶	\$9.94x10 ⁶	\$9.97x10 ⁶
K.	Total Annual BTU's Delivered (B + F)	1.21x10 ¹² BTU/yr	1.44x10 ¹² BTU/yr	1.90x10 ¹² BTU/yr
L.	Cost per 10 ⁶ BTU's (J/K)	\$ 8.21	\$6.90	\$5.25
M.	Utilization Efficiency	23%	26%	33%

Table 3-7

COMBINED HIGH ENERGY DENSITY MODULAR SYSTEM AND INDUSTRIAL PARK CONCEPT

Residential/Commercial High Density Modular System

A.	Annual Cost	$\$4.50 \times 10^6$
B.	Annual BTU's Delivered	0.46×10^{12} BTU/yr
C.	Cost per 10^6 BTU's (A/B)	\$9.79
D.	Utilization Efficiency	20%

Industrial Park ConceptCase ICase IICase III

E.	Annual Cost	$\$0.30 \times 10^6$	$\$0.42 \times 10^6$	$\$0.73 \times 10^6$
F.	Annual BTU's Delivered	0.23×10^{12} BTU/yr	0.46×10^{12} BTU/yr	0.92×10^{12} BTU/yr
G.	Cost per 10^6 BTU's (E/F)	\$1.31	\$0.92	\$0.79
H.	Utilization Efficiency	76%	76%	76%

Combined High Density Model and Industrial Park

I.	Incremental Annual Cost	$\$0.15 \times 10^6$	$\$0.16 \times 10^6$	$\$0.19 \times 10^6$
J.	Total Annual Cost (A + I)	$\$4.65 \times 10^6$	$\$4.66 \times 10^6$	$\$4.69 \times 10^6$
K.	Total Annual BTU's Delivered (B + F)	0.69×10^{12} BTU/yr	0.92×10^{12} BTU/yr	1.38×10^{12} BTU/yr
L.	Cost per 10^6 BTU's (J/K)	\$6.74	\$5.07	\$3.40
M.	Utilization Efficiency	27%	34%	48%

The Industrial Park Concept Costs are then combined with the Citywide and High Density Modular System Costs in Tables 3-6 and 3-7 to determine the cost benefits of increasing the overall heat utilization through energy cascading. Incremental costs for building, operating, and maintaining the distribution system for the Industrial Park were calculated and included.

Again it was assumed that direct process heat would be required by the industrial users and that energy cascading techniques would be used such that no new brine wells would be required. Line I of Tables 3-6 and 3-7 show the incremental annual cost to include an industrial load on the city system load (utilizing the same brine wells already established for the city system). Line J is the new total cost (city system plus the incremental industrial park system). Line F is the added industrial park load in annual BTU's of heat. Line K is the total annual heat load, city plus industrial, in BTU's per year. Line L is the new cost per delivered BTU. Line M is the new combined utilization efficiency.

Table 3-7 is identical in format to Table 3-6. The only difference is that the heating and cooling cost figures are for the high energy density model described in Section 3.10.3.

As can be seen from Tables 3-6 and 3-7, a wide range of prices for geothermal energy can be obtained based upon varying industrial usage and increased utilization efficiency. For example, with the inclusion of an onion dehydrating and alfalfa drying plant into the high density residential/commercial geothermal system, the utilization efficiency can be increased from 20 percent to approximately 27 percent (see Case I). 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. This figure would be the cost of delivered BTU's to the residential and commercial users for space conditioning and water heating purposes. Industrial applications being more stable, lower year around rates can be allowed for the industrial consumer to encourage wide spread participation. The economics of an industrial park taken on its own merits is addressed in more detail in Section 6.4.

3.10.5 Acceptable Costs For Geothermal Systems

Various areas have been explored in seeking the ideal geothermal system for El Centro. Geothermal system life cycle costs have been reduced to $\$6.74/10^6$ BTU including retrofit in a model that is composed of modular geothermal systems in high energy density districts combined with a reasonably sized energy intensive industrial park. There are many factors involved in defining an acceptable cost for geothermal 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 cash flow 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 Tables 3-8 and 3-9 show the incremental cash flows for typical commercial and residential geothermal/conventional systems over straight conventional systems. Each table shows the incremental cash flow, i.e., the difference in energy costs, operations and maintenance costs, income taxes, etc., between the geothermal/conventional system case and the conventional system case. Through a trial and error calculation, levelized annual energy savings required of the geothermal/conventional system were determined in order to affect a 2 percent and 4 percent rate of return for the residential and commercial consumers, respectively.

Operating and maintenance costs used in the examples were taken from Table 3-1 for conventional fuel equipment. For the geothermal equipment, annual operations and maintenance costs were estimated to be about 2 percent of the capital cost of the equipment. Depreciation of equipment, used in computing taxes for the commercial case, was taken over the full life of the equipment using the straight-line method to simplify the analysis. 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 consumer and 40 percent for the corporate consumer. Government tax incentives were included in the analysis based on the National Energy Act of 1978. For the commercial application, a 10 percent energy investment tax credit was included, along with the regular 10 percent investment tax credit, for the installation of geothermal retrofit equipment. This resulted in a tax reduction of \$688.40 in the Year 1 cash flow of the geothermal/conventional system analysis, which appears as a positive incremental cash flow of \$453.72 in Year 1 income taxes of Table 3-8. For the residential application, a tax credit of 30 percent of the first \$2,000 of installed geothermal retrofit equipment and 20 percent of the next \$8,000 up to a maximum limit of \$2,200 for the total credit was included in this analysis. Any portion of the credit that is unused in the first year may be used up to 7 years later. This resulted in no income tax for the first two years of the geothermal/conventional system cash flow and a \$449.10 tax credit overall, which results in a positive incremental cash flow for income tax in Table 3-9.

It was concluded that the effect of property tax and insurance would be about the same for either the conventional or the geothermal case, therefore these factors were excluded from the incremental analysis tables.

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 $\$5.93/10^6$ BTU and $\$5.75/10^6$ BTU for the residential and commercial cases respectively. These costs reflect 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 and do not reflect retrofit financing charges. It should be noted that the rates of return are extremely sensitive to the cost factors used in this analysis. Even a small change (one or two dollars) in the assumed annual incremental operations and maintenance costs could change the rate of return by 1 or 2 percent. These figures are offered only as an estimate of the maximum acceptable

Table 3-8

INCREMENT CASH FLOW (COMMERCIAL)
(Constant 1977 Dollars)

Year	A Energy Cost Savings	B O & M Costs	C Depreciation Of Equipment	D Loan Interest Costs	E Income Tax	F Loan Payment Costs	G Net Cash Flow	H 4% Present Worth Factor	I P.W.
0	—	—	—	—	—	—	\$ 3.80	1.0	\$ 3.80
1	\$147.50	\$-0-	\$435.11	\$ 4.10	\$453.72	\$14.24	\$615.46	0.9615	\$591.76
2	\$147.50	\$-0-	\$435.11	\$ 2.88	\$(234.20)	\$14.24	\$(72.46)	0.9246	\$(66.99)
3	\$147.50	\$-0-	\$435.11	\$ 1.52	\$(233.66)	\$14.24	\$(71.92)	0.8890	\$(63.94)
4	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.8548	\$(73.12)
5	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.8219	\$(70.30)
6	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.7903	\$(67.60)
7	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.7599	\$(65.00)
8	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.7307	\$(62.50)
9	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.7026	\$(60.10)
10	\$147.50	\$-0-	\$435.11	\$ -0-	\$(233.04)	\$ -0-	\$(85.54)	0.6756	\$(57.79)

1. Positive cash flow in year zero is incremental down payment on new equipment.
2. Incremental income tax, $E = (A + B + C + D) \times (0.40)$. The value for Year 1 includes a tax credit of \$688.40.
3. Loan interest based on 12% cost of borrowed money.
4. Net cash flow, $G = A + B + E + F$.
5. Present worth of net cash flow, $I = G \times H$.

Table 3-9

INCREMENTAL CASH FLOW (RESIDENTIAL)
(Constant 1977 Dollars)

Year	A Energy Cost Savings	B O & M Costs	C Depreciation Of Equipment	D Loan Interest Costs	E Income Tax	F Loan Payment Costs	G Net Cash Flow	H 2% Present Worth Factor	I P.W.
0	—	—	—	—	—	—	\$ (65.70)	1.0	\$ (65.70)
1	\$11.25	\$23.00	—	\$ (70.96)	\$207.07	\$ (246.18)	\$ (4.86)	0.9804	\$ (4.76)
2	\$11.25	\$23.00	—	\$ (49.93)	\$219.79	\$ (246.18)	\$ 7.86	0.9612	\$ 7.56
3	\$11.25	\$23.00	—	\$ (26.38)	\$ 59.05	\$ (246.18)	\$ (152.88)	0.9423	\$ (144.06)
4	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.9238	\$ 31.64
5	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.9057	\$ 31.02
6	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.8880	\$ 30.41
7	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.8706	\$ 29.82
8	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.8535	\$ 29.23
9	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.8368	\$ 28.66
10	\$11.25	\$23.00	—	\$ -0-	\$ -0-	\$ -0-	\$ 34.25	0.8203	\$ 28.09

1. Negative cash flow in year zero is incremental down payment on new equipment.
2. Incremental income tax, $E = (D) \times (0.25)$. The values for Years 1 thru 3 include a tax credit of \$449.10.
3. Loan interest based on 12% cost of borrowed money.
4. Net cash flow, $G = A + B + E + F$.
5. Present worth of net cash flow, $I = G \times H$.

cost of geothermal energy. Information derived from actual field experiments can greatly increase the accuracy of these cost estimates and thereby aid in future decisions made regarding financial risks involved in geothermal implementation.

The estimates of acceptable geothermal utility energy charges can now be compared with the preceding economic evaluations of geothermal system costs by calculating a composite geothermal energy charge for combined residential and commercial applications based on the amount of energy consumed in each of the two sectors. The composite residential/commercial acceptable cost is $\$5.86/10^6$ BTU delivered. In order to compare this cost with previous analyses, we must now add in the same retrofit charges assessed in those earlier calculations. The retrofit charges for the Citywide Modular and High Energy Density Modular Cases were $\$3.49/10^6$ BTU and $\$2.94/10^6$ BTU respectively. This brings the total charges assessed for each case to $\$9.35/10^6$ BTU and $\$8.80/10^6$ BTU, respectively. These figures represent the maximum acceptable costs for each of the respective cases and can now be directly compared with the costs calculated in Tables 3-6 and 3-7.

A comparison of these figures with Tables 3-6 and 3-7 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. Tables 3-6 and 3-7 show the effects of energy cascading to an industrial park on the overall utilization efficiency and resulting cost per million BTU delivered.

Calculations of the effect of new refrigeration processes, such as the organic rankine compression cycle, on combined district heating and cooling costs show that the cost per million BTU for the Citywide Modular Case can be reduced from $\$10.04$ to $\$9.53$, while the cost for the High Energy Density Modular Case can be reduced from $\$9.79$ to $\$9.13$ by utilizing this technology, if large commercial units can be produced in the cost range predicted in Table 2-1. These costs, however, are still not within the acceptable limits established by the cash flow analyses in Tables 3-8 and 3-9.

The impact of conceptual refrigeration processes, such as the Ammonium-Nitrate/Water Absorption Process described in Section 2.4, cannot be assessed at this time because of the lack of definitive data on parasitic energy requirements and equipment capital costs. However, calculations show that a process such as this, even with its high refrigeration thermal utilization, will not make large scale district heating and cooling economically feasible in El Centro, unless these units can be built and operated considerably cheaper than conventional lithium-bromide absorption units. Energy cascading to an Industrial Park appears to be the only means presently available to make large scale district heating and cooling economically viable for the City of El Centro.

3.11 SUMMARY AND CONCLUSIONS

A conservative model of conventional energy costs was established for the study period 1983-2012 and evaluated for constant dollar cost escalations. Levelized fuel costs are calculated in Appendix A.

Life cycle costs for conventional space conditioning and water heating systems were calculated for the study period on a 1977 constant dollar basis. A figure of \$11.90/10⁶ BTU has been estimated as a reasonable value for the average life cycle cost for a conventional energy system in El Centro.

Geothermal fluid prices range from \$1.67/10⁶ BTU, based on private resource development, to \$0.33/10⁶ BTU, based on municipal resource development.

The two-pipe system has been shown to be economically favored over other pipe systems for distribution of hot water in the winter and chilled water in the summer.

Retrofit costs for geothermal interface equipment have been estimated at \$1,497 for the homeowner and \$3,442 for a commercial establishment. These figures do not include the capital costs of conventional equipment to supplement the geothermal equipment.

A capital cost model of a district heating and cooling system was made for the entire City of El Centro to determine the feasibility of replacing fossil fuel with geothermal energy.

Sensitivity analyses were undertaken to determine the economic effect of modifying various parameters. Evaluation of a municipal utility concept, use of preinsulated pipe, a partial geothermal load of about 90 percent of the total load, and peak load shaving techniques have lowered the preliminary distribution system costs from \$13.36/10⁶ BTU to \$7.00/10⁶ BTU for the heating system and from \$10.32/10⁶ BTU to \$5.40/10⁶ BTU for the cooling system.

With the incorporation of the modular system concept and high energy density model into the geothermal district system, the overall cost of delivered energy to the consumer for district heating and cooling has been estimated to be as low as \$9.79/10⁶ BTU. The implementation of relatively new refrigeration technology can potentially reduce these costs further to \$9.13/10⁶ BTU. However, an analysis of the maximum acceptable price to the consumer for geothermal heating and cooling, based on a minimum rate of return for the retrofit investment, shows that the maximum cost must be in the order of \$8.80/10⁶ BTU. The use of energy cascading to an industrial park, with process heat requirements in the appropriate temperature range, is the only clear method presently available to make large scale geothermal district heating and cooling economically feasible in the City of El Centro.

SECTION 4

INSTITUTIONAL BARRIERS ASSESSMENT

4.1 INTRODUCTION

To complement the efforts of the economic and engineering evaluation of nonelectric utilization of hydrothermal resources in the City of El Centro, an institutional barriers assessment was undertaken. This assessment explored two major topics and numerous related, but subsidiary, issues. The first major topic of consideration was the investigation of institutional options available to the City of El Centro in structuring a geothermal utility which could supply the needs of residential, commercial and potential industrial users for space heating/cooling and hot water heating. For the preliminary analysis, legal constraints to the formation of each option were identified. These constraints fell into two general categories: (1) the authority of a municipality to organize or to participate in the organization of a geothermal utility; and (2) the financing mechanisms available to the City for implementing a selected option.

After reviewing various options for utility formation, a second major topic was explored, namely what incentives and disincentives exist for geothermal utilization by the residents of El Centro in their homes or businesses. These incentives/disincentives will ultimately influence the attitude of residents toward nonelectric utilization of geothermal energy should it prove economically and technically feasible. As a part of the incentives/disincentives inquiry, it is first appropriate to address the validity of the assumption that the public will accept geothermal energy. Secondly, what is being and has been done in El Centro to encourage citizen participation and willingness to convert to geothermal energy is discussed. The measures, if any, community leaders are taking to involve the general population in the decision-making process regarding geothermal utilization is also examined.

A related institutional consideration pertinent to both major topics is the probable relationship between a newly-created geothermal utility and the existing utility systems in the City of El Centro. There are currently two utilities serving the municipality. The Imperial Irrigation District (IID), a quasi-public corporation organized pursuant to the California Water Code and governed by a Board of Directors elected by the people within the District boundaries, provides inhabitants with electric and water service. Southern California Gas Company (SoCal), an investor-owned utility, serves all natural gas customers in the area.

Any newly organized El Centro geothermal utility will require standby service from both of these utilities. The need for standby service raises questions of possible changes in the existing utilities' obligations to serve El Centro residents and of possible changes in rates occasioned by a major shift to geothermal energy.

4.2 BACKGROUND

During the first quarter, the Institutional Barriers Assessment Team identified potential institutional barriers to the use of geothermal energy in the City of El Centro. It resolved problems of zoning and right-of-way in connection with a conceptual brine

transmission corridor between the center of the Heber KGRA and the City (Section 2.2). Completion of the latter task concluded the discussion in that area. For the remainder of the study, the Team evaluated those remaining institutional barriers identified and the outgrowth of issues raised by its evaluation.

During the second quarter, the Team focused its efforts on utility formation. Early discussions on this subject with City staff indicated an initial staff reluctance to organize a utility that was totally municipally owned and operated. There was doubt that the City had resources to secure adequate funding and to provide the additional manpower required by utility operation. It was suggested that the City approach the Imperial Irrigation District (IID) to serve as the operator of the utility with City staff utilized for support services, if required.

Shortly thereafter, the City learned that it owned several parcels of land that overlay potential geothermal resources and that might be suitable for development. At this point, interest in a more City-controlled operation emerged. Nevertheless, the City Attorney contacted IID management to determine what interest the District might have in participating in a utility project. Late in the second quarter, an IID spokesman indicated to City staff that a City/IID joint venture was not probable.

The City staff next evaluated three selected parcels to determine an appropriate drilling site. A potential drilling site, located in the southeastern part of the City of El Centro, east of Second Avenue and several blocks north of Ross Avenue, was chosen. The City of El Centro owns this land in fee; title to the mineral as well as surface estate being held by the City. The site is currently partially occupied by the City's Recycling Center and is zoned for manufacturing and light industry. This zoning classification and the suitability of nearby property for the location of an industrial geothermal energy park enhanced the site's attractiveness for geothermal operations and applications. At this juncture, the Environmental Assessment Team began its preliminary environmental impact analysis of the proposed drilling site.

4.3. DEVELOPING THE RESOURCE

When City staff learned that there was a good probability that El Centro owned property overlaying a geothermal reservoir, the Team focused its attention on problems associated with resource development. Three options available for resource exploration and development were considered. The City of El Centro could contract the well drilling operations to another but maintain ultimate control over resource development. The City could lease development rights to a developer, conditioned upon City receipt of any production from the well(s) at an agreed-upon price. Or the City could pursue a combination of the previous two options by participating in a joint venture with a private developer.

There appears to be statutory authorization for a general law city to implement any of the three options. In addition to Section 39732¹ of the Government Code*, giving municipalities broad authorization over utility-related activities, Section 39792² of that Code grants municipalities the power to "hold and use any land,

*See Section 4.4.1 for discussion.

water . . . (or) other mineral deposits, within or without the City" for purposes of "using, maintaining, or operating any facility."

Leasing the drilling rights to another avoids potential problems for the municipality. One such problem is the City's power to finance its own exploration and drilling venture. The authority to use water or other mineral deposits probably does not grant specific authorization to finance the riskier activities of exploration and development. Three independent statutory bases of financing were considered: (1) revenue bonds; (2) general obligation bonds; and (3) a loan secured through a lending institution and guaranteed under the Federal Loan Guaranty Program.

4.3.1 Revenue Bonds

The Revenue Bond Law of 1941³ is controlling on the issue of whether a general law city, such as El Centro, can finance amounts needed for resource exploration and development for a city-wide utility. The Revenue Bond Law authorizes municipalities to issue bonds for the acquisition, construction, or improvement of any "enterprise" upon a simple majority vote of the electorate. That term is defined as a "revenue-producing improvement, building, system, plant, works, facilities or undertaking" used for specified purposes.⁴

Two of the enumerated purposes have potential application to the development of a geothermal resource prior to the formation of a nonelectric utility. Bonds can be issued for a system which is used for "the obtaining, conserving, treating and supplying of water for domestic use . . . , industrial use, . . . or any other public or private uses."⁵ Because the purposes clause is stated in the conjunctive, a literal reading of the statute permits bond issuances only for systems used for all the activities mentioned. It is suggested that if El Centro's total "system" were viewed as including the drilling and subsequent operation of production and reinjection wells, as well as activities at the district heating level (Section 4.4), the entire system would arguably be used to obtain, conserve, treat and supply water, i.e. geothermal brine. A counter-argument is that geothermal resources are akin to mineral rather than water resources and, therefore, are excluded from this subsection of the statute.* Furthermore, by including resources exploration and development in the definition of "enterprise,"

*The controversy over classifying geothermal resources as mineral or water apparently continues despite the decision in Geothermal Kinetics, Inc. v. Union Oil Co.⁶ The court held that a general grant of minerals underlying property included a grant of geothermal resources, rejecting the surface owner's right to geothermal "waters." The applicability of the court's classification to other cases is unresolved. The California definition of "geothermal resources" contained in Section 6903 of the Public Resources Code provides no definitive answer.

repayment is dependent in part upon a potentially high risk venture which may not produce revenue as contemplated.*

Revenue bond financing for an enterprise is also available for "the generation, production, or transmission of electric energy for lighting, heating, and power for public or private uses."⁷ Assuming the statutory requirement of electric generation poses no barrier (Section 4.4.1.1.1), it is still doubtful that nonelectric generation can be interpreted to include such a remote activity as the exploration for a geothermal "fuel" supply.

4.3.2 General Obligation Bonds

Prior to the passage of Proposition 13 in California (Section 4.4.1.1.2) the ability of El Centro to finance drilling costs through general obligation bonds was more tenable. General obligation bonds are authorized for "any municipal improvement."⁸ A well drilled in order to supply geothermal brine for heating and cooling buildings in the City would arguably qualify as a "municipal improvement." However, voter approval to fund this activity would first be required. While institutional aspects may prove no obstacle to funding, securing City voters' approval to drill wells costing more than \$400,000 each may pose difficulties. The City Council's commitment to geothermal development, evidenced by statements contained in the Economic Development Strategy submitted to Imperial County, may reflect a positive attitude on the part of their constituency. If so, the financial obstacle should not be insurmountable.

4.3.3 Loan Guaranty Program

The Department of Energy Loan Guaranty Program was implemented in 1976 pursuant to the Geothermal Energy Research, Development and Demonstration Act of 1974.⁹ The program's primary purpose is to assist in the development and utilization of geothermal energy in an environmentally acceptable manner by helping to minimize the financial risk in geothermal energy by guarantying loans made by certified lenders to qualified borrowers.

Under implementing regulations,¹⁰ an eligible borrower, which includes a municipal corporation, teams with a qualified lending institution to apply for a loan guaranty. If successful, the Federal government agrees to guaranty lenders against the loss of principal and accrued interest on loans made for specified projects.

A loan guaranty would permit the City to maintain control over geothermal resource development. It would eliminate the risk factor with respect to repayment of the funds loaned by the lending institutions, because the full faith and credit of the United States is pledged.

*In November 1978, the Department of Energy selected for negotiation a proposal by the City of El Centro to heat and cool the El Centro Community Center with geothermal energy. As part of this project, the City will drill a production and a reinjection well at the drilling site under discussion. The verification of a resource in this area would reduce some of the high risk associated with exploration and development.

A guaranty application for funds to drill a geothermal well, however, would be given lower priority, since the objective of that project would be to "exploit the commercial potential of new geothermal resource areas."¹¹ Nevertheless, this option continues to be a viable financing mechanism for at least the drilling portion of any proposed geothermal utility project.

4.3.4 Private Investment

Until recently, private investors had little incentive to risk their money in geothermal exploration and development, since the tax advantages accorded oil and gas development were not applicable to geothermal energy. Provisions of the Energy Tax Act of 1978 attempt to resolve certain tax inequities by permitting the taxpayer the option of expensing intangible drilling costs associated with geothermal drilling.¹² The effect of this provision is to allow an investor to write off that portion of his investment relating to intangible drilling costs even though the well is productive. The Energy Tax Act also amends previous law to provide for percentage depletion on income from geothermal deposits.¹³ The depletion allowance through 1980 is 22 percent and declines to 15 percent for 1984 and all years thereafter. The only limitation imposed by the provision is that percentage depletion cannot exceed 50 percent of the taxable income from the property.*

The aforementioned changes to the tax code should encourage private investment in geothermal exploration. If private investors are willing to take some of the risk of resource development, the City of El Centro may elect to permit private development of the resources underlying and adjacent to the City. Once assured of a supply of geothermal "fuel", the City could undertake the less risky prospect of utility construction and operation.

Early in the study, prior to the passage of the Energy Tax Act, the need for an economically, as well as technically and institutionally, viable project precluded serious consideration of private resource development. It is still doubtful that the new tax provisions can improve the economics of private versus public development sufficiently to warrant further investigation.

4.4 AVAILABLE UTILITY OPTIONS

The following discussion evaluates those administrative vehicles initially considered available for the formation of a geothermal utility within the City of El Centro. Some of the issues associated with each option are raised. Tentative conclusions based on applicable laws and regulations are suggested. The analysis emphasizes those options which give the City greater control over operations. The Team reasoned that if there were viable alternatives within the City's legal and financial capabilities, these alternatives should be given primary consideration. Constraints arising from the City's ownership of the geothermal resource were also evaluated for their effect, if any, on a particular administrative vehicle.

*For a good discussion of tax changes, see Eisenstat, Samuel, "Federal Tax Treatment of Geothermal Exploration and Production," article submitted to the GRC Conference on the Commercialization of Geothermal Resources (November 1978).

4.4.1 A Municipally-Owned Utility

The present Department of Public Works or a separate power or energy department within the City organizational structure would provide the maximum opportunity for local control of geothermal resources and applications.

The question initially raised by a City-run utility operation is City authorization to furnish such a service. El Centro is a general law city. As such it possesses only those powers expressly given it by the State Constitution or general laws of the State, or impliedly granted as necessary and appropriate to the effective exercise of its express powers.

The express authority of El Centro to provide utility service to its residents is founded on Section 9 of Article XI to the California Constitution which states,

"A municipal corporation may establish, purchase, and operate public works to furnish its inhabitants with light, water, power, heat, transportation, or means of communication. It may furnish those services outside its boundaries, except within another municipal corporation which furnishes the same services and does not consent."

Section 39732 of the Government Code grants further authorization for a utility operation. That section reads, in part: "the legislative body (of a municipality) may acquire, own, construct, maintain and operate . . . gas and other works for light, power, and heat . . ." ¹⁴ While this latter provision reads more restrictively than the Constitution, a California appellate court held that the constitutional provision is self-executing and enabling legislation is not required. ¹⁵ The Government Code provision, the enabling legislation, reinforces El Centro's right to establish a utility but does not diminish any rights given the City under the State Constitution.*

4.4.1.1 Financing a Municipal Geothermal Utility

Based upon the foregoing, El Centro's authority to operate a municipal geothermal utility is clear. The financing of such an operation poses more difficult problems. Following the same approach used for evaluating financing for drilling, four alternative vehicles for raising needed utility capital were evaluated: (1) revenue bonds; (2) general obligation bonds; (3) a loan guaranteed under the Department of Energy Loan Guaranty Program; and (4) a government-funded loan or grant.

4.4.1.1.1 Revenue Bonds

As discussed in Section 4.3.1, the Revenue Bond Law of 1941 ¹⁶ limits the power of the City to float a revenue bond issuance for enterprises constructed for

*Related language in the California Public Utilities Code also supports a municipality's right to operate a utility. Section 10001 of the Code includes in the definition of public utility a corporation providing residents with water, light, heat, power, transportation or communication.

enumerated purposes. Water generation/supply and electrical service are two statutory purposes arguably applicable to geothermal utilization in El Centro. Under the first purpose, bonds can be issued for a system used for "the obtaining, conserving, treating and supplying of water for domestic use..., industrial use..., or any other public or private uses." For the purposes of this study, it was assumed that geothermal brine, in passing through the heat exchanger, would heat water which would be "supplied" via a distribution system to various end users. A liberal interpretation of the statutory language seemed to allow revenue bond financing for the described scenario, particularly if municipal development of the resource itself were excluded. A City decision not to develop the resource with municipal backing removes two potential barriers to utility construction financed by revenue bonds: (1) the high risk associated with resource exploration and development and (2) the argument that a mineral i.e. geothermal, rather than water, resource is being supplied by the municipality in contravention of the statute (see Section 4.3.1).

Perhaps the more compelling argument for revenue bond financing can be made under another provision of Section 54309 of the Government Code. A subsection of Section 54309 authorizes a revenue bond issuance for any enterprise used for "the generation, production, or transmission of electric energy for lighting, heating and power for public or private uses."¹⁷ The statute makes reference to an electric system; El Centro's proposed system is nonelectric. Nevertheless, the end uses to which both systems are dedicated remain the same — heating/power applications for public or private uses. Courts often avoid a literal interpretation of a statute where it will frustrate the underlying purpose of the law. One can argue that disallowing revenue bond financing for nonelectric, but not electric applications frustrates the purpose of the statute. This reasoning may be particularly persuasive where, as here, it can be shown that the state of the art in energy applications at the time the statute was enacted precluded legislative consideration of alternative energy financing.

The second statutory category clearly omits this method of financing for the distribution of energy. The costs of constructing a distribution system, which will consume roughly 2/3 of El Centro's total project requirements, will probably require the issuance of general obligation bonds. Such a large sum may exceed El Centro's bonding capacity (see Section 4.4.1.1.2).

Barring a liberal construction of the statute authorizing revenue bonds, the Team concluded that this means of funding may be unavailable for nonelectric applications under the second category of "enterprise", but may be possible under the first. One member of the Team suggested that the City explore the possibility of legislative amendments to the statute. Two fundamental changes to the second category would be required: authorization to finance nonelectric "generation" and distribution of geothermal energy. In the absence of amendatory language, revenue bonds for drilling geothermal wells and for constructing a distribution system, both costly operations, do not appear feasible for the El Centro geothermal utility system.

4.4.1.1.2 General Obligation Bonds

Under the California Government Code,¹⁸ the legislative body of a municipality has the authority to issue general obligation bonds for any "municipal

improvement" requiring a expenditure greater than the amount allowed for it by the annual tax levy. The definition of municipal improvement includes construction of power works,¹⁹ which is sufficiently broad to include the facility which El Centro would construct.

Prior to the issuance of general obligation bonds, however, the residents must approve such an action. While the residents of the Imperial Valley appear to have adopted a favorable stance toward geothermal development as a concept (see Section 4.6), estimates of the cost of a city-wide geothermal system are high, reducing the likelihood that the community would approve such a bonding measure. Moreover, two other factors could defeat this financing option. The first factor is voter passage of Proposition 13. This state constitutional amendment places a one percent ceiling on any increase in property taxes, which secure the bonds issued. As a result, municipalities like El Centro will probably find it impossible to fund major capital improvements by this means of financing. Secondly, the bonding capacity of a municipality the size of El Centro may be insufficient for an undertaking of this magnitude.

4.4.1.1.3 Loan Guaranty Program

As previously noted, financing backed by the Department of Energy (DOE) Loan Guaranty Program offers many attractive features for a municipality like El Centro. Under DOE regulations, the project category most closely analogous to the El Centro utility concept encompasses the development, construction, and operation of equipment or facilities for the demonstration or commercial production of energy (e.g. space heating) from geothermal resources.²⁰ El Centro's proposed utilization of geothermal energy for space heating/cooling, and domestic hot water heating qualifies for a guaranty under the general guidelines. In addition, the Secretary is directed to give preference to projects having a plan of operations showing substantial promise of prompt development of useful geothermal energy.²¹ The success of the El Centro Core Utility Field Experiment (see note to Section 4.3.1) will, hopefully, satisfy this evidentiary requirement should El Centro decide to apply for a loan guaranty.

Recent amendments²² to the Act now provide the following additional incentives for borrowers to apply for a loan guaranty.

(1) DOE may make interest differential payments for guaranties on taxable borrowing by municipalities and other political subdivisions of states.

(2) DOE can guarantee 75% of a project's total estimated costs up to a limit of \$50 million (rather than \$25 million) for any nonelectric project or \$200 million per borrower (up from limit of \$50 million) where certain conditions are met.²³ (El Centro's needs will likely be within the loan guaranty dollar limitation, even if the entire residential and commercial sectors of El Centro are retrofitted for use of geothermal energy.)

(3) DOE is authorized to give loan principal assistance should the borrower find it cannot meet current interest charges or principal payments. The Secretary must first conclude that continuation of the project is in the public interest and must secure the borrower's promise to repay the amounts received.²⁴

Another attractive feature of the program is a provision permitting "sunk costs," or costs already expended on a project, to be applied toward the aggregate project cost and, therefore, toward the allocated 25 percent portion of costs not includable within the guaranteed portion of the loan.²⁵ For example, assuming a City-wide district heating and cooling system were feasible, the City could locate district facilities on City-owned property. The market value of such property could be applied toward the equity portion of funding; the property itself would serve as project collateral for the loan guaranty. The regulations also permit, as a credit to the required equity portion, any funds expended by a non-borrower as long as the non-borrower is a participant in the project.

The City of El Centro will be subject to one drawback under the program because of the selection of its Field Experiment under a separate DOE-demonstration program. DOE financial assistance to the Field Experiment will reduce the percentage of project costs which can be guaranteed by DOE under the loan guaranty.²⁶ However, because total project costs for a City-wide utility will substantially outweigh the costs of the pilot project, no significant reduction in the amount qualifying for a guaranty is expected.

It should be pointed out that while the above referenced amendments to the statute have been enacted, not all of the regulations implementing these amendments are in effect. Final adoption of the proposed regulations is expected within the next several months without significant change.

4.4.1.1.4 Government Grants or Loans

A federal or state grant was the final source of funding considered for an El Centro municipal utility. A review of state and federal programs which specifically aid municipalities was conducted. A review of current literature disclosed no major state funding programs available to El Centro for a municipal utility concept in the alternative energy area. On the federal level, the Economic Development Administration (EDA)-administered Grants for Public Works and Development Facilities²⁷ was initially identified as having aims similar to those of El Centro's. The EDA programs are designed to encourage economic and social growth in areas like El Centro which suffer from high unemployment and low family incomes. Eligible projects may receive funding for 50 percent of total eligible project costs, but must be located in an EDA-designated area. El Centro is within such a designated area. Eligible projects include utilities, but exclude those utilities involving (1) the generation, transmission, or distribution of electric energy; (2) the production or transmission of gas; or (3) competition with an existing privately-owned public utility. Since Southern California Gas Company, a privately-owned public utility serving El Centro, falls within this third category, funding for a utility serving the residential and commercial sectors would be unavailable. However, this source of funding may be applicable to the concept of an industrial park utilizing geothermal energy (Section 4.7).

The relatively recent creation of the Southwest Border Regional Commission (SBRC) offers yet another source of financial help. The Commission is authorized to disburse funds to promote economic development pursuant to the same Act²⁸ under which the EDA operates its public works program. Local governments in designated counties of the Southwest, including Imperial County where El Centro is situated, may apply for funding. Funds are administered pursuant to individual Southwest border programs.* Like the EDA programs, no assistance is given to projects (1) "for the generation, transmission or distribution of electric energy" or (2) "for the production or transmission of gas." However, there is no restriction prohibiting competition with an existing private utility, nor technically will El Centro's proposed utility utilize either "electric energy" or "gas."

A final area of grant activity, particularly for the residential sector, is through the Department of Housing and Urban Development (HUD) Community Development Block Grants.²⁹ The Community Development Block Grant program is HUD's primary means of providing community development assistance. Through the program HUD provides 100 percent Federal grants (with no matching requirement) to local governments for funding a wide range of community development activities. Units of local government are eligible to apply for funding in a number of areas, including housing rehabilitation and the acquisition, rehabilitation, or construction of certain public works facilities and improvements. The City of El Centro has already received funds from HUD for water and sewer lines in an area designated in the City's General Plan as Tract 98. Tract 98 is proximately located to the proposed drilling and utility site and is part of a larger area earmarked for housing revitalization.

Initially, the Team considered as a possible alternative to direct or supplementary grant funding from the Federal government, the concept of the municipal utility's leasing of the necessary geothermal equipment to residents. This practice is currently employed by some gas companies which lease appliances to customers within their service area. While the utility is able to amortize the cost of leased equipment over the life of the system, the utility would still be required to locate a source of revenue for equipment purchase. In addition, this concept only has practical applications for a business concern desirous of the tax benefits of expensing the lease cost versus financing the entire cost of the equipment and recouping these costs through depreciation. It is doubtful that equipment leasing would be of any benefit to the residential sector.

4.4.2 Municipal Utility District

Since the Team recognized that institutional or economic constraints might ultimately dictate the formation of a utility not wholly owned and operated by the City, other alternatives were investigated. The first of these alternatives was the formation of a municipal utility district pursuant to the Municipal Utility District Act.³⁰ The Act provides that a public agency (which includes a city, county water district, county sanitation district or sanitary district) together with unincorporated territory or two or more public agencies may incorporate as a district.³¹ No public agency can be divided in the formation of the district.³²

*The City of El Centro has already been awarded SBRC funds for a solar water heating demonstration at a senior citizen housing complex.

Initially, it was suggested that El Centro could team with another public agency such as the Imperial Irrigation District (IID) or the Imperial County. However, the provision against dividing public agencies would probably prohibit participation by either the County or the IID.

The other possibility under this statute was a joint effort between El Centro and unincorporated territory. This option also appeared unavailable, since most areas surrounding El Centro are incorporated in the county or some other district. But a California Attorney General's opinion declaring that a district can consist of an unincorporated city and a part of the incorporated territory of a county suggested otherwise.³³

The Municipal Utility District Act provides ample authorization to form a geothermal utility. Statutory language paralleling that governing municipally-owned utilities grants a district broad powers to own and operate "works...for supplying the inhabitants of the district and public agencies therein, or some of them, with light, water, power, heat...and may do all things necessary or convenient to the full exercise of the powers herein granted."³⁴ Nevertheless, just as a municipal utility operated by a general law city derives its authority to finance a utility by statute, a statutorily-created district is limited by law in the way in which it can finance its utility system. Municipal utility districts are authorized to incur a bonded indebtedness in order to pay for the cost of the utility or works referred to in the statute and for "acquiring any works, land, structures, rights or other property necessary or convenient to carry out the objects, purposes, or powers of the district."³⁵ Acquiring rights to geothermal brine and for constructing a utility system appear to fall within the enumerated uses for which bonds are issuable. The power to issue bonds, however, is somewhat restricted by subsequent provisions of the Act. Those provisions permit a district to issue general obligation bonds upon a two-thirds (2/3) vote of the voters voting,³⁶ but contain no language granting a district the power to issue revenue bonds for a nonelectric system.³⁷

The district is empowered to finance a "special district enterprise by levy and collection of taxes upon property within the special district" without prior voter approval, notwithstanding any other provisions in the Act.*³⁸ Assuming a geothermal utility system can be defined as an "enterprise," the imposition of additional taxes on property in El Centro is not realistic, particularly on those parcels included in the Engineering Team's high density case. The high density districts of El Centro are also low income areas already designated for federal and state improvement aid.

Finally, the element of City control in a municipal utility district was considered. A district is governed by an independently elected Board of Directors. The Board fixes rates and charges for any service provided by the district. This ratemaking authority and other powers of the Board would, by definition, restrict the City's input into management of the utility. Since the desirability of maintaining City control would ultimately depend on many factors, including utility system size, financing and manpower resources, the concept of a municipal utility district was not rejected out of hand. But late in the second quarter, the Team concluded that the municipal utility

*The passage of Proposition 13 may affect the power of a special district to levy taxes.

district concept presented several major drawbacks, as noted above, and provided no singularly positive feature otherwise unavailable in other alternatives.

4.4.3 Joint Powers Agency

The joint powers agency is an administrative vehicle selected by at least one group of cities involved in geothermal development.* Statutorily-created pursuant to the Joint Exercise of Powers Act,³⁹ a joint powers agency basically provides a procedure whereby existing powers may be exercised by cooperative action.⁴⁰ Public agencies authorized to enter into joint powers agreements include cities, public corporations, and public districts of the State.⁴¹ By law, their organizing documents must state the purpose of the agreement or the power to be exercised. The document must also provide for the manner in which the stated purpose will be accomplished.⁴²

Since El Centro does have the power to construct and operate a utility system, the Joint Exercise of Powers Act authorizes it to act in concert with others having the same power. Early team discussions raised the possibility of a joint City-Imperial Irrigation District (IID) system. Closer examination of the Act suggested that this arrangement would not be possible since there was considerable doubt whether the IID had the power to join the City in a nonelectric geothermal project. In order for an irrigation district to act in concert with another public agency and perform some function under the Act, the district must be "concerned with the work to be performed."⁴³ The powers of an irrigation district are strictly controlled by the California Water Code⁴⁴ and fall within two general categories: (1) the power to control and distribute water for beneficial uses⁴⁵ and; (2) the power to provide electric power by any available means.⁴⁶ The District, governed by an elected Board of Directors, is also authorized to issue bonds for the purposes of acquiring necessary irrigation, power development, or distribution works.⁴⁷ Whether District participation in a nonelectric application falls within the scope of the above-mentioned powers or "concerns" is debatable. The Team made no further inquiry into this area of the law, once the IID disclaimed any current interest in pursuing a joint project with El Centro.

The Team did investigate financing options under the Act. Since the Joint Exercise of Powers Act authorizes participating entities to exercise existing powers, restrictions on the power of El Centro, as a general law city, to issue revenue bonds remained. One other financial option to circumvent this restriction came to the Team's attention. The Act authorizes the participants to make contributions from their treasury and advance public funds.⁴⁸ It also permits repayment of advanced funds from the revenue-producing project acquired or constructed with the funds.⁴⁹ Other writers have suggested that from this grant of authority, the necessary power to issue bonds may be implied apart from the general laws. Moreover, these writers raised the possibility that one public agency may generate funds needed for the entire project.⁵⁰ Application of this concept would permit an entity with the power to issue revenue bonds to raise all funds required for a joint utility project with El Centro.

*The Northern California Power Agency, comprised of charter and general law cities, was organized pursuant to the Joint Exercise of Powers Act.

4.4.4 Non-Profit Corporation

4.4.4.1 Background

In reviewing the previous administrative vehicles, the Team examined the degree of utility control offered by a particular option. These options ranged from ones in which El Centro had complete control over utility operations (municipally-owned utility) to a joint venture arrangement with another public agency where utility control would reside in an independent Board (Municipal Utility District or Joint Powers Agency). The not for profit or non-profit corporation would provide a slightly different approach to a workable utility scheme.

The formation of a non-profit corporation is governed by the California Non-Profit Corporation law.⁵¹ Under the statute, power is vested in a Board of Directors. Members of the corporation, here the City of El Centro, generally decide who is to serve on the Board. By choosing as its Board of Directors elected City officials, City control could be maintained in a separate organizational structure. However, having City officials serve on a board making decisions on utility service to the municipality raises a potential conflicts of interest problem. An independent Board to direct corporate affairs would avoid the appearance of improper utility transactions.

In order to evaluate the suitability of this concept for geothermal operation, the Team examined several non-profit corporation models developed by other public entities. The model developed for an electric project in the City of Susanville, a general law city like El Centro, served as one illustration. The scenario suggested initially for Susanville provided that all city project assets were to be assigned to the corporation. In return, all corporate income would flow to the community. Susanville's power department would purchase all power produced and would distribute this power directly or through another utility to the agency.

The City of Burbank also structured a non-profit corporation as a financing vehicle for its joint venture with Republic Geothermal, a geothermal resource exploration company. One of Burbank's options provided for primary funding through the corporation via bonds backed by a Federal guaranty. The City, on behalf of the corporation, would apply for the guaranty and supply the remaining funds out of its own treasury.

Finally, the Northern California Power Agency, mentioned above in connection with the formation of a joint powers agency, also formed a non-profit corporation for the purpose of potentially financing energy projects through revenue bonds issued by the agency. Take or pay contracts with each member city of the Agency would serve as collateral for the bonds. Under both the NCPA and Burbank arrangements, bond issuances by a non-profit corporation raised tax and securities registration problems not typically found in bond issuances by municipalities. These problems were exacerbated in Burbank's case by the fact that funding was potentially sought for exploration of the resource as well as development of the utility system (see discussion below).

4.4.4.2 Financing the Non-Profit Corporation

The institutional barriers associated with the selection of a non-profit corporation as a vehicle for utility formation depend in part upon whether tax-exempt financing is sought. If tax-exempt financing is the objective, the corporation will want to be assured that the interest on its debts receives tax-exempt treatment by the Internal Revenue Service. If tax-exempt financing is not desired, e.g. if the City is a successful applicant under the DOE Loan Guaranty program which requires that interest on the non-profit corporation's securities be taxable,⁵² questions regarding the need for securities' registration and compliance with other regulatory requirements are raised.

4.4.4.2.1 Tax-Exempt Financing

The choice of a non-profit corporation as an administrative vehicle for utility formation permits the issuance of bonds without the necessity of voter approval. Nevertheless, the funding for the project must still be arranged. Typically, an agreement between the city and corporation provides that bonds will be issued by the non-profit corporation on behalf of the municipality and will be served out of periodic payments made to the corporation by the City. The City must take care to ensure that these payments do not violate debt limitation provisions of the State Constitution. Section 18 of Article XI of the California Constitution prohibits local governments from incurring any indebtedness in any manner for any purpose exceeding the entity's current revenues except upon the favorable vote of two-thirds of the electorate.

Despite this restrictive language, the courts have carved exceptions to the constitutional prohibition. One exception potentially available to the City is the lease-purchase agreement.* The origin of the concept of lease-purchase is found in the doctrine of contingent obligations. This doctrine states that a debt payable on a contingency is not really a debt at all until the contingency occurs. Thus, in a leading case, the court held that a City's aggregate payments under a five-year contract with an individual for services did not exceed debt limitations.⁵³ The court reasoned that the contract obligated the City to pay only if the individual performed and was, therefore, an obligation contingent upon performance.

The doctrine was later extended to cover lease payments. The lease rent, like periodic payments for service, was not due from month to month until the leasehold was actually furnished. One test to determine whether a particular lease violates the debt limitation provision was announced in City of Los Angeles v. Offner.⁵⁴ That case holds that there is no violation if the lease (1) is entered into in good faith and (2) creates no immediate indebtedness for the aggregate installments, but instead limits payment as it falls due and is for consideration actually furnished.

Cities now apply the contingent obligation doctrine to lease-purchase financing schemes by creating a non-profit corporation. The corporation issues bonds to

*Another exception to the debt limitation provision, the special assessment district, is, in theory, an additional option if a less than City-wide system is considered. However, assessing property which is to receive the utility service is not a realistic alternative for the City of El Centro.

raise the necessary funds, giving the lease and rental payments thereunder as security for the bond payments.

In order for the corporation's bonds to be given tax-exempt treatment, the corporation must comply with the requirements of Revenue Ruling 63-20.⁵⁵ That ruling, in part, requires that the sponsoring city (i.e. one on whose behalf the bonds are issued) acquire title to the utility at the end of financing. This requires in turn that there be a capital asset, i.e. some "facility," to transfer. In the case of geothermal exploration, the only arguable asset is the geothermal supply well. For the development phase, the district heating and cooling system would probably qualify. Typically, the non-profit corporation agrees only to supply the "facility" in return for "rental" payments. These payments in effect reflect an amount sufficient to return the principal cost of construction (or drilling) plus interest. The City typically reimburses the corporation for taxes, assessments and insurance, and agrees to maintain the facility.

The foregoing arrangement may become unavailable to the City if proposed regulations by the U.S. Treasury are adopted. On February 2, 1976, the U.S. Treasury proposed regulations redefining which entities are eligible issuers of tax-exempt bonds under Section 103(a) of the Internal Revenue Code.⁵⁶ These proposals outline requirements of who may be an issuer "on-behalf-of" a state or political subdivision. To date, no final action has been taken on these proposed regulations. Recent I.R.S. rulings⁵⁷ based upon the current regulations held that a state university and community development authority were not "political subdivisions" for purposes of Section 103(a). Later "clarifications" appeared to reverse any negative effects of these rulings, but do illustrate the uncertainties presently surrounding tax-exempt issuances.⁵⁸

4.4.4.2.2 Financing by Taxable Bond Issues

The City of El Centro may wish to file an application for a loan guaranty under the DOE program (Section 4.4.1.1.3). The program specifies that the interest on the non-profit corporation's securities must be taxable. Other authors have suggested that this raises potential securities' registration problems.⁵⁹

The Securities Act of 1933 exempts from registration those securities guaranteed by the United States. Since the bonds of a non-profit corporation will only be issued if the loan guaranty is approved, the issue would likely be exempt under the statute. "No action" letters issued by the Securities and Exchange Commission (SEC) in situations involving similar guaranties indicate that the exemption from registration applies as long as the full faith and credit of the United States is backing the guaranty. A recent amendment to the statute authorizing the Loan Guaranty Program⁶⁰ now specifically states that the full faith and credit of the U.S. supports these guaranties. Discussions with DOE officials indicate no major problems to date in the Federal securities' registration area. Language patterned after the Federal statute in California securities' qualification laws⁶¹ administered by the Commissioner of Corporations similarly appears to pose no problems.

The California Public Utilities Commission (CPUC) also has extensive jurisdiction over public utilities in the areas of securities' issuances and rates. The California Public Utilities Code grants exemption from CPUC jurisdiction in the area of securities' issuance to those corporations "performing services or delivering commodities to or for . . . municipal . . . corporations."⁶² The non-profit corporation would be performing such services; therefore, its issuances would probably be exempt. The statute likewise grants exemption from the CPUC's ratemaking authority to utilities operated by municipal corporations.⁶³ Even though the non-profit corporation would provide the financing, the City of El Centro would probably operate the utility. As a municipal corporation, the City, not the CPUC, would set the appropriate rates for geothermal utility service.

4.4.4.3 Privately-Owned Utility

The final alternative considered for the formation of a geothermal utility was a privately-owned and operated system. This option obviously affords El Centro the least amount of control over operations. Some control is retained by virtue of the municipality's right under the California Public Utilities Code to franchise all public utility operations within its jurisdiction.⁶⁴ In granting a franchise, a municipality has the authority to impose additional terms and conditions not in conflict with law whether governmental or contractual in character.⁶⁵ The City also retains the right of eminent domain in respect to any public utility.⁶⁶

At the State level, the CPUC has primary regulatory jurisdiction over the financial transactions, safety of operations, and rates of privately-owned "heat"⁶⁷ corporations. If the CPUC were to decide that a nonelectric utility were a "heat corporation," and, therefore, within its jurisdiction, the Commission would require the private utility to secure a certificate before constructing any facility.⁶⁸ To secure a certificate, the Commission must find that the public convenience and necessity will be served by the operation of the utility. While other public utilities serving the area have no constitutional right to be protected from competition, they are entitled to a hearing before the Commission can grant a certificate to a competitor.⁶⁹ In this manner, the Commission prevents duplicative efforts in providing utility service.

Once an application for certification is granted, the Commission is directed to set a "just and reasonable" rate which includes a rate of return on the utility's investment. Providing a return on investment will obviously increase the costs of the system and the ultimate rate paid by the consumer. Thus, economic constraints and the City of El Centro's interest in some form of public utility influenced the Team's decision not to pursue the private utility option further.

4.5 INCENTIVES FOR UTILIZATION OF GEOTHERMAL ENERGY

4.5.1 Background

The public will take advantage of incentives for using geothermal energy only after it has some basic understanding of this alternative energy form. To find out public attitudes toward and awareness of geothermal energy in Imperial County, the Team reviewed existing literature on the subject.

One study conducted in connection with the preparation of the Imperial County Geothermal Element found that about 90 percent of the population of Imperial County is in favor or strongly in favor of geothermal development. Fifteen percent of those questioned believed there was opposition to geothermal development. Only 19 percent felt they had a good understanding of geothermal development, while three-fourths of the respondents advocated strong regulation of geothermal development.⁷⁰ The conclusions drawn by this report and another authored by researchers at University of California at Riverside⁷¹ indicate that the potential of geothermal development is seen as a significant solution to the area's economic problems. Fostering the County's economic growth is of top priority to area residents who view bringing jobs to the area through secondary industries as the most helpful aspect of development for County residents. A recommendation of both reports was that Imperial County should attempt to involve citizens more actively in decisions associated with geothermal development.*

4.5.2 Incentives for Residential Applications

The above-referenced studies concluded that Imperial County residents see geothermal energy as a means of reducing their energy costs and thus look upon geothermal development favorably. The problem is whether the public is willing to invest now in retrofitting or in installing a geothermal system in order to reap the potential long-term benefits of a cheaper fuel source.

During the second quarter, the Team discussed the feasibility of raising the necessary money for the district equipment and distribution system by means of a bond issuance. However, the bond funds would not likely be applied to certain costs associated with the retrofitting or initial installation of geothermal equipment in the home. These costs would be borne by the homeowner. In most cases, the residential system will include the distribution system or piping from the main pipeline, and the fan coil unit within the homeowner's existing heating/air conditioning system. It was mentioned earlier that, assuming adequate utility funds, these expenses might be initially financed by the newly-formed utility. The utility would, in turn, lease the equipment to residents. However, the Team concluded that equipment leasing has potential appeal to businesses rather than to residents (see Section 4.4.1.1.4). The new Energy Tax Act now offers residents a tax stimulus to use geothermal energy.

4.5.2.1 Residential Tax Credit

The recent passage of the Energy Tax Act of 1978⁷² (one of five bills comprising the National Energy Act, effective November 1978) makes the purchase of equipment by the resident preferable to a leasing arrangement. With respect to the residential dweller,** the Energy Tax Act amends the Internal Revenue Code to provide for a non-refundable credit against taxes for specified equipment which uses

*Community leaders in El Centro appear to be providing the greatest opportunity for citizen involvement with respect to the development of the proposed industrial energy park (Section 4.7)

**The dwelling unit must be the taxpayer's principal residence, but no ownership requirement may be imposed.

geothermal energy. The allowable amount of the credit is 30 percent of the expense up to \$2,000 and 20 percent of the expense from \$2,000 to \$10,000 or a maximum credit of \$2,200. The equipment must transmit or use geothermal energy and must have an operational life of five years. It must also meet certain performance and quality standards when such standards are finally promulgated by the Department of Energy.⁷³

The Act also provides that expenditures made in connection with the construction or reconstruction of a dwelling to utilize geothermal energy shall be treated as made when the original use of the constructed or reconstructed dwelling by the taxpayer begins. No credit may be claimed after December 31, 1985.⁷⁴

The Technical Team estimates that the cost of installing and equipping a geothermal system in El Centro would run about \$1,500 per dwelling. This amount would entitle an El Centro taxpayer to a credit of approximately \$450 for utilizing a geothermal system. The credit applies to purchases made before January 1, 1986, and can be carried over to future years for those unable to use the credit in the year of purchase.

4.5.2.2 Incentives Under Government Programs

The new residential energy tax credit discussed above will only be of benefit to those taxpayers who have a need to offset potential taxes due. To those low-income residents of El Centro, some leasing arrangement or other means of financing must be made available.

Unfortunately, the new National Energy Conservation Policy Act of 1978⁷⁵ (part of the NEA) does not authorize any new Federal assistance for installation of geothermal systems. The Energy Conservation Program loans and grants (to Federally-assisted housing) to be administered by the Department of Housing and Urban Development (HUD) and its various offshoot agencies (e.g., the Government National Mortgage Association (GNMA), the Federal Home Administration (FHA), and the Farmers Home Administration (FMHA) are to be applied toward solar energy systems and "energy-conserving improvements" (defined as weatherization materials) only. Thus, any funding will have to come from existing State and Federal programs which often spread limited sums over many competing areas.

One State program recently made available to El Centro residents is the Home Ownership and Home Improvement Loan Program (HOHI)⁷⁶ which assists low and moderate income people in purchasing or rehabilitating their homes by providing loans at below market interest rates. This program could be useful for residential funding of a geothermal system in the context of a plan to rehabilitate an existing dwelling or to construct a new dwelling. HOHI is operated by the California Housing Finance Agency (CHFA) through the assistance of private lenders and local governments. For the City of El Centro to become eligible for loan assistance, the CHFA was required to designate El Centro as a mortgage assistance area.

There are four types of loans available in localities participating in CHFA's HOHI program.

- Mortgage loans to rehabilitate and refinance;
- Mortgage loans to purchase and rehabilitate;

- Add-on loans for rehabilitation only;
- Mortgage loans to purchase a new or existing residence.

Each loan program specifies loan terms, amounts, and types of structures for which a loan may be available.

4.5.3 Incentives for Commercial/Industrial Applications

4.5.3.1 Business Investment Tax Credit

The newly enacted Energy Tax Act of 1978 amends Section 46 of the Internal Revenue Code to provide for an additional investment tax credit for businesses utilizing geothermal equipment. A credit is given either for equipment used to produce, distribute or use geothermal energy ("alternative energy property") or for equipment, "...the principal purpose of which is reducing the amount of energy consumed in any existing industrial or commercial process and which is installed in connection with an existing industrial or commercial facility..." ("specially defined property").⁷⁷ Examples of specially defined energy property include heat exchangers, waste heat boilers, and preheaters. The tax credit is 10 percent, is non-refundable and can be applied through December 31, 1982. By definition, all businesses, whether converting existing facilities to geothermal or installing new systems, can qualify for the tax credit. Assuming no alternate means of financing, this tax incentive would provide a stimulus for attracting business to the proposed El Centro Geothermal Industrial Park (Section 4.7).

4.5.3.2 Incentives: Loan Assistance

There are presently three programs which offer businesses in El Centro loans with attractive interest rates and which appear to allow the expenditure of loan funds for the purchase and installation of a geothermal system. A brief description of each follows.

4.5.3.2.1 Business Development Loan Program

The State of California and the U.S. Economic Development Administration (EDA) participate in a joint funding program⁷⁸ which provides businesses low interest, long-term loans which result in new permanent jobs in the private sector. The program appears to have its greatest potential application to the proposed industrial energy park. Most private businesses, non-profit organizations and local political subdivisions are eligible for loans from \$50,000 to \$350,000. These business loans may be used to finance the cost of buildings and fixed assets, as long as new jobs are created. The program specifically prohibits the use of funds for public utility purposes. Therefore, it was not considered an option under the earlier discussion on financing for a municipal geothermal system.

4.5.3.2.2 Local Development Company Loans

The Small Business Administration (SBA) finances small business loans through a local vehicle called a local development company (LDC). To date, there are two LDCs in El Centro. The El Centro Development Company (ECDC) concentrates

on assisting businesses in the downtown area, while the Commercial and Industrial Development Company (CID) works with businesses throughout the rest of the city. Virtually every business in the City of El Centro qualifies as a small business under SBA eligibility criteria.* The loans are available for the purchase, renovation, or modernization of buildings and for fixed asset acquisition. The SBA share of the loan may not exceed \$500,000. Professional fees for engineering and architectural services applicable to the project are also allowed.

The loans are usually amortizing term loans providing for regular monthly payments of principal and interest. The loan term for a proposed geothermal system would likely depend on the life of the system. The small business itself is required to fund 20 to 25 percent of the amounts needed. Moreover, the business must typically secure repayment of the loan portion with collateral -- a mortgage on the building purchased or a lien on equipment and fixtures acquired.⁷⁹

4.5.3.2.3 Regular Business Loan Program

The Small Business Administration (SBA) offers a regular business loan program to assist small businesses in financing their needs. Guaranteed/insured loans are provided to construct, expand or convert facilities, to purchase buildings, equipment or materials, and for working capital. This program differs from the previously mentioned program (Section 4.5.3.2.2) in that it allows the expenditure of loan funds for working capital and no local sponsoring organization is required. The SBA may lend up to \$150,000 on a direct basis and up to \$500,000 on a guarantee basis. The program is similar to the SBA/LDC sponsored loan program as to eligibility criteria, collateral required, and repayment provisions.⁸⁰

4.5.4 Redevelopment: Incentive for Applications in Designated Area

Redevelopment is an activity by local government to bring about new development in "blighted" urban areas. To accomplish this objective, the Agency is empowered to rehabilitate structures or to assist homeowners in doing so and to install, construct or reconstruct streets, utilities and other public improvements. Therefore, it can indirectly serve as a means of funding a geothermal utility system for any portion of the City of El Centro within the redevelopment project area (Fig. 4-1).

In accordance with the authorizing state statute,⁸¹ redevelopment activities are carried out by community redevelopment agencies (CRA). The City of El Centro has established a CRA and has adopted a redevelopment plan, effective October 1978.⁸² The plan permits the Agency to finance any project with financial assistance from the City, State of California, property tax increment funds, interest income, Agency bonds and loans, and any other proper source.

The City of El Centro Staff foresees redevelopment programs funded primarily by tax increment financing. This method of financing freezes the assessed valuation of the redevelopment sector's tax base. Tax revenues in excess of that base, i.e. those generated by new development in the redevelopment area, are earmarked for

*A non-profit corporation, however, is ineligible to receive funds.

CITY OF EL CENTRO
REDEVELOPMENT
PROJECT AREA

City of El Centro Redevelopment Project Area

FIGURE
4-1

further redevelopment rather than going into the City's general fund.* The taxes on increases in total assessed value are paid to the Agency to pay the principal and interest on any loans, moneys advanced to, or indebtedness incurred by the Agency to finance redevelopment activities in the area. A CRA, then, may use increased tax revenues to pay off debts directly or as security for the sale of bonds. The sale of bonds at the project's start-up has the advantage of providing the CRA with funds that would otherwise be received through tax increments over a long period of time.

The City of El Centro CRA plans to issue tax allocation bonds, when feasible, to finance redevelopment costs. Since the bonds are obligations of the CRA and not the City, they can be issued without voter approval. Bondholders cannot require a levy of additional property tax to assure the payment of principal and interest for an unsuccessful project.

Because of this added risk, tax allocation bonds are less attractive to investors than general obligation bonds. It usually takes one dollar in tax increment funds to sell about eight dollars worth of bonds. For example, \$1,000 in tax increment revenues usually generate \$8,000 in revenues for redevelopment projects.⁸³ Since the approval of Proposition 13 by California voters, the amount of funds generated by tax increment funding may be severely limited, inasmuch as revenues are based upon the tax rates in effect from year to year.

The sale of lease revenue bonds by the CRA is another financing option discussed earlier in connection with the selection of a non-profit corporation as a utility administrative vehicle. Lease revenue bonds are used to raise money to permit the CRA (a type of non-profit corporation) to construct certain facilities. The facilities are leased to the City. City payments under the lease are then utilized to repay the bondholders. The CRA is also empowered to use tax increment funds to subsidize the City's lease payments.

Generally, bond investors look more favorably upon lease revenue bonds than tax allocation bonds. As with all financing, however, the specifics of a project and the risks perceived by the investor would heavily influence the outcome of funding.

Municipal borrowing under redevelopment plans has been challenged as providing municipal financing in aid of private entities and as violating the State constitutional prohibition against the lending of State or municipal credit. Nevertheless, the trend in the law has been to uphold the validity of municipal bond authorizations on one of the following grounds: (1) that the issuing entity is a separate State agency with separate funds from which to satisfy bond obligations; or (2) that, even if a loan of State credit is involved, the bonds are not obligations of the State. Therefore, no grant of the State's credit for these bonds has been given.⁸⁴

In a recent case,⁸⁵ a redevelopment plan was attacked for lending public credit in aid of private persons or corporations. The plan involved financing a

*It should be pointed out that tax increment financing is currently being challenged in court by a group of taxpayers. The suit filed against 15 Los Angeles counties, cities, and their redevelopment agencies alleges that the method is a violation of due process and equal protection of the law.

redevelopment housing project through the issuance of revenue bonds. The court held that what constitutes adequate public purpose for expenditures which incidentally benefit private persons is a matter of legislative discretion. While there was no guarantee that low-or moderate-income people would be benefited by the project, the court found that there was a sufficient public purpose served by providing decent housing for the public in a general way. No prior voter approval was needed because the planned housing might go to low- to moderate-income persons.

At present, the City of El Centro CRA appears to be taking a cautious approach toward project funding. The Redevelopment Plan provides that funds will be expended in the proposed project area only when working capital becomes available. As indicated above, working capital will not be available unless there is development or a guarantee of development sufficient to generate a flow of tax increment funds. At such time as working capital is obtained, the Agency in limited areas, for specific purposes, plans to acquire real property, relocate occupants, clear land, make necessary public improvements and incur other necessary redevelopment costs. Moreover, it is the intent of the Redevelopment Agency to provide assistance only if the redevelopment or revitalization of the area cannot be accomplished through private developers.

It should also be pointed out that the City of El Centro CRA must operate under certain statutory constraints. Some of the more important limitations imposed upon redevelopment programs specify: (1) the amount of tax increment dollars which can flow to a project; (2) the length of time for establishing debt to finance a project; and (3) the amount of bonded indebtedness which can be outstanding at any one time.⁸⁶

Despite these restrictions, community leaders look upon redevelopment as providing direction in planning and marketing what is now vacant, stagnated or unproductive property. The Redevelopment Agency may ultimately wish to consider a geothermal utility as part of its overall commitment to achieve these objectives.

4.6 INTERFACE WITH EXISTING UTILITY SYSTEMS

An issue related to the selection of an appropriate utility option is the impact a nonelectric geothermal system will have on existing utilities in El Centro. Presently the Imperial Irrigation District (IID) provides residents with electrical and water service. Southern California Gas Company (SoCal) operates natural gas service under a franchise granted by the City. A franchise typically grants the utility the exclusive right to provide such service until otherwise terminated by the City. An El Centro geothermal utility, however, would provide neither natural gas nor electric service to residents. Any use of the geothermal resource would be reserved for nonelectric applications. Therefore, only minor adjustments to existing utility franchises would be likely if a municipally-controlled system were implemented.

Under a municipal system, it is clear that the need for both electrical and natural gas service will be reduced if residential/commercial heating and cooling systems, hot water heating, and industrial applications are found feasible. Residential/commercial cooling applications will substantially reduce electrical consumption, while geothermal energy applied to industrial processes will reduce the natural gas demand.

The continued need for a backup conventional system raised two basic questions: (1) whether SoCal and the IID would be willing to provide standby service to El Centro and (2) what the utilities would propose to charge for this service. The final answer to these questions will depend upon the individual utility. The City hopes for favorable responses since any El Centro geothermal utility system will be designed to supplement energy needs when the existing utilities most need this help (i.e. space cooling for summer; hot water and space heating for winter).

4.6.1 Natural Gas System

With respect to natural gas service, energy shortages within the past several years have caused this fuel source to become supply constrained. Therefore, the Team first requested a statement from SoCal on its ability to hook-up new residential and industrial customers in El Centro.⁸⁷ A response by a company spokesman⁸⁸ indicated that, based upon current supply projections, the Company would be able to serve all new and existing residential customers in the foreseeable future. In accordance with the California Public Utilities Commission, new service for certain commercial and industrial loads is somewhat restricted. Generally, new gas service is possible when the customers' equipment is unable to use fuel oil as an alternative to natural gas. Nevertheless, SoCal indicated that new service to large industrial concerns in the El Centro area could not likely be provided. (This situation should make the concept of an industrial park utilizing geothermal energy all the more attractive to El Centro.)

In response to the Team's question on availability of natural gas standby service, SoCal's initial position was that gas facilities are not normally committed on a standby basis for the purposes mentioned by the Team ("continued availability of backup service to the City in the event geothermal energy can supply a portion of its needs"⁸⁹). For facilities already in place, one solution appears to be a commitment of these facilities with an adjustment in the rates charged to consumers using a geothermal system.

Assuming standby service will be provided via continued use of SoCal's existing mains, services, and meters, the Team asked SoCal what the cost of such service would be to the consumer. SoCal indicated that there would be a demand charge for standby service in addition to the commodity charge billed customers for actual gas consumed. This demand charge represents the annual cost of pipeline and related facilities, including storage requirements held in reserve for possible standby needs. Use of a geothermal system would reduce the amount of gas consumed and, consequently, the commodity charge and could potentially affect the demand charge.

SoCal offered to provide an estimated demand charge for the study, once the Technical Team supplied SoCal with an estimate of El Centro's monthly supplemental gas requirements. Late in the fourth quarter, this estimate was calculated and transmitted to SoCal, however, an immediate response has not been forthcoming.

4.6.2 Electric System

Service and charges for electricity from the IID may present somewhat different considerations. Unlike SoCal, the IID is not subject to rate regulation by the State Public Utilities Commission. The IID Board of Directors establishes rates for

various categories of service. Like most regulated public utilities, the IID charges less per kilowatt hour (kwh) as electrical consumption increases. One could infer that reducing the electrical demand by geothermal utilization might reduce the consumer's overall utility bill. Nevertheless, the cost per kwh would rise under the District's present General Service Schedule, because fewer kilowatt hours will be consumed.

It became apparent that this simplistic analysis was misleading since the IID's General Service A-1 Schedule specifically excludes the applicability of the Schedule to standby service. The IID does not currently have a standby rate schedule in effect with any customer. Any such rate schedule for the City of El Centro would have to be negotiated separately between the IID and the City of El Centro and would most likely reflect demand charges differing from the present schedule.

Many factors will ultimately influence the demand charges associated with electrical standby service. An IID spokesman said the District would first look to the methods utilized by other utilities.⁹⁰ He indicated that the District does not generally favor the provision of such service, because of the loss of revenue to the IID. The electrical demand for summer space cooling, which the use of geothermal energy would reduce by approximately 85-90 percent, represents the major portion of IID revenues generated from the City of El Centro. Severely reduced electrical consumption may push the cost of standby service much higher than current charges.

Nevertheless, the development of alternative energies and the emphasis on energy conservation is forcing all utilities to evaluate ratemaking practices. Under the recently enacted Public Utilities Regulatory Policy Act, both regulated and non-regulated (e.g. the IID) utilities must consider within the next two years utility practices related to rate design and energy conservation. Utilities must evaluate time of day rates, seasonal rates, interruptible rates and declining block rates. There is no requirement, however, that the utility adopt any of these practices. Because the IID's present rates (about 3.4 cents per kwh for domestic service in 1977⁹¹) are still substantially lower than many other State utilities (approximately 4.4 cents per kwh for San Diego Gas and Electric Company⁹²), the Board may ultimately feel justified in making no alteration to its present rate design structure.

4.7 PROPOSED INDUSTRIAL ENERGY PARK

The City of El Centro is developing the concept of an industrial park which emphasizes the usage of geothermal and solar energy. The City of El Centro has delineated a large area of land in the southeastern portion of the City as being suitable for the location of the park. El Centro has secured an option to purchase 40 acres in this area and is in the process of obtaining an option for an additional 14 acres.

An incentive for locating in the industrial park is the probability of using solar and/or geothermal energy as a power source. These sources will help to reduce the high costs of fuel needed throughout the summer in El Centro. City leaders hope that energy intensive industries may find this location ideal in terms of reducing operating costs. They have already received informal commitments from businesses to locate in this area and to utilize geothermal energy if it is available. In order to market this concept to other businesses, the City is developing a comprehensive plan for the park through a grant provided by the California Office of Planning and Research (COPR). A

portion of the final plan will identify those businesses and industries with energy needs which alternative energies can supply.

The major economic problem which the industrial park will address is that of unemployment. The park concept allows businesses to expand or locate on property which already has all of the necessary off-site improvements while providing new and permanent employment for local residents. A potential exists for a minimum employment of 150 people on the 54 acre site. As the population growth of El Centro increases, a demand for services will attract new business and give others the incentive to expand. The location of the industrial park is ideal in terms of access to the major arteries of Ross Avenue, Dogwood Road, and Interstate 8.

The industrial park will be developed through the joint efforts of the City and several Federal agencies. The Department of Housing and Urban Development may fund the purchase of the land. The City Staff has also submitted a proposal requesting funding from EDA for off-site improvements. Industrial park development is specifically listed as an eligible project under the EDA Public Grants for Works and Development Facilities. City expectations for the success of this proposal are high. The SBA loan programs mentioned in a previous section (Section 4.5.3.2) will financially assist businesses locating in the park.

Nor will citizen participation be ignored in the proposed development of the El Centro Geothermal/Solar Industrial Park. One objective of the COPR planning grant is to integrate several ongoing vehicles for citizen participation into the planning process. Objectives of the El Centro Community Development Block Grant Citizen Participation Plan will be followed in the COPR planning grant, and input from the following groups will be sought: (1) the Redevelopment Project Area Committee (PAC) comprised of representatives of business, residents and community organizations located in that project area; (2) the El Centro Local Development Corporation, comprised of downtown businesses; and (3) a proposed Citizens Energy Committee. Supervision by the City of El Centro Planning Department will ensure program goals of equitable citizen representation of all ethnic, economic and geographical sectors of the City.

The recent selection by DOE of the City of El Centro Geothermal Utility Core Field Experiment will also provide visible evidence to residents and outside businesses of the applications of geothermal energy to space heating and cooling of buildings and hot water heating. During the project, a strong marketing and public relations program will be undertaken to advise local and state-wide businesses of the opportunities for geothermal utilization in the commercial and industrial sectors. An information center in the Community Center itself and tours of the demonstration project will further these program goals.

Since the opportunities for geothermal industrial applications appear to be promising, appropriate institutional structures must also be investigated. A geothermal utility for an industrial park is, in effect, a microcosm of the utility concepts discussed above. A municipal utility, non-profit corporation and privately-owned public utility are all alternatives. Financing for the first two entities may be possible by an issuance of lease revenue bonds or special assessment districts. Since the City of El Centro is

already actively pursuing municipal development of the energy park, the Team made no investigation into funding and ownership by the private sector.

4.8 SUMMARY AND CONCLUSIONS

4.8.1 Second Quarter Analysis

During the second quarter, the Institutional Team researched various issues, including the administrative options for structuring a geothermal utility, the financial resources potentially available for developing a utility, the utility's impact on existing utilities, and the feasibility of integrating the concept of an industrial energy park into the overall economic strategy of El Centro.

Initially, five alternative administrative vehicles for implementing a geothermal heating and cooling system in the City of El Centro were selected for preliminary investigation. For the preliminary analysis, the following information and conclusions were developed:

1. El Centro has the statutory authority to develop the concept of a municipal utility system operating within the existing City infrastructure. Entire control over the utility operations would reside in the City. Financial alternatives for raising the needed capital were explored. General obligation bonds may be available with voter approval for this municipal improvement. The project's exclusion from the statutory definition of "enterprise" may preclude issuance of revenue bonds. El Centro is clearly an eligible borrower and its project an eligible program, as outlined in the Federal Loan Guaranty Program regulations. A direct grant of funds under other Federal programs investigated looks unpromising. The EDA Public Works program, initially considered a prime choice for utility funding, disburses no funds to projects competing with privately-owned utilities. El Centro's system would compete with SoCal. A similar program under the SWRBC apparently imposes no restriction against competition and, therefore, may be available.

2. The concept of a municipal utility district provides shared authority for utility development between El Centro and another public agency or unincorporated territory. The California statute authorizing the formation of these districts permits the issuance of voter-approved general obligation bonds. The issuance of revenue bonds for nonelectric systems, however, is not expressly sanctioned. Financing a project by special assessment on property within designated boundaries is within district powers, but lacks practicality for the City of El Centro at this time.

The Team was unable to identify agencies within the geographical area which would have an interest in a joint geothermal utility effort. The joint participation of El Centro and unincorporated territory outside the city limits was equally without promise for the near term. The Team concluded that the municipal utility district concept offered no unique advantages to utility formation or financing and was not pursued further.

3. The Joint Powers Agency, a third alternative, is merely another statutory vehicle which permits public entities to exercise together powers possessed by

each separately. The Team's original idea of teaming the City with the Imperial Irrigation District, the current supplier of electricity and water to El Centro, was eliminated. Late in the second quarter, the El Centro Staff learned that the IID is not currently interested in participating in a joint enterprise. Moreover, there is some doubt that the District has the requisite authority to join. Other combinations may ultimately be feasible, but none became apparent during the project effort.

The authority to raise needed funds for a joint powers project is subject to the same restrictions imposed upon the municipal utility concept. However, an independent source of power may be implied from authorization in the Joint Exercise of Power Act to advance public funds and to repay these funds with revenues from the utility. Revenue bonds, potentially unavailable under the municipal utility option, would be permissible under this interpretation.

4. The California Non-Profit Corporation statute authorizes the formation of a non-profit corporation. Control of a corporation is vested in a Board of Directors. To avoid potential conflicts of interest, the Team concluded that a Board composed of members other than the City Council was preferable.

The Team examined scenarios developed by other municipalities which utilize the non-profit corporation vehicle. Each of their situations differs from El Centro's. For example, none proposes to drill within the City limits nor is concerned with strictly nonelectric development. Several of the municipalities are charter rather than general law cities and therefore have greater financial flexibility than El Centro. Most either presently operate their own utility or are supplied by a private utility. Nevertheless, the Team concluded that ideas raised by the non-profit corporation concept merited further investigation.

5. The private utility concept basically eliminates City control. The City does retain the power to condition issuance of a franchise to operate a utility on the utility's compliance with certain requirements. Adopting this concept would eliminate El Centro's concern over raising needed capital, but otherwise appeared to be the least desirable alternative. In doubt was the likelihood of finding a private utility willing to undertake a highly capital intensive project, to face regulatory requirements mandated by the Public Utilities Commission, and to invest in a project where the potential rate of return might be low.*

6. Each of the foregoing administrative vehicles would impact on existing utility services provided by the Imperial Irrigation District and Southern California Gas Company. Until the extent of the geothermal utility undertaking is determined, no accurate assessment of actual impact is possible. The utilities' decisions with respect to El Centro's project will depend on circumstances at the time an actual project is proposed.

7. If the City chooses to develop a geothermal project of limited scope, the concept of an industrial energy park is promising. El Centro has identified an area in the southeastern part of the City for the location of the park. An industrial

*In fact, the Economic Team independently concluded early in the study effort that the minimal rate of return required by a private investor precluded City consideration of this option.

energy park, not dependent on conventional fuel sources, should be attractive to businesses and would provide a boost to the local economy presently suffering from high unemployment. The administrative options discussed above with reference to a City-wide operation can probably be applied to the energy park concept. Ongoing City staff work directed towards raising funds for park construction through State and Federal government participation attests to the City's commitment to develop this concept. Moreover, if drilling is successful on the site currently proposed for the Field Experiment, the park will have a readily available energy resource.

4.8.2 Third and Fourth Quarter Results

For the third and fourth quarters, the Institutional Team shifted its focus to examine: (1) public attitudes held by Imperial Valley residents toward geothermal development; and (2) ways in which existing institutional incentives and barriers may ultimately affect the public's acceptance of nonelectric applications of geothermal energy in the City of El Centro. Having determined that there are various incentives for residents to install a geothermal system, the Team reexamined appropriate administrative options for implementing a utility system.

Based upon our research and analysis, we made the following findings of fact and drew several preliminary conclusions:

1. Surveys of the attitudes of Imperial Valley residents toward geothermal development reveal a strong majority of residents (about 90 percent) favor this alternative energy resource. However, less than 20 percent feel that they have good understanding of geothermal energy. The El Centro City Council and staff have attempted to heighten the public's awareness of the potential of geothermal energy and to correct any lack of understanding of this energy form in the following ways:

a. The City submitted a proposal and was awarded a DOE contract to drill a geothermal well within the City and to retrofit the heating, cooling and hot water systems at the Community Center for geothermal utilization. As a part of this project, the City will undertake a strong marketing and public relations program to inform and to advise residents and businesses of the opportunities created in El Centro by geothermal utilization.

b. The City is the recipient of a planning grant from the California Office of Planning and Research to develop a comprehensive plan for a Geothermal/Solar Industrial Park. The plan will identify industrial applications with energy requirements which can be met by geothermal or solar "fuel" supplies.

2. There are incentives which should encourage the residents of El Centro to install a geothermal system in their homes or businesses.

a. The new Energy Tax Act of 1978 permits a maximum \$2200 residential tax credit for those taxpayers who purchase and install a geothermal energy system in their residences. For the estimated \$1500 it will cost to equip and install such a system in an El Centro dwelling, a taxpayer would receive a credit of \$450. Leasing, rather than purchasing, a geothermal system does not offer this tax advantage for the resident.

b. For businesses, the Energy Tax Act provides an additional investment tax credit of 10 percent when geothermal equipment is purchased and installed. The tax credit should provide additional financial encouragement for businesses locating in the proposed Geothermal/Solar Industrial Park.

c. The City of El Centro has been designated a mortgage assistance area by the CHFA. Under several CHFA programs El Centro residents are now eligible to receive low interest loans to rehabilitate old homes or to construct new ones. Loan funds could likely be applied toward the cost of purchasing and installing a geothermal system in these homes.

d. For El Centro businesses, there are at least three government-assisted (California/EDA and SBA) loan programs which arguably permit funds to be expended for a geothermal system. Each has eligibility requirements and specified activities for which a loan is available. An interested business should check with the appropriate agency for the program specifics of each.

e. The newly established Redevelopment Agency may assist in financing a geothermal system for those residents and businesses in the large redevelopment sector of the City of El Centro. The Agency expects to raise funds through tax increment financing. Under this concept, funds are raised from the increases in ad valorem tax revenues resulting from new developments within the project area. When collected, these funds can be used on approved projects directly to pay project debts or as security for bond issuances. Bonds are obligations of the Agency, not the City; therefore, no voter approval on the bond issuance is necessary. The Agency is also empowered to issue revenue bonds as a means of funding appropriate projects within the area. Providing utility service qualifies as a statutorily-authorized redevelopment project, but there are statutory constraints on amounts allocable to any one project.

3. The public utilities currently serving El Centro are potential institutional barriers to geothermal utilization in the City. The need for some natural gas and electricity provided by SoCal and the IID, respectively, will not be eliminated if a geothermal system is utilized. Therefore, El Centro residents must be assured of standby or back-up service from these utilities. Such service is generally not provided by SoCal under the circumstances outlined by the Team. Assuming standby service were available, a new SoCal-City of El Centro agreement would be required and would likely be subject to the approval of the California Public Utilities Commission. Under any agreement, the rate for standby service would include a demand charge for having utility facilities available as a back-up system. The demand charge would reflect the cost to the company of pipeline and related facilities.

The IID Board of Directors sets the rates for electric service. Under its general rate schedules, charges for electricity rise with decreased consumption. Because there are presently no standby customers on the IID system, it is difficult to predict what a standby rate schedule for El Centro would provide. Rate charges would be the subject of a newly negotiated agreement between the parties.

4. Upon completion of the Second Quarter, the Team met to discuss those utility formation options which El Centro should still pursue. All but the municipal utility and non-profit corporation were eliminated for the present time as not

being viable alternatives for an El Centro utility system. A desire to maintain City input to any geothermal development project and the more favorable financing and economic considerations associated with municipal control eliminated the private utility concept. The failure to identify either a statutorily-appropriate agency or interested government entity made the selection of the municipal utility district or joint powers agency as utility vehicles appear unlikely.

a. Municipal Utility. Financing a municipal geothermal utility via traditional sources of funding may be difficult. The issuance of general obligation bonds has been severely restricted by the passage of Proposition 13. Revenue bonds for nonelectric applications may be more tenable.

Financing guaranteed under the DOE Loan Guaranty Program offers the following attractive features: (a) the 25 percent equity portion of project funds which cannot be guaranteed by DOE may be satisfied by funds committed or previously expended on the project. For example, the value of City-owned land committed for the site of a district heating and cooling utility could be applied toward this equity portion; (b) costs incurred by a non-borrower project participant may be applied to the 25 percent requirement; and (c) DOE may authorize loan principal assistance payments in order to forestall imminent project failure.

While municipal control over the utility itself may be desirable, the City may want to encourage private development of the geothermal resource to avoid direct involvement in a risk taking venture. New provisions in the Energy Tax Act of 1978 permitting the expensing of intangible drilling costs and percentage depletion of geothermal production are designed to encourage private investment in the geothermal industry. The private sector's willingness to invest in geothermal exploration for the ultimate benefit of the City of El Centro may depend on the outcome of the proposed drilling of a geothermal well under the DOE-sponsored Field Experiment.

b. Non-Profit Corporation. At present, formation of a non-profit corporation appears to be the better alternative for utility implementation. A corporation needs no voter approval before issuing bonds. If tax-exempt financing is desired, current tax regulations permit the corporate issuance of bonds on behalf of a municipality. A lease-purchase arrangement can be structured so as to avoid a violation of State constitutional debt limitations. If taxable bonds are desired (such as would be the case if a loan guaranty were sought), tax problems are eliminated, but securities registration and public utilities laws are potentially applicable. Closer examination of registration requirements, however, indicates that any securities guaranteed by the United States (i.e. loans guaranteed by DOE) are exempt from federal and state registration. Nor is it likely that the Public Utilities Commission (PUC) would assert jurisdiction over the securities or rates of the utility.

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SECTION 5

ENVIRONMENTAL ASSESSMENT

5.1 INTRODUCTION

Before geothermal operations can begin in the City of El Centro, a complete environmental assessment will be needed for all phases of development. Regardless of those nonelectric applications finally selected as suitable for implementation in El Centro, the City or a private developer must drill a successful well(s). Therefore, the Environmental Assessment Team evaluated potential environmental impacts associated with geothermal drilling operations. The analysis was restricted to one site located in the southeastern portion of the City of El Centro. (This proposed drilling site has now become part of a field experiment to space heat/cool and provide water heating for the El Centro Community Center). Potential drilling sites farther south, outside the City limits, were not completely eliminated from future consideration by selecting this site, but were found less preferable due to the loss of heat associated with the transportation of fluids. The drilling site under present investigation offers the advantage of being proximately located to several potential nonelectric applications.

The scope of the environmental assessment includes data on geothermal drilling impacts as well as addressing generally the impacts resulting from the distribution and application of geothermal energy. In order to more realistically evaluate the potential impacts of geothermal development, the environmental assessment focuses its analysis where appropriate on the proposed Field Experiment involving space conditioning and water heating at the El Centro Community Center. The environmental assessment of the proposed Field Experiment considers those potential impacts identified by the Final Environmental Impact Report (EIR) to the Imperial County Geothermal Element as relevant to geothermal operations in the Imperial Valley. These include subsidence, induced seismicity, water availability, water pollution, socioeconomic impacts, reallocation of land and public facilities, and impacts on biological resources.

It should be emphasized that the following assessment is only a preliminary overview of the environmental effects of the proposed project. A complete environmental impact report will be prepared and made available for public review when the specific plans for the Field Experiment become finalized.

5.2 PROJECT DESCRIPTION

Since one of the study objectives is to determine the feasibility of using moderate temperature geothermal heat in a City district heating/cooling and hot water system, a study of the potential environmental impacts associated with a total project system was undertaken. The proposed project would:

- Provide a "core" for geothermal heat utility supply within the City to be utilized in space cooling and heating for commercial and government buildings, business complexes and residences.

- Provide a demonstration of the availability of low grade geothermal heat on the periphery of a well-defined geothermal resource.

Chevron Resources Company, the City of El Centro and WESTEC Services identified a potential drilling site in the southeastern part of the City, an area included in the Heber KGRA as defined by the USGS. The site is located on approximately 2½ acres of City-owned property, a small portion of which is currently being used as a City-run recycling center. It is not anticipated that there will be a need to relocate the recycling center. Initially, an exploratory/production well would be drilled on this site to assess reservoir potential. Preliminary geological information indicates that a producing formation exists at approximately 6000 feet. The success of the first well would determine any future drilling at this site. If preliminary evaluation testing at the project site confirms the productivity of the well, a reinjection well will be drilled approximately 30 feet from the production well to a depth of approximately 4000 feet. The used brine will be reinjected into this shallower zone. Siting the wells in close proximity would: (a) minimize the negative impacts of drilling within the community and (b) utilize City-owned land, thereby eliminating the need to acquire private property by purchase.

Before drilling, a conditional use permit from the City and a permit from the State Division of Oil and Gas to drill and operate a well must be secured. A permit, "Report of Waste Discharge Requirements," must also be secured from the Regional Water Quality Control Board (RWQCB) prior to the time a project is started. This permit covers the quality and quantity of any surface discharge of fluid including quality and disposal methods of fluids from drilling operations and wastes from on-site sanitary facilities. The local Air Pollution Control District (APCD) issues two permits, one granting authority to construct and another granting permission to operate, for all activities which discharge air pollutants into the atmosphere. The local district may require the preparation of an environmental report on a single well basis.

Following well drilling, permanent surface facilities will be constructed at the site to provide for geothermal fluid production and transmission of hot water by underground pipeline. To accomodate the pipeline, the City will need to excavate trenches from the drillsite(s) to the end use and construct a buried pipeline in the trenches. The pipelines will serve to transport clean water which has been heated by the geothermal brine at the well(s) in a closed loop between an on-site heat exchanger and distribution center(s)/chiller plant(s). At the center(s), either chilled water for space cooling or hot water for space and domestic hot water heating will be distributed, depending on the seasonal requirements. Modifications to existing facilities to accommodate geothermal space heating/cooling and hot water heating should be minimal in most instances. For example, the only visible evidence of change to the existing El Centro Community Center (the subject of an upcoming DOE-funded demonstration program), will be the addition of some piping on the building exterior leading from the base of the building to the roof. The modifications to the building will be made on the roof-mounted air conditioning equipment to accept hot and chilled water for space conditioning, and in the hot water heater to accept a hot water source for sanitary water heating.

5.3 PROJECT CHARACTERISTICS

For the purposes of this environmental analysis, the definition of the "typical" project includes: (1) a geothermal production and reinjection well at the site heretofore discussed; (2) a closed loop pipeline or distribution system to transport clean water from the drillsite to the distribution center/chiller plant; and (3) the modification of the existing heating/cooling system and the installation of the necessary equipment for geothermal utilization. In this environmental analysis, it is assumed that the well drilled at the drillsite will be productive and capable of supplying the requisite heat for project use. In the case of the El Centro Field Experiment, the geothermal well site and the distribution center/chiller plant will be located on the same plot of land.

5.3.1 Drilling Activities

Geothermal resource exploration wells are normally drilled in accordance with oil field procedures, utilizing conventional mud-drilling methods. The drilling program, casing program and installation of blowout protection equipment will be in accord with the California Division of Oil and Gas (CDOG) requirements.

5.3.1.1 Drillsite Preparation

Site preparation involves grading operations to remove any existing vegetation, to provide for proper drainage, and to develop a reserve pit (cuttings pit). Though the proposed drillsite is essentially level in its present condition, some grading may be necessary to develop a flat drill pad. Since the drillsite borders First Street, no new roads will be required.

Site preparation, including drill rig assembly, should require approximately one to two weeks and employ a maximum of 12 to 15 persons at any one time.

5.3.1.2 Drilling Operations

A proposed site layout during drilling operations is shown on Figure 5-1. The relative locations of the wellhead, drilling equipment, cuttings pit, and ancillary features are illustrated.

5.3.1.2.1 Drilling Equipment and Casing Program

Production and injection wells are usually drilled with a rotary drilling rig. An estimated nine weeks on a 24 hours a day basis will be required to complete both wells. Approximately six workers will be on duty at any one time, but occasional special operations, such as electric logging or cementing, can require as many as 12 workers. Approximately 25 workers will be involved with drilling operations, depending on work loads and scheduling.

It is estimated that an initial well will be drilled as the production well to a depth of at least 6000 feet and cased to the surface. Production is expected at approximately this depth.

The injection well will be drilled to a total depth of 4000 feet and cased to the surface. Both the supply and injection wells will be perforated at selected intervals with approximately two holes per foot.

5.3.1.2.2 Drilling Fluid

Drilling fluids, usually referred to as drilling "mud," serve the following nine major functions:

1. Remove cuttings from the hole.
2. Control subsurface pressure.
3. Cool and lubricate drill bit and pipe.
4. Prevent borehole walls from caving.
5. Release drill cuttings at surface.
6. Prevent formation damage.
7. Provide maximum information from formations penetrated.
8. Suspend cuttings when circulation stops.
9. Suspend weight of drill string and casing.

The mud is circulated through a closed loop system. After coming out of the drillhole, the mud passes through a desilter and across a fine screen shale shaker, which separates cuttings from the mud. The mud then passes through a cooling tower, which reduces the temperature by about 40F (22C), and is returned to the drillhole via mud pumps. The cuttings are stored in the reserve pit (cuttings pit) until they are transported to an approved sanitary landfill, or neutralized and made arable. Drilling fluid is primarily a mixture of water and clay (sepiolite and/or bentonite), containing varying quantities of additives depending on the particular drilling conditions.

5.3.1.3 Well Clean-Out and Testing Operations

After drilling is completed and the blowout protection equipment removed from the surface casing, annulus wellhead valves (the Christmas tree) are installed on the wellhead. The supply well is then production-tested from 24 to 48 hours. These tests are performed to determine the production rate, quality, composition and characteristics of the geothermal resource. The discharged fluid from the production well during the test period is continuously conveyed by pipeline to a holding tank and later trucked to an approved disposal site.

Samples of reservoir fluid and steam phase constituents will be collected during clean-out flowing for chemical analysis. However, due to the presence of drilling fluid contaminants during early clean-out operations, these analyses are often inconclusive. Samples collected during the latter phases of clean-out operations may be

representative because of the substantial quantities of reservoir fluid produced — up to 90,000 barrels (14,300 m³). Drilling of the reinjection well will begin immediately following verification of the presence of an acceptable production formation.

5.3.1.4 Geothermal Fluid Production/Reinjection

Once the well drilling and testing has been completed, the permanent piping and instrumentation for the production, surface and reinjection facilities is installed as shown in Figure 2-5.

A totally submersible, electric-driven downhole pump, with a setting depth of 500 feet, will pressurize the production system to prevent brine flashing. A sand separator will eliminate entrained solids upstream of the heat exchanger, which will provide the interface between the geothermal fluid production/reinjection and the closed hot water distribution system. An electrically driven centrifugal reinjection pump will pressurize the reinjection system to provide adequate flow through the cement-cased reinjection well.

5.3.2 Additional Facilities at Wellsite

A concrete pad will be provided at the drillsite as a foundation for the mechanical equipment required. The equipment located on the pad will include a sand separator, heat exchanger, and blowdown tank.

The counterflow shell and tube heat exchanger provides the interface between the geothermal fluid production/reinjection and the closed forced circulation hot water distribution loop. The closed forced circulation hot water loop will be heated directly by the geothermal fluid heat exchanger at the wellsite. Clean water will be used as the heat transfer medium between the production site and the distribution center/chiller plant.

5.3.3 Hot/Chilled Water Distribution System

A preinsulated pipe will be used for transporting the hot water from the wellsite to the distribution center/chiller plant and the hot or chilled water from the center to the end use. The hot water/chilled water distribution system will consist of one supply line and one return line. These two pipelines will be buried in covered trenches along appropriate rights-of-way throughout the City.

5.3.4 Distribution Center/Chiller Plant Installation

A concrete pad, similar to that at the wellsite, will be constructed at the distribution center/chiller plant as a foundation for the equipment required. The equipment located on the pad will include a storage tank, a liquid chiller, a cooling tower, and miscellaneous pumps and motors.

A closed hot water loop between the wellsite and the distribution center/chiller plant will provide heat for space and domestic hot water heating to the El Centro resident as well as heat to operate an absorption chiller at the distribution center. The absorption chiller system interfaces with the chilled water distribution

system and the hot water distribution system by means of internal heat exchangers. In addition, the absorption refrigeration system has internal process cooling and heat rejection requirements which must be satisfied by cooling water supplied to internal heat exchangers from a cooling water system.

The cooling water system will utilize a packaged wet mechanical-draft cooling tower. The cooling tower operates on the basic principle of bringing the water to be cooled into intimate contact with a moving airstream where about 75 percent of the water-cooling process takes place by evaporation and the remainder by conduction to raise the dry-bulb temperature of the air.

The cooling tower will only be in operation to cool the process liquid in the absorption chiller during the summer months when the rate of evaporation is also greatest. There is little foreseeable need to utilize the cooling tower in other months when the absorption chiller units, which supply cold water for air conditioning, are not in use. Cooling tower blowdown from summer operations will probably be transferred to an on-site shallow pond for evaporation. Remaining solids will be transported to an approved Class II-1 disposal site. Evaporation losses, drift losses and blowdown from the cooling tower will be made up utilizing City water supplies during the demonstration phase. Alternate sources of cooling tower makeup will have to be found before full scale operations can be implemented.

Finally, a network of smaller buried pipes will transport the hot/chilled water from the distribution center to the various end users served by each district, requiring selection of appropriate rights-of-way and excavation of trenches to permit pipeline installation.

5.3.5 Installation of Geothermal Equipment at the End Use

The hot/chilled water distribution systems will interface with existing air handling units and zone heating coils for space conditioning. For domestic hot water heating, the systems will interface with new preheater tanks located adjacent to the existing hot water tanks. Control logic will be required to optimize the operation of the combined geothermal/conventional heating and cooling system.

5.4 DESCRIPTION OF THE ENVIRONMENTAL SETTING

The City of El Centro is located in the heart of the vast Imperial Valley agricultural zone, lying approximately 100 miles east of San Diego, 90 miles south of Indio and 12 miles north of the Mexican border. The City is an important gathering point for agricultural products raised in the County of Imperial and for travelers going east to Yuma and Phoenix, west to San Diego, and north through the Imperial and Coachella Valleys toward Los Angeles.

The initial project site covered one lot on City-owned property, located in the southeastern portion of the City of El Centro and described as Block 47, Second Addition (Figure 5-2). The lot is 180 ft by 600 ft with an overall area of 108,000 sq ft or approximately 2½ acres. A portion of the site is currently being used by the City as a recycling center, consisting of a mobile office, compacting machinery, and underground storage tank for used crankcase oil.

CITY OF EL CENTRO
ENGINEERING DEPARTMENT

Proposed Drilling Site Locations

**FIGURE
5-2**

The project site is situated within the City's industrial area and zoned M-1 restricted manufacturing. The zoning is consistent with the City of El Centro General Plan. The proposed use would be allowed in the zone subject to conditional use provisions.

The site is bordered to the west by south Second Street where various businesses such as a lumber yard, Sears warehouse and a ceramic tile company are located. A railroad spur crossing in an east-west direction forms the northern boundary. The property adjacent to the subject site on the north is being utilized by the City Public Works Department for open storage of gravel, soil and other aggregates. Two oil storage tanks are also located on the site; one tank holds 4000 gallons of oil while the other is capable of storing 7000 gallons. Materials, such as concrete, pipes and wooden poles are also stored there. A cement storage facility owned by the Halliburton Company is located directly north of the City's storage yard. Still farther north of this site is a block of single-family residential units, located about 560 ft north of the subject site and consisting of approximately 11 older dwelling units. There is also a 30 ft wide alley along the southern perimeter of the block separating the residences from business and industry. The area east of the site is bordered by south First Street. A seed processing plant dominates the land use in this area, although a wholesale paper and supply company is also located there. A single-family residential block with about 10 units is situated northeast of the site, with the closest dwelling unit about 400 feet away. To the south, the site is bounded by the Pacific Telephone Company yard. A trucking company occupies the area south of Pacific Telephone.

As stated previously, Block 47, the subject site, is zoned M-1 restricted manufacturing. The M-1 zone borders the site to the south, west and north. That area east of the site is zoned M-2, general manufacturing.

5.5 POTENTIAL ENVIRONMENTAL IMPACTS

The development of geothermal resources has the potential to produce many environmental impacts, including subsidence, induced seismicity, water availability, water pollution, noise, air pollution, well blowouts, aesthetics (visual pollution), socioeconomic impacts, reallocation of land and public facilities, and impacts on biological resources. The final EIR to the Imperial County Geothermal Element concluded that only a few of the above-mentioned impacts pose a threat of a significant nature. Those that fall within this category include subsidence, induced seismicity and water availability. With specific reference to drilling within the City of El Centro, noise should also be included in the significant category. Most of the other areas of impact are subjects of ongoing research, and initial results indicate that no major concern is warranted. In the case of impacts on the socioeconomics of Imperial Valley, tentative conclusions drawn by researchers in this area indicate favorable County-wide consequences.

5.5.1 Geology

5.5.1.1 Overview

The project site lies at an elevation of approximately 45 feet below sea level. It is located on the broad, flat, alluviated plain of the Mexicali-Imperial Rift

Valley, known as the Salton Trough, which is cut off from the Gulf of California to the south by the Colorado River delta. The regional geology of the Salton Trough has been discussed frequently (Elders, et al., 1972; Biehler, et al., 1964; Dibblee, 1954; VTN, 1978; and Morton, 1977).

The project site contains undeveloped, exposed soil classified as Vint loamy fine sand, wet (Vi). Typically this is a deep soil with slopes of 0 to 2 percent on basin floors and floodplains at elevations of 35 feet above to 230 feet below sea level. It formed in alluvial and aeolian sediments from diverse sources.

The geothermal reservoir which is the energy source for applications within the City of El Centro is included in the outer limits of the 13.5 square mile Heber KGRA. The Heber geothermal anomaly is estimated to contain 12.4 percent of the Imperial Valley's total resources. The temperature regime (360F at the center of the anomaly) and the salinity of geothermal fluids (total dissolved solids equal 14,000 parts per million) make the center of the Heber Geothermal Field a prime candidate for geothermal electric production. The area of maximum temperature gradient is centered around the township of Heber which is approximately 4.5 miles south of the City of El Centro.

The prevailing geothermal gradient at the selected drilling site is expected to be in the range of 2.0-3.3F per 100 feet. This is based on data published by the U.S.G.S. and the California Division of Mines and Geology, and data gathered by Chevron in the Heber area. 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, unless geothermal anomalies are encountered, 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.

5.5.1.2 Overview: Geologic Hazards

Potential geologic hazards at the El Centro site include the following:

- a. Seismic activity resulting in effects due to:
 - (1) Ground rupture
 - (2) Ground shaking
- b. Induced seismicity potential created by withdrawal and reinjection of geothermal fluids.
- c. Seismically-induced liquefaction potential.
- d. Potential subsidence due to withdrawal of geothermal fluids.

5.5.1.3 Impacts and Mitigation

5.5.1.3.1 Geothermal Resources

With the assumption that the used brine for the proposed supply well will be reinjected into a different zone, the continuous production will result in depleting the reservoir pressure. For an assumed continuous aquifer of 5000 acres, the maximum cumulative production is estimated at 32 million barrels. Consequently, assuming no vertical replenishing of the reservoir, project life at the demonstration phase level of consumption would be approximately 310 years based on minimum annual production rates. Annual production rates in excess of the minimum demonstration phase usage would, of course, significantly lower the reservoir project life. The actual project life, however, could be extended if the reservoir is replenished by brine encroachment from a larger aquifer or by brine imbibition from overlying and underlying strata. Reinjected brine may also help replenish the reservoir if there are any vertical communications between injection and production zones.

It is currently unknown to what extent reservoir replenishment, if any, will occur. During the drilling of the production well, core samples will be taken and a reservoir analysis will be conducted based on lithologic evidence. These samples will be analyzed in an attempt to determine at what depth vertical replenishment can take place. This evidence can then be used to determine optimum depths for reinjection and in monitoring the actual results of the field experiment.

5.5.1.3.2 Seismic Ground Rupture

It is possible that the proposed drill holes could intersect a fault plane within the project area. Should movement occur on such a fault, subsurface rupture of the well casing could result. In such an instance, geothermal reservoir fluid could reach the surface or shallow subsurface, thereby presenting a water quality problem.

In the unlikely event of damage due to fault rupture of well casing, the severity of the damage must be taken into consideration in assessing corrective measures. Casing washout may necessitate the berming of surrounding areas of land in order to contain the flow while remedial action is being evaluated. However, no known faults traverse the site location.

5.5.1.3.3 Seismic Ground Shaking

Although the Imperial-Mexicali Valley is an area of high seismic potential, the frequency of high magnitude earthquake occurrence is relatively low. In the event of an earthquake during drilling operations, safe continuance will be dependent on earthquake severity. In all but extreme cases, normal rig safety procedures would prove adequate.

5.5.1.3.4 Induced Seismicity and Subsidence

Induced seismicity and subsidence are not expected to be a significant problem. However, current experience does not allow a complete evaluation of the effects of large-scale withdrawal of geothermal fluids on the accumulated strain within

the reservoir area. In the decade or so that water-dominated geothermal systems have been under production, both with and without reinjection, no increase in seismic activity has been noted. However, only long-term seismic monitoring programs will provide any information regarding this potential hazard. The proposed drillsite could be tied into the existing Imperial County seismic and subsidence monitoring network. Other mitigation measures for these phenomena are not considered necessary.

5.5.1.3.5 Seismically-Induced Liquefaction

The soil type beneath the project site is recognized as capable of supporting perched water tables between 36 and 60 inches (91 to 152 cm) in depth because of neighboring irrigation practices. Although a potential for seismically-induced soil liquefaction exists, significant impacts due to potential soil liquefaction during any proposed drilling are considered to be minimal. Liquefaction potential to project elements would be addressed during the engineering design phase of required foundations.

5.5.1.3.6 Soils

As described above, the project site contains soil classified as Vint loamy fine sand, wet (Vi). Permeability is moderately rapid for this soil, thus prohibiting its use in lining brine retention ponds. Because of this fact, it will be necessary to line the ponds with bentonite or another impermeable clay. The adverse engineering qualities of this soil (sandy texture, low bearing strength and potentially high water table) will require that the drill rig and ancillary drilling and flow testing facilities be set up with care to avoid foundation stability problems. Likewise, careful attention shall be given to the need for adequate foundations and drainage.

5.5.2 Hydrology

5.5.2.1 Groundwater

The Imperial Valley comprises a drainage basin defined by the New and Alamo Rivers extending from the Salton Sea southward into Mexico. A comprehensive geohydrologic examination of groundwater resources in the Imperial Valley was reported by Loeltz, et al. (1975). Groundwater in the region is characteristically brackish and not used for potable water or irrigation purposes.

The primary adverse impacts to groundwater that could occur at the project site include: shallow aquifer contamination due to the loss of drilling or geothermal fluids through a weak formation in the borehole; seepage from the reserve pit or sump; or upward movement of injected brines. The primary adverse impact that could occur off-site would be due to improper waste disposal or practice, or disposal at an unsuitable site.

A casing program approved by the Division of Oil and Gas will assure that the casing is set to protect weak formation materials and to minimize the potential for contaminating shallow subsurface waters with drilling or geothermal fluids. Adverse impacts to local groundwater, due to possible upward movement of injected brines, are not expected to be of major importance. This is due to the poor quality of groundwater

in a regional sense, i.e. groundwater in the El Centro region is of poor quality, as far as is known. However, the chemical quality of groundwater in deep zones, those most likely to be affected by injection, is unknown. If subsequent exploration indicates the presence of fresh water, a suitable monitoring program should be instituted.

5.5.2.2 Surface Water Quality

The El Centro region receives its water from the Colorado River via the All American Canal and associated canal system network. The quality of the incoming Colorado River water is shown in Table 5-1. Raw water is used directly for irrigation, but the high TDS level requires extensive subterranean tiling of agricultural land to provide adequate draining of the soils to prevent salt accumulation. Agricultural drainage and treated municipal wastewater flow to the Salton Sea along drainage canals and the New and Alamo Rivers. Regional water quality has been discussed extensively in many environmental documents (WESTEC Services, 1979a and 1979b and VTN, 1978).

The most direct surface water-related effect of any proposed geothermal exploration project will be a consumptive requirement of water for use in drilling operations. In addition, potentially significant water quality impacts could occur due to a spill of geothermal brine. A discharge of geothermal brine from the proposed drillsite could overflow into nearby City streets and gutters. Should this occur, it is anticipated that the discharge would flow into City storm drains and eventually into the Salton Sea in a diluted state.

Numerous project characteristics and regulatory controls would significantly aid in preventing possible adverse surface water impacts. Construction of a berm around any drilling site and site grading which permits drainage into a reserve pit should contain all but very large spills within the confines of the drilling site.

Waste discharge requirements, containing very specific water quality control measures, must be obtained from the Regional Water Quality Control Board, Colorado River Basin, prior to commencement of drilling or testing operations. In addition, the California Division of Oil and Gas prescribes and rigorously enforces the adequate provision and operation of blowout protection equipment for all geothermal wells drilled in the State. These regulatory controls will serve to reduce substantially the potential for uncontrolled discharges of geothermal fluid from any drillsite.

5.5.3 Air Quality

With agriculture as the major industry in the Imperial Valley, the most prevalent airborne pollutant is particulate matter in the form of fugitive dusts. These dusts, plus naturally occurring haze, often obscure views across the valley (VTN, 1978).

The increasing development of geothermal facilities in the Imperial Valley may be expected to result in an increasing level of hydrogen sulfide (H_2S) in the ambient air. Recent air quality monitoring programs have stressed the measurement of this pollutant. Air quality in El Centro is monitored by the Imperial County Air Pollution Control District.

Significant air quality impacts would not be anticipated as a result of this proposed project. However, air quality impacts are associated with well drilling, well

Table 5-1
ANALYSIS OF COLORADO RIVER WATER
YEAR 1972 - 1973

Constituent or Characteristic	Units	Imperial Dam	
		Maximum	Average
Sodium (Na)	mg/l	173.0	145.0
Potassium (K)	mg/l	5.1	5.0
Calcium (Ca)	mg/l	95.0	88.0
Magnesium (Mg)	mg/l	36.0	34.0
Chloride (Cl)	mg/l	152.0	128.0
Carbonate (CO ₃)	mg/l	0.0	0.0
Bicarbonate (HCO ₃)	mg/l	188.0	174.0
Sulfate (SO ₄)	mg/l	370.0	336.0
Nitrate (NO ₃)	mg/l	2.2	1.6
Boron (B)	mg/l	0.21	0.18
Fluoride (F)	mg/l	0.7	0.5
Total Dissolved Solids	mg/l	962.0	856.0
Conductivity	Micromhos	1403.0	1306.0
pH	Scale	8.1	8.0

Source: Electric Power Research Institute, 1976.

testing and well operation phases, as well as chiller cooling tower operation. Based on present and projected air quality in Imperial County, the emissions of particulates and hydrogen sulfide are the two areas of most concern. Hydrogen sulfide emissions are of particular concern because of its low threshold for odor nuisance. Included in these four phases are the following seven potential sources of air pollutants:

- a. Fugitive dust during grading and drill pad preparation.
- b. Heavy-duty construction equipment emissions during site preparation activities.
- c. Pollutants emitted from the diesel engines used during well drilling.
- d. Employee vehicular pollutants emitted during periods of intense site activity.
- e. Drift from the cooling towers used to cool drilling mud and to cool the absorption chiller process.
- f. Noncondensable gas emissions from the flashed steam emitted during well testing and, to a lesser extent, during well drilling and well maintenance.

A brief discussion of the project activities potentially causing air pollution follows:

The production drilling of a geothermal well is comprised of site preparation, drilling and resource testing. Pad preparation and general grading operations will be responsible for the emission of fugitive dusts. These can be reduced to a negligible level by the use of water sprays and/or the application of wetting agents. Construction equipment is diesel-powered, releasing gaseous and particulate emissions associated with heavy-duty diesel engines. The level of pollutant emissions from this equipment, however, is considered negligible.

Well drilling operations for the initial project will take place for about nine weeks. Vehicular traffic comprised of supply trucks and personnel automobiles will be entering the site each day. An estimated round-trip distance for the 20 to 25 personnel involved is estimated to be less than 5 miles (8 km), equivalent to vehicle exhaust emissions of less than 20 lb/day, a relatively insignificant rate.

The hydrogen sulfide (H_2S) emissions during the drilling phase are relatively insignificant, being a function of the efficacy of the drilling technique and the H_2S content of the geothermal fluid. The H_2S content of the geothermal fluid within the Heber anomaly has been measured to be approximately 0.18 ppm, by weight (Chevron, 1977). One could assume the very worst conditions, that 20 percent of the well production rate is permitted to escape to the surface with the recirculated drilling mud flow. At a production rate of 0.6 million lb/hr of brine (using the Community Center requirements as an example), containing 0.18 ppm by weight of H_2S , the maximum H_2S emission rate from a well would be approximately 0.01 lb/hr. Again, this would represent a very insignificant air pollution impact. The impacts of large scale direct

use applications within the city will be subject to review following monitoring of the demonstration phase.

The air pollution impacts from H₂S emissions during the well testing and preproduction operations are negligible. The minimal operating periods associated with these activities and the fact that the produced geothermal fluid is reinjected should reduce H₂S pollutants.

After the well is in operation, it is sometimes necessary to perform maintenance operations such as downhole pump overhaul or reworking of the well, which require limited venting of the well to atmosphere. These operations are expected to occur infrequently, probably one or two times annually for each well. Typically, the release of gases during each shut-down period would be at approximately 60,000 to 70,000 lb of steam and 15 to 16 lb of noncondensables. The equivalent H₂S release to the atmosphere would be less than 0.01 lb, a negligible amount. The occasional release of small amounts of hydrogen sulfide could create an odor problem in the immediate area. However, because of the very small and infrequent H₂S emission rate, it is not expected to have a significant impact. Likewise, other geothermal test wells in the Heber anomaly have not resulted in odor problems.

Mitigation of the air quality effects during the demonstration phase is difficult because the impact is minimal, providing little incentive to reduce it further. One unexpected, but nevertheless major, area of concern, i.e. possible H₂S levels sufficient to create an odor nuisance, can be treated chemically to abate noticeable levels. Thus, even though there are indications of little H₂S in the resource around the project site, the potential problem could be treated. Technology for further reducing other pollutants associated with well drilling, except for beneficial construction practices such as frequent watering to abate dust, and keeping equipment in good running order, does not exist. Although the proposed demonstration project would indeed slightly increase the El Centro area pollution levels, the projected small magnitude of that increase and the dispersion potential of the local atmosphere would be sufficient to minimize any significant air quality effects.

5.5.4 Noise

5.5.4.1 Ambient Noise Level

Ambient noise was measured on February 8, 1979, at the southeast corner of the proposed well site and along the eastern (1st Street) boundary of the second residence south of the well site. Additional data was obtained in the area of noise emanating from the various existing industrial uses (see Section 5.4 for description of project setting).

Noise measurement results are summarized in Table 5-2, which presents the ambient sound levels including L₉₀, L₅₀, L-max, L-min, and L-eq. The descriptor of L₉₀ is normally used as a measure of the background noise since it depicts that level exceeded ninety percent of the time. The L-eq is the energy average over the measurement period, and is useful in calculating the Day-Night Sound Level (L-dn) or the Community Noise Equivalent Level (CNEL).

Table 5-2

EXISTING NOISE LEVELS

Measured Ambient Sound Levels - February 8, 1979

<u>Time</u>	<u>L₉₀</u>	<u>L₅₀</u>	<u>L_{max}</u>	<u>L_{min}</u>	<u>L_{eq}</u>
1010-1110	50	55	80	47	58
1215-1315	47	55	78	45	59

Measured Sound Levels of Industrial Activity - February 8, 1979

<u>Time</u>	<u>L_{max}</u>	<u>L_{eq}</u>	<u>Operation</u>	<u>Distance to Source Feet</u>
1020	71	63	Recycling Plant	300
1030	80	75	Recycling Plant	75
1323	66	56	Paper & Supply Co.	300
1511	74	57	Paving Co.	300
	65	63	Pacific Telephone	150
1100	70	55	Ambient	—

Measured HUD Criteria Levels

<u>Time</u>	<u>1/24</u>	<u>.5/8</u>	<u>8/24</u>
1010-1100	62	62	56
1215-1315	66	64	57

Noise Spectra

<u>Frequency</u>	<u>63</u>	<u>125</u>	<u>250</u>	<u>500</u>	<u>1000</u>	<u>2000</u>	<u>4000</u>	<u>8000</u>
Octave Band Level	64	56	50	43	44	39	27	19

Calculated Ambient Community Noise Levels

<u>L_{dn}</u>	55
<u>CNEL</u>	55

The Day-Night Sound Level (L-dn) and Community Noise Equivalent Level (CNEL) are twenty-four hour averages calculated from hourly sound level measured in A-weighted decibels (dB(A)). The L-dn and the CNEL system weights evening (7 pm to 10 pm) data by adding 5 dB. In practice there is little difference between L-dn and CNEL, on the order of one (1) dB. Both are used interchangeably in this section.

The U.S. Department of Housing and Urban Development (USHUD) criteria levels are also shown in Table 5-2. The USHUD descriptors, however, must be used with care since the full 24-hour measurement period was not employed. A set of octave band spectra are also given in Table 5-2. These data represent the noise level within the octave frequency bands and are useful for comparison with the local noise ordinance.

The noise levels for each measurement period, as well as the calculated L-dn and CNEL, are given at the bottom of Table 5-2. Based on these measurements, the existing L-dn and CNEL levels are each 55 dB.

5.5.4.2 New Levels of Noise

Noise levels resulting from development and operation of water-dominated geothermal projects are produced by the following activities: 1) drill site preparation; 2) well drilling; 3) well cleanout and plant operation; and 4) well flow testing and operation. Based on noise measurements taken at other geothermal operations in Imperial Valley, on manufacturers' design standards for various components of the proposed application, and on data presented by the U.S. Environmental Protection Agency (USEPA, 1971); VTN (1978); and U.S. Department of Energy (USDOE, 1978), sound levels at various distances from the source were calculated for each of the project-related activities. These predicted sound levels are shown in Figure 5-3, and octave band sound pressure levels at 100 feet are shown in Table 5-3.

5.5.4.3 Impacts and Mitigation

The CNEL values given in Figure 5-4 can be used to determine the impact of each operation upon nearby residences. The nearest residences are located just south of the proposed well site at distances of 50 and 150 feet from the well site boundary line. Other sensitive receptors include residences to the northeast of the well site at a distance of 500 feet from the well site northeast corner boundary line. As shown in Figure 5-4, community noise levels from all phases of the proposed project become virtually equivalent to the ambient level 2000 ft from the source. Using the CNEL/L-dn data and a source to fence distance of 85 feet on the south and 135 feet on the north, the resulting estimated CNEL/L-dn at the nearest residence for each operation is shown in Table 5-4.

Since the existing community noise level is a CNEL or L-dn of 55, some of the proposed activities will be audible out-of-doors at receptors within 2000 feet of the source. The maximum impact will be due to well drilling, which will raise the ambient exterior noise level by an estimated 26 decibels at the nearest receptor. However, the attenuation in noise afforded by normal construction in buildings with windows open is sufficient to reduce this level by 15 dB. Thus the nighttime impact, which is the most critical in terms of community response, would be reduced to interior levels of less than 66 dB at the nearest sensitive receptor, and even lower at other receptors in the vicinity.

A-Weighted Sound Levels for Various Project Activities as Functions of Distance from Source

**FIGURE
5-3**

Table 5-3

OCTAVE BAND SOUND PRESSURE LEVELS (dB)
AT 100 FT (30 M) FOR VARIOUS PHASES OF THE PROJECT

<u>Octave Band</u>	<u>Drillsite Preparation</u> ¹	<u>Well Drilling</u>	<u>Well Cleanout and Flow Testing</u>	<u>Facility Operation</u>
63	84/57	86	50	59
125	92/72	82	49	59
250	76/66	75	47	59
500	71/59	69	47	56
1000	74/57	68	47	53
2000	68/55	67	43	50
4000	62/46	55	38	47
8000	54/42	44	34	42
Overall A-weighted Sound Pressure Level	79/64	75	51	59

1. Excavation equipment/truck noise.

Community Noise Levels for Various Project Activities
as Functions of Distance from Source

FIGURE
5-4

Table 5-4

ESTIMATED COMMUNITY NOISE LEVELS (CNEL/L_{nd})
AT NEAREST RESIDENCE

	Noise Level At		
	Residence 1 (135')	Residence 2 (235')	Residence 3 (650')
Site Preparation	70.5	66	58.5
Well Drilling	81	75.5	64.5
Well Cleanout & Flow Testing	55*	55*	55*
Plant Operation	61.5	56.5	55*

*ambient

Evaluating noise impact according to USHUD criteria utilizes the A-weighted sound levels given in Figure 5-3. At the nearest receptor, 135 feet from the project site, the maximum noise level is 81 dB(A). Thus, the level exceeds 80 dB(A) for 60 minutes per 24-hour time period. Therefore, the operations lie within the clearly unacceptable range. The clearly unacceptable USHUD rating equates with an Imperial County rating of "Critical". It is felt that sound reduction afforded by existing construction is insufficient to mitigate the exterior noise to acceptable interior level.

The noise has been evaluated based on the City of El Centro Noise Standards, and on the "Terms, Conditions, Standards and Application Procedures for Initial Geothermal Development in Imperial County" (Imperial County Planning Department, 1971), for the Class II-Normal Residential Criteria and Industrial Criteria. The proposed project site is 170 feet wide by 350 feet in length. Thus, the noise at the site boundary is a function of the distance of the activity from the nearest boundary. The approximate distances to the project boundary for each proposed operation is 85 feet. The data from Table 5-3 (which shows octave band sound pressure levels for various project activities at 100 feet) have been extrapolated to the appropriate distances and the results plotted in Figure 5-5. For comparison, the applicable Class II-Normal Residential, Industrial and City standard is also shown on this figure.

As mentioned in the previous section, it is evident that the impacts from drill site preparation, well drilling, well cleanout, flow testing, and facility operation vary according to the site and criteria in question. Analysis of the community noise impact using the L-dn/CNEL criteria is summarized in Table 5-4. The maximum impact is expected at the nearest residence as a result of the well drilling operation.

NOTE

1. Predicted sound pressure levels are based on measurements of equipment with no special purpose mufflers.

Parcel Boundary Noise Spectra for Each Phase of Project Development and Operation (assumes the use of no special noise attenuation devices on noise-generating equipment)

**FIGURE
5-5**

Noise resulting from this operation will raise the existing exterior noise level by 26 dB. This impact will not, however, be mitigated by the sound reduction afforded by existing residential construction.

An evaluation of noise impact according to USHUD criteria demonstrates that the noise levels lie within the range of Clearly Unacceptable. However, the Clearly Acceptable USHUD rating equates to an Imperial County rating of "Critical." Sound reduction afforded by existing home construction is probably insufficient to mitigate the exterior noise to an acceptable interior level. When compared to the spectral limits defined by the Class II - Normal Residential, and Industrial criteria in the "Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development in Imperial County" and the El Centro noise standards, a significant impact is predicted. However, it should be noted that the definition of a significant impact in this case is largely a function of applying a very rigorous standard to the project. The Class II - Normal Residential standard is the second most stringent noise limit available. While conformance to this standard will assure project compatibility with existing and future adjacent land uses, it will require the implementation of sophisticated mitigation measures.

The data used throughout this section to predict project-related noise is based on noise levels generated by equipment having no special purpose mufflers or other sound attenuating features. Thus, to achieve the prescribed noise reduction, all equipment used in drill site preparation and well drilling, especially diesel engines and generators, should be fitted with hospital-type mufflers to reduce exhaust noise. Noise attenuation devices will also be required within the plant. In addition, drilling equipment should be enclosed or located behind barriers to reduce engine-radiated noise. The mufflers should provide a minimum of 25 dB noise attenuation over the frequency range of 63 to 8000 hertz.

Noise resulting from well cleanout and flow testing, will not exceed ambient noise levels when measured at the nearest residence to the south.

While facility operation will be slightly noisy, the nearby residences to the south and those homes to the northeast along Hamilton would not be significantly impacted as attenuation afforded by the existing construction will reduce the interior noise to acceptable levels.

5.5.5 Water and Land Resources

5.5.5.1 Water Use

Some 6800 acre feet of water were delivered to El Centro in 1968 compared to 2.9 million acre feet of water diverted per year for the farmland included in the Imperial Irrigation District. A long-term water supply to El Centro and the Imperial Valley is well protected by various laws and agreements over priority rights to the Colorado River. However, projected population growth and development within California, adjoining states and Mexico point to long-term excessive water demands, especially once the Central Arizona Project is completed. As a consequence, California cannot rely on more than its priority share which may result in a reduction to 2.6 million acre feet in water rights for the Imperial Irrigation District.

Potable water within the City of El Centro is stored in two 2½-million gallon storage tanks and one 5-million gallon storage tank located at a water treatment plant. There are also two storage tanks, 100 thousand gallons and 250 thousand gallons, located within the City. This storage capacity represents sufficient water to serve the needs of the City for about one day during peak demand periods.

For the proposed field experiment, highest water usages will occur during the predicted nine weeks of drilling operations. In the order of 12,000 gallons of water per day with peaks of 20,000 gallons per day will be needed (Garrett, 1978). This level of water usage represents a significant impact. While there are no overall water supply problems to El Centro as a whole, without proper mitigation, water usage of this magnitude would seriously exacerbate existing water delivery/pressure problems to some northern sectors of the City. These water delivery problems sometimes occur during hot weather (May through October) at early evening peak water usage periods. These water delivery/pressure problems to the outlying northern sectors would require the project's ability to reduce or to withhold its water demands from the municipal system during times of peak demand.

In addition, the field experiment operation will consume 676,800 gal/yr (roughly 2 acre ft/yr) in evaporation and drift losses associated with one chiller plant cooling tower. Some cooling tower blowdown loss will also take place, although this loss is expected to be insignificant.

To mitigate the effects of potentially excessive water use, sufficient on-site water storage should be required during drilling operations to avoid heavy water demands upon the municipal water system at peak evening hours. For example, the presence of two 8 ft. x 8 ft. water tanks could provide up to six hours of on-site water use based on the projected 20,000 gallons per day (833 gallons per hour) demand. This or similarly sufficient on-site water storage capabilities would permit the drilling activities to continue during peak hours without exacerbating existing City water delivery/pressure problems. The drilling crew would be required to cooperate with the City's Public Works Department in coordinating and scheduling their water needs.

In the future, alternate sources of cooling tower makeup will have to be found before wide spread utilization of the absorption chiller process can take place.

5.5.5.2 Land Use

According to the proposed City of El Centro Amended General Plan (1978), current land use within the City consists of 33 percent residential, 6 percent commercial, 10 percent industrial/railroad R.O.W., 5 percent utility, 11 percent public/institutional, 3 percent mixed uses, 4 percent vacant, and 20 percent streets/highways/alleys. There are approximately 570 acres in the City limits zoned for medium and heavy industry; about 50 percent of these lands ranging in size from 1 to 60 acres are vacant or largely underutilized.

The project site consists of 63,000 square feet of vacant, City-owned property located in the southeastern portion of the City. The site is part of three City-owned lots totaling 7.43 acres. A more detailed description of the site is contained in Section 5.4 of this environmental analysis.

The proposed usage at the well site is consistent with the City's zoning policy as outlined in its Amended General Plan. Project implementation will require the issuance of a Conditional Use Permit (CUP) by the City of El Centro. Site specific review and conditions for operation, such as landscaping and parking requirements, are addressed in the CUP process. The project will not result in the loss of any agricultural land. Two neighboring, nonconforming, single-family residences to the south present the only conflicting land usages within the immediate project area.

Because the proposed project usage is in accordance with the Amended General Plan and zoning policy, no specific land use mitigation measures are required. Barring extenuating local circumstances which warrant a variance, a project applicant would follow guidelines contained in the Imperial County Geothermal Element and the "Terms, Conditions, Standards, and Application Procedures for Initial Geothermal Development in Imperial County."

5.5.6 Socioeconomics

Addressing long term benefits of geothermal development, studies for the Geothermal Element to the Imperial County General Plan concluded that: (1) employment in the year 2020 without geothermal development would be 48,000, and 62,000 with it (assuming a total of 4500 MW are developed by 2020); (2) 1.24 percent of the County labor force would be displaced by the effect of geothermal development on farm laborers by 2020; (3) additional jobs related to operations and construction of geothermal facilities could potentially reduce unemployment from 16.8 to 10 percent, if all jobs were filled by County residents; and (4) most important to this study, non-electric utilization of the resource has the greatest long range employment benefits.

Nevertheless, the near term employment of local residents for geothermal operations within the City of El Centro, particularly for those activities associated with drilling, is unlikely. The expertise needed for drilling geothermal wells and the absence of local workers trained in this area will require use of out-of-County residents. This loss of employment could be mitigated, if training programs related to increased geothermal development in the Imperial Valley were initiated to provide resident workers with the necessary skills.

Another short-term impact associated with drilling operations will be an increase in the traffic. Transportation of workers and equipment to and from the drill-site should cause only slight congestion of nearby City streets.

5.6 UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

The foregoing analysis indicates that the proposed geothermal demonstration project could potentially result in several adverse environmental effects. Such effects would lie primarily in the areas of water quality, air quality, noise, and water consumption. However, for the most part, mitigation measures have been or easily could be included in project plans. These measures should either completely eliminate or reduce these adverse effects to levels of insignificance.

Despite mitigation measures, the project will invariably result in some additional air pollution, the consumption of natural resources, such as water, concrete and

diesel fuel, and temporary adverse noise. Of these unavoidable impacts, water use, and noise concerns seem least subject to complete mitigation. However, the majority of these impacts are temporary in nature, primarily occurring during the site preparation and drilling phases.

5.7 ALTERNATIVES TO THE PROPOSED PROJECT

Alternatives to the proposed demonstration project fall within three general categories: (1) alternate project drillsite locations, (2) alternate operational procedures, and (3) no project. A discussion of each follows.

5.7.1 Alternate Sites

The choice of the 2½-acre drilling site herein discussed was based not only on the underlying potential resource but also on the suitability of the site for development. The City of El Centro determined that this City-owned property would cause less disruption of present land uses than would other suggested sites. Currently, the only use being made of the lot is the City-recycling center. Relocation of the center can probably be avoided because of its location near the western boundary of the drillsite. However, should it become necessary to move the center in order to permit drilling, any impacts associated with removal will be assessed at that time.

Two alternative sites owned by the City of El Centro were initially considered. The first site is currently occupied by the El Centro City shops. The shops are located on Orange Avenue directly west of the train station and close to the Central Business District (Figure 5-2). This location makes it attractive for a potential commercial heating and cooling project. There is a pending proposal to relocate the City Shops yard which would free this site for other uses within the next two years.

Nevertheless, several negative factors temporarily eliminated this site. The first factor is the site's unavailability for the near term. Other City projects have also been suggested for this site, projects which may take priority in a given situation. The surrounding area, while zoned for commercial and industrial uses, includes some nonconforming residential dwellings. These residences are situated close to the yard and would, therefore, be more acutely affected by any adverse impacts associated with drilling operations. For these reasons, it was concluded that the El Centro City Shops site was not suitable for geothermal operations.

The other alternative site houses the City outfall lift station and animal shelter. The station lifts City sewage, centrally collected at this point, and transports sewage to the City's Sewage Treatment Plant. The station is located in the northwest portion of the City on Villa Avenue, close to a shopping center and to a residential development, both conforming uses under the City's Zoning Element. The site has been designated for some time as a future park site under the City's General Plan. The community would not, in all likelihood, be receptive to a change from park to drilling site. Consequently, the area occupied by the lift station has been eliminated from any future consideration as a geothermal well site.

5.7.2 Alternate Operational Procedures

The technical and engineering procedures proposed for project operations are among the most efficient and safe currently available for geothermal resource evaluation, and cannot be changed to any significant degree without compromising the primary objectives of the project. In addition, with one exception, there are no technically viable alternate operational procedures available that would result in significantly reduced environmental impacts. The exception is to restrict drilling operations to the daytime hours. This would substantially reduce the potential noise impact and require considerably less extensive noise mitigation measures. This restriction is not presently recommended, because it would potentially impose a significant hardship in terms of completing any exploration project within an appropriate timeframe and budget.

5.7.3 No Project

Implementation of the "no project" alternative (that is, denying or delaying approval of the conditional use permit for the proposed project) would eliminate all potential adverse environmental effects discussed in Section 5.4. However, the long-term economic benefits associated with the possible future development of the area for geothermal utilization would also be eliminated, or at least postponed, by this alternative.

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SECTION 6

SPECIFIC ENGINEERING AND ECONOMIC EVALUATIONS

6.1 INTRODUCTION

The general engineering and economic evaluations in the preceding sections have been based on City-wide energy consumption data averaged for each building in El Centro. In order to verify the findings of the general analysis, it was decided to conceptualize specific applications of geothermal energy in the residential/commercial and industrial sectors of the El Centro Community to the point that the life cycle costs of systems modified for geothermal applications could be computed for comparison with conventional system costs. Specific applications chosen for detailed evaluation are the El Centro Community Center (space and water heating along with space cooling), the American Linen Supply Company (process hot water), and the concept of an Industrial Park containing an onion dehydrating and alfalfa drying facility (process hot water).

6.2 RESIDENTIAL/COMMERCIAL APPLICATION - EL CENTRO COMMUNITY CENTER

6.2.1 Introduction

The overall objective of this study is to determine the engineering and economic feasibility of the utilization of low to moderate temperature geothermal resources within the City of El Centro. Since the residential/commercial sector consumes the vast majority of geothermally replaceable energy in the City of El Centro, a detailed evaluation was made of a typical application of hydrothermal fluids in this sector, namely space cooling and space and water heating at the El Centro Community Center.

The Community Center is located in a small residential/commercial area within a larger industrial area east of the Southern Pacific Railroad (see Figure 4-1). The Community Center is located on a site of 2.7 acres, approximately one-half mile north of a proposed well site and modular chiller plant. The Community Center is operated by a Director and staff of seven personnel. Use of the facility is continuous, seven days a week and over sixteen hours per day. The Center is the only such type of facility located in the City. It serves the entire community including all age and race groups. An average of 700 persons use the facility per day, totaling more than 260,000 people per year. Some of the programs being offered at the Center are health services, external college classes, employment services, branch library, day care services, senior citizens activities, lunch program for children, film programs, health programs, recreation activities, and various organization meetings. Figure 6-1 is a master plan for the existing Community Center. The parking area, access road, play showers and creative play structures are still in the planning stages. The Community Center building itself is of concrete block wall construction with steel supported roof and fire resistant construction throughout. The total square footage of the enclosed area is approximately 13,200 square feet with an additional roofed-over shaded area of approximately 3,000 square feet (see Table 6-1). Figure 6-2 shows site elevations of the Community Center indicating the location of the packaged rooftop air conditioning units.

COMMUNITY CENTER MASTER PLAN

FIGURE
6-1

Table 6-1

EL CENTRO COMMUNITY CENTER SQUARE FOOTAGE

There are nine (9) rooms including storage and auxiliary space, used as follows:

1.	Multi-purpose Room (Day-care, meetings, dinners, large classes, wedding receptions, etc.)	5,350 square feet
2.	Day Care Office and Crib Room	1,600 square feet
3.	Director's Office	500 square feet
4.	Reading Room and Study	850 square feet
5.	Crafts	900 square feet
6.	Pool/Billiard and Table Tennis	900 square feet
7.	Gymnastics	1,200 square feet
8.	Conference/Small Classes	520 square feet Divisible
9.	General Office	530 square feet
10.	Hall and Toilets	<u>850 square feet</u>
	TOTAL:	13,200 square feet

WEST ELEVATION SOUTH ELEVATION EAST ELEVATION NORTH ELEVATION SECTION

ALL ELEVATIONS & SECTION
SCALE 1"=20'

COMMUNITY CENTER SITE ELEVATIONS

FIGURE
6-2

6.2.2 Community Center Engineering Evaluation

6.2.2.1 Existing System

The existing space conditioning equipment at the Community Center consists of packaged rooftop gas (heating)/electric (cooling) units. A brief description of the equipment is listed in Table 6-2. The design capacity of the installed equipment totals 744,000 BTU/hr or about 62 tons of space cooling and 511,830 BTU/hr of space heating. Water heating requirements are satisfied by one 52 gallon and one 20 gallon gas fired water heater. There is no commercial size refrigeration required at the Community Center.

It can be seen in this example that there is a large potential amount of energy that can be replaced by geothermal energy. A total of approximately 1.5×10^9 BTU/yr of conventional energy has the potential for replacement by geothermal heat to provide the bulk of the space conditioning and water heating needs of the Community Center. An optimally sized geothermal system, according to the general economic discussion section, should provide 1.31×10^9 BTU/yr. The remaining 2.0×10^8 BTU/yr should be satisfied by supplemental conventional equipment.

6.2.2.2 El Centro Community Center Interface

It is assumed for this analysis that the El Centro Community Center is part of a High Energy Density Modular two-pipe geothermal hot/chilled water distribution system coupled with a Case I Geothermal Industrial Park utilizing cascading or off-peak energy. The hot/chilled water distribution system would interface with the existing rooftop air handling units and zone heating coils at the Community Center. Separate rooftop air handling units would provide variable volume supply air for each building to prevent the necessity for zone reheat. The air handling unit will have a chilled water coil and will either cool or ventilate. Supply air will be distributed to each zone through a heating coil for zones requiring heat and satellite volume control units. Each zone has a thermostat which modulates the supply air quantity thereby maintaining space temperature. An adjustable throttling range between full heating and full cooling is provided.

A combined hot water heat exchanger/storage tank would provide domestic water heating during the winter months with the conventional gas fired water heater providing back-up service during the summer months.

6.2.3 Community Center Economic Evaluation

Section 6.2.2 describes the basic engineering modifications to the existing space conditioning and water heating systems required to utilize geothermal energy. This section deals with economic factors involved in making the change-over.

Life cycle costs for conventional and geothermal/conventional systems are presented in Table 6-3. The costs listed in Table 6-3 are calculated on an annual basis for the period 1983-2012 in three categories: (1) annualized capital replacement costs, (2) annual operating and maintenance costs, and (3) annual energy costs. A comparison of costs is made between the conventional system and the geothermal system beginning

Table 6-2

EL CENTRO COMMUNITY CENTER
EXISTING SPACE CONDITIONING EQUIPMENT

1 - Air Conditioning Unit,	Packaged rooftop multizone unit
	supply air = 12,000 CFM
	cooling capacity = 350,000 BTU
	heating capacity = 350,000 BTU
	input
	262,000 BTU
	output
	condenser fans = 3 - 1 Hp
	supply fan = 7½ Hp
	return/exhaust fan = 3 Hp
3 - Air Conditioning Units,	Packaged rooftop gas/electric
	supply air = 5,500 CFM
	cooling capacity = 118,000 BTU
	heating capacity = 175,000 BTU
	input
	131,250 BTU
	output
	condenser fans = 2 - ½ Hp
	evaporator fan = 5 Hp
1 - Air Conditioning Unit,	Packaged rooftop gas/electric
	supply air = 1,600 CFM
	cooling capacity = 40,200 BTU
	heating capacity = 150,000 BTU
	input
	112,500 BTU
	output
	condenser fan = ½ Hp
	evaporator fan = ½ Hp
1 - Electric duct heater,	1.7 KW, 5780 BTU, 275 CFM
1 - Evaporative cooler,	1,800 CFM
5 - Exhaust Fans,	capacities ranging from 90 CFM to 2,000 CFM

Table 6-3

EL CENTRO COMMUNITY CENTER
30-YEAR LIFE CYCLE COSTS
1983-2012

<u>Annual Levelized Costs (1977\$)</u>	<u>Conventional System</u>	<u>Geothermal System</u>
Capital ¹	\$ 5,740	\$ 1614
O & M	\$ 608	\$ 230
Energy	\$ 13,064 ²	\$ 11,770
	\$ 19,412	\$ 13,614
Annual Conventional Energy Load:	1.51x10 ⁹ Btu	2.02x10 ⁸ Btu
Annual Geothermal Energy Load:	-----	1.31x10 ⁹ Btu
Life Cycle Cost:	\$12.86/10 ⁶ Btu	\$9.02/10 ⁶ Btu
Annual Conventional Energy Consumed ³ :	1.42x10 ⁹ Btu	4.99x10 ⁸ Btu
Annual Energy Costs:	\$8.65/10 ⁶ Btu	\$7.79/10 ⁶ Btu ⁴

-
1. Based on 12 percent cost of borrowed money.
 2. Based on \$0.367/therm levelized cost of natural gas and \$0.044/KWH levelized cost of electricity.
 3. Natural gas and electricity consumption converted to BTUs.
 4. Composite geothermal/conventional energy charges.

in the year 1983, at which time it is expected the existing system will have worn out and will have to be replaced.

The annualized capital replacement costs are based on a 9 year packaged air-conditioning unit life and a 5 year water heater life for the conventional system. Geothermal fan-coil units and preheater tank are assumed to have a 15 year life, heater tank a 7½ year life, and controls and supplemental conventional system equipment a 30 year life. Total capital costs for modifying the Community Center are estimated to be \$11,500. A 12 percent cost of borrowed money with 100 percent financing is assumed.

The annual operating and maintenance costs are based on 2 percent of the first costs (capital costs of the equipment).

Conventional fuel and energy costs are based on levelized costs for the period 1983-2012 using the scenarios presented in Section 3.2. Geothermal heat is expected to provide 33 percent of the water heating needs, 85 percent of the space heating requirements, and 88 percent of the cooling required in the Community Center. This would amount to about 87 percent of the overall energy required for these needs. The remaining portion of the load would be fulfilled by conventional space conditioning and water heating equipment.

As can be seen from Table 6-3, the geothermal system could save as much as \$5,798 per year to operate and maintain over the conventional system on a constant 1977 dollar basis. The geothermal/conventional system would affect a 65 percent reduction in the amount of conventional energy consumed at the Community Center for space cooling and space and water heating. An annual energy cost savings of about 10 percent on a cost per million BTU basis could be realized. The geothermal energy costs are based on the High Energy Density Modular system model combined with a Case I Geothermal Industrial Park utilizing cascading or off-peak energy (see Table 3-7).

6.3 INDUSTRIAL APPLICATION - AMERICAN LINEN SUPPLY

6.3.1 Introduction

The application of geothermal energy in the industrial sector would be most beneficial in terms of providing high utilization efficiencies as a result of the constant demand for process heat. The economics of geothermal hot water as applied to an industrial laundry facility is addressed in the following sections. American Linen Supply was chosen as an example of the industrial sector to which process water heating techniques can be applied. This laundry facility provides industrial laundry and uniform supply services as well as commercial laundry and linen supply services to the El Centro community and the greater Imperial Valley. American Linen is located on approximately a one-half acre site about ¾ of a mile north of a proposed well site and modular chiller plant. The facility basically consists of washers, dryers, ironers, and presses in two main enclosed areas operating eight hours a day, five days a week.

6.3.2 American Linen Supply Engineering Evaluation

6.3.2.1 Existing System

Figure 6-3 is a flow diagram of the existing cleaning, drying, and pressing process. A 175 Hp boiler is used year around to supply 100 psig steam for ironers, tumble dryers, and presses. The boiler is fired by either natural gas or, when gas is unavailable, by stored standby fuel oil. Steam is injected directly into the washers to raise water temperature to 190F. This steam, along with the wash water, is discharged to the sanitary sewer system after use, while the condensate return from the steam equipment (CON 1 as shown on Figure 6-3) is used to heat city water supplied to the hot water storage tank. Steam is also used to heat this water to 170F, after which it is used in the wash cycle of the cleaning process. Cold city water is used in the rinse cycle of the washers.

The existing boiler is required to provide 12.6×10^9 BTU/yr of heat for the plant facilities. With a measured boiler efficiency of 0.594 this means that 2.16×10^{10} BTU/yr is consumed in the form of natural gas or distillate fuel oil. While these forms of energy are still relatively inexpensive, they can no longer be considered a dependable source of energy considering the priorities being set for natural gas and crude oil. The fuel costs for these energy sources are highly speculative as a result of the world political situation.

A potentially large amount of the conventional fuel energy can be replaced with geothermal energy. Approximately two-thirds of the total required energy for the plant is used to heat the city water from 72F to 170F. This energy can be replaced by geothermal heat. The remaining heat is used to provide steam to the various presses, ironers, and dryers. This steam would continue to be provided by a boiler, but of a much smaller capacity, under the geothermal modification.

6.3.2.2 Modified System

Figure 6-4 shows the modification required to integrate geothermal heating into the existing system. A heat exchanger would be placed between the water softeners and the hot water storage tank. City water would be heated by 195F geothermally heated water. A 60 Hp boiler would then be required to fulfill steam requirements.

Unlike a residential application, which requires hot water in the winter and chilled water in the summer, this industrial facility would require hot water year around. Therefore, this facility would be treated somewhat similar to a modular plant requiring hot water throughout the year.

6.3.3 American Linen Supply Economic Evaluation

The application of geothermal energy to the industrial sector is the key to the economic feasibility of the utilization of hydrothermal resources in the City of El Centro. The industrial sector makes up the foundation upon which the entire geothermal system must be based. The American Linen Supply facility was used as an example to show the economics involved in geothermal application in the industrial sector.

Figure 6-3. AMERICAN LINEN EXISTING SYSTEM

Figure 6-4. AMERICAN LINEN MODIFIED SYSTEM

For the American Linen Supply laundry facility, costs were compared between the existing system and a modified system as described previously in Section 6.3.2.2. Costs were compared on an annual basis for the period 1983-2012 in three categories: (1) annualized capital replacement costs, (2) annual operating and maintenance costs, and (3) annual energy costs. The comparison in Table 6-4 is made beginning from the year 1982 at which time it is expected the present boiler would have to be replaced. Thus the choice in 1982 is whether to replace the old boiler with a new full capacity boiler or whether to use a smaller boiler supplemented with a geothermal hot water system.

The capital replacement costs of \$25,900 for the geothermal/conventional system are based on a 15 year boiler life and a 30 year heat exchanger life. A 12 percent cost of borrowed money with 100 percent financing is assumed.

The annual operating and maintenance costs are based on 2 percent of the first costs (capital cost of equipment).

Conventional fuel costs (natural gas and commercial distillate) are based on levelized costs for the period 1983-2012 using the scenarios presented in Section 3.2. Geothermal heat is expected to provide about two-thirds of the total heat required in the plant. All of the 170F hot water required in the plant would be supplied by the geothermal system.

The geothermal system would save close to \$15,000 per year. Energy costs would be reduced 17 percent. This is based on a scenario that natural gas would be subject to curtailment 200 days per year in the years 1983 through 2012. This would mean natural gas would be available only 160 days per year. During the remaining days, standby fuel oil would provide heating requirements. The geothermal energy costs are based on a hot water distribution system between a proposed drill site and American Linen Supply. Annual geothermal utilization efficiency for this application was assumed to be approximately 25 percent, typical of a single-shift five day per week operation.

The amount of fuel saved with the geothermal modification would be about 66 percent. This would mean over 14 million cubic feet of natural gas or over 100,000 gallons of fuel oil per year could be saved in this application.

The geothermal energy costs used in this example were calculated based upon a separate hot water distribution system from the nearest modular plant site (in this case the proposed drill site) to the laundry. Since an industrial user such as American Linen would require a high volume of process hot water year around, the economics justify the construction of a separate supply and return pipeline for this industrial application.

6.4 GEOHERMAL INDUSTRIAL PARK CONCEPT

6.4.1 Introduction

An industrial park concept was investigated to determine whether a geothermal energy industrial park would be feasible in the City of El Centro. The site

Table 6-4

AMERICAN LINEN SUPPLY
30-YEAR LIFE CYCLE COSTS
1983-2012

<u>Annual Levelized Costs (1977\$)</u>	<u>Old System</u>	<u>New System</u>
Capital ¹	\$ 3,230	\$ 3,506
O & M	440	518
Energy	\$ 87,709 ²	\$ 72,653
	\$ 91,379	\$ 76,677
Annual Boiler Load:	12.6x10 ⁹ Btu	4.4x10 ⁹ Btu
Annual Geothermal Load:	-----	8.2x10 ⁹ Btu
Life Cycle Cost:	\$7.25/10 ⁶ Btu	\$6.08/10 ⁶ Btu
Annual Fuel ³ Consumed:	2.16x10 ¹⁰ Btu	7.4x10 ⁹ Btu
Annual Energy Costs:	\$6.96/10 ⁶ Btu	\$5.77/10 ⁶ Btu ⁴

-
1. Based on 12 percent cost of borrowed money.
 2. Based on \$0.367/therm levelized cost of natural gas and \$0.59/gal levelized cost of fuel oil.
 3. Natural gas and fuel oil.
 4. Composite geothermal/conventional energy charge.

for the proposed industrial park would be located approximately 1.5 miles south of a proposed well site and modular chiller plant (see Figure 5-2). The evaluation considered the industrial park application to be totally separate from the residential/commercial district heating and cooling system. All of the engineering and economic factors were based solely on the merits of this industrial park concept.

There are a number of potentially ideal industrial processes requiring heat in the temperature range suitable for geothermal application based on predicted resource temperatures for the City of El Centro. A full-scale evaluation of these processes would be required for the selection of the ideal energy park members to promote the eventual melding of these members into a synergistic industrial complex.

6.4.2 Industrial Park Concept Engineering Evaluation

For this report, two examples have been chosen to indicate some of the technical and economic factors involved in a geothermal industrial park concept, namely: onion dehydration and alfalfa drying. Data for these geothermal processes was taken from work performed by the Geo-Heat Utilization Center at the Oregon Institute of Technology, based on geothermal resources in the Klamath and Western Snake River Basins of Oregon.

At present no onion dehydrating facilities exist in the Imperial Valley. Raw onions are presently trucked out of the Valley to remote dehydration plants for processing. The onion dehydration process proposed for the City of El Centro involves the use of a continuous operation belt conveyor in four stages using fairly low-temperature hot air from 100F to 220F. The plant reduces moisture content of the onions from 83 percent to 4 percent using from 0.15 to 0.20 therms per dry pound processed, or 4,000 BTU per pound of water evaporated. Typical processing plants of this type will handle 10,000 pounds of raw product per hour. The dehydration plant would require approximately 0.177×10^{12} BTU/year of geothermal heat for production of 10 million pounds of dry product annually from 67 million pounds of raw onions. Crop yields in recent years have ranged between 30 and 100 million pounds for Imperial County.

The two alfalfa drying processes presently used in the Imperial Valley are kiln drying and field wilting. Kiln drying of alfalfa by fuel heat at 1800F has several advantages over sun drying. Fuel drying produces a harder and heavier pellet and retains a greater percentage of Vitamin A and xanthophyll. Only through complete fuel drying can the ideal amounts of Vitamin A and xanthophyll be retained. However, through a combination of field wilting and then some fuel drying, 17 percent of the protein and an average of 50 percent of the ideal amounts of Vitamin A and xanthophyll are retained. A plant using this combined field wilt and fuel drying process can produce 80 to 110 tons of pellets per eight-hour shift. A geothermally heated triple pass rotary drum dryer can be made for this combined field wilt and fuel drying process. Temperature of the geothermally heated water going to the plant would be 220F to provide dryer air at 200F. The drying plant would require 0.053×10^{12} BTU/yr of geothermal heat for production of 100,000 tons per year of dried pellets from 110,000 tons per year of wilted alfalfa, assuming 12 percent moisture content in the crop after field wilting. Annual crop yields for cube and dehydrated alfalfa have ranged between 80,000 and 190,000 tons for Imperial County in recent years.

Together the onion dehydrating plant and the alfalfa drying plant would require 0.23×10^{12} BTU/yr. A peak demand has been estimated, based on the combined hourly load of both the onion dehydrating plant and the alfalfa drying plant, to be 34.5×10^6 BTU/hr. This would require only one brine production well and one reinjection well. A six-inch distribution pipeline would be required for supply and return of the geothermally heated water from the proposed well site to the industrial park, a distance of approximately 1.5 miles. Preinsulated carbon steel pipe would be used for water temperatures in excess of 200F supplying the industrial park.

6.4.3 Industrial Park Concept Economic Evaluation

The economic benefits resulting from the incorporation of industrial processes into the residential/commercial geothermal system have been explored in a previous section (3.10.4) and have been shown to be the key to economic viability. An industrial park would not only be the showcase for the future city-wide acceptance of geothermal energy and provide the necessary economic foundation but would also provide much needed employment opportunities. New industry would help to stabilize the community by providing an economic tax base for the City while at the same time protecting the agrarian economic base.

The proposed industrial processes previously cited in Section 6.4.2 were evaluated on an economic basis. This analysis reveals a promising outlook for the economic foundation of a geothermal energy park.

The "GEOCITY" computer program was once again utilized for an industrial model consisting of an onion dehydrating plant and an alfalfa drying plant. The financing scenario was based on resource exploration and development along with distribution system construction and operation by a municipal utility district.

Capital costs for the production and distribution of geothermal heat to the onion dehydrating and alfalfa drying plants approach \$1.25 million. Cost of delivered heat at the industrial park site was calculated to be $\$1.31/10^6$ BTU in constant 1977 dollars based on a utilization factor of 0.76 (where 1.0 assumes that all of the geothermal heat energy between 250F and 160F is continuously utilized to recover the reservoir capital investment). This number includes distribution costs, reservoir field development costs, interim capital replacement costs, operating and maintenance expenses, and taxes and insurance. As a comparison, the levelized cost of industrial natural gas has been estimated to be $\$3.67/10^6$ BTU in constant 1977 dollars (see gas pricing scenario in Section 3.2). Based on a total heat requirement of 0.23×10^{12} BTU/yr, fuel savings of over \$500,000 per year with the geothermal drying systems would be realized when compared with natural gas without even considering the conversion losses when burning natural gas. Even more savings would be incurred with the geothermal systems if compared with burning fuel oil.

From this example, it is safe to conclude that the highest potential for geothermal energy lies within the industrial sector. A large reason for this potential is the fact that distribution costs for a point demand (a highly concentrated load requirement at one point) make up only one-third of the total capital costs, as compared to one-half of the total for a residential/commercial district-wide distribution system. The largest portion of the distribution costs for an industrial application

consists of the piping from the well site to the industrial park. Once at the park, piping to each individual industrial consumer is minimal. As more users are added on-line, the effective cost of the distribution system will become less. The remaining two-thirds of the capital costs for industrial applications consists of production well cost, injection well cost, and brine transmission and disposal costs. The effective cost of these field development charges can be lowered by increasing the size of the industrial application as demonstrated by Cases II and III shown on Tables 3-6 and 3-7. This can be accomplished by adding new industries while maintaining the full use of the geothermal heat through energy cascading. It is important to realize that not only the quantities of industries is influential in the formation of a geothermal energy park but also the types of industries and how their energy profiles interrelate.

6.5 SUMMARY AND CONCLUSIONS

Engineering and economic evaluations were performed on specific applications within residential commercial and industrial sectors of the El Centro community to determine the life cycle cost savings of systems modified for geothermal applications over conventional systems. The three specific applications chosen for detailed evaluation were the El Centro Community Center, the American Linen Supply Company, and the concept of an industrial park containing an onion dehydrating and alfalfa drying facility.

In the Community Center evaluation, approximately 87 percent of all the energy required for space heating, space cooling, and water heating can be replaced by a two-pipe hot/chilled water distribution system providing chilled water in summer and hot water in winter. Total capital costs for the geothermal modifications to the existing systems is estimated at \$11,500. Annual levelized life cycle cost savings for the proposed geothermal systems would be approximately \$5,800 in constant 1977 dollars. This would result in a payback period of approximately two years. Energy charges for the geothermal system were based on combined residential/commercial and industrial geothermal applications relying on energy cascading techniques to achieve a utilization efficiency of 27 percent.

The American Linen Supply evaluation shows that approximately two-thirds of the total heat required in the plant can be replaced by a two-pipe geothermal hot water distribution system. Total capital costs for the geothermal/conventional system would be approximately \$25,900. Annual levelized life cycle cost savings approaching \$15,000 per year in constant 1977 dollars would be realized with this modification. This would result in a payback period of less than two years. The geothermal energy charges for this evaluation were based on a separate hot water distribution system from a modular plant site (in this case the proposed drill site) to the American Linen Supply facilities and an overall geothermal utilization efficiency of 25 percent (typical of a single-shift five day per week operation).

The evaluation of the geothermal industrial park concept concentrated on the scenario of industrial development through the utilization of geothermal technology in the onion dehydrating and alfalfa drying industries. The industrial park was assumed to contain two facilities producing 10 million pounds of dehydrated onions and 200 million pounds of dried alfalfa pellets per year. Assuming similar capital, operating and maintenance costs for conventional and geothermal systems, annual energy savings were calculated for the geothermal systems based on a yearly energy requirement of 0.23×10^{12} BTU. Levelized natural gas prices were used for calculating the annual

energy savings without taking gas fuel conversion losses into account. Annual fuel savings would exceed \$500,000 for these two facilities in constant 1977 dollars. Geothermal energy charges for the industrial park concept were based on one production well supplying the two facilities exclusively, with an annual geothermal utilization efficiency of 76 percent.

The specific economic evaluations confirm the results of the general analysis of geothermal applications in the El Centro community. Industrial applications have the highest probability of economic success because of their large concentrated load requirements, resulting in minimized distribution costs. Industrial applications also tend to have lower peak demands compared with their average loads resulting in higher geothermal energy utilization efficiencies and thereby lower costs per delivered BTU. The evaluation of the El Centro Community Center shows that once the geothermal industrial applications are underway, the community can begin to look toward geothermal district heating and cooling systems as a viable economic alternative to conventional heating and cooling systems.

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APPENDIX A

LEVELIZED UNIT FUEL COST

A levelized unit fuel cost is an equivalent unit fuel cost which is used to compute the present worth total fuel expenses as would be produced by the sum of the present worth of the annual fuel expenses throughout the entire study period. The levelized unit fuel costs were calculated for the study period in order to eliminate the added complexity of dealing with yearly escalation, thereby simplifying the analysis to one cost for each fuel during the study period. The calculation of levelized unit fuel costs was done in constant December 1977 dollars on a present worth basis for the year 1983 and covers the study period of 1983 through 2012. Nominal and constant dollar fuel costs were obtained from projected utility rates as well as various fuel and energy price forecast studies. Where nominal fuel cost projections were obtained, constant dollar fuel costs, as shown on Figure 3-1 and on Table A-1 were calculated by dividing the nominal fuel costs by the Consumer Price Index. The Consumer Price Index is assumed to increase at 6 percent per year for the period 1977-1984 and at 4.5 percent per year for the period 1985-2012. An interest rate of 8 percent was assumed for these calculations. Levelized unit fuel costs are calculated by dividing the sum of the present worth fuel costs by the sum of the present worth factors for the study period. The calculation is summarized in Table A-1.

Table A-1
LEVELIZED UNIT FUEL COSTS
(December 1977 - dollars)

Period 1983 - 2012

End of Year	8% PWF	Residential/Commercial Natural Gas		Residential/Commercial Electricity		Industrial Natural Gas		Industrial Electricity		Commercial Distillate	
		\$/10 ⁶ BTU	PW	\$/10 ⁶ BTU	PW	\$/10 ⁶ BTU	PW	\$/10 ⁶ BTU	PW	\$/10 ⁶ BTU	PW
1983	0.9259	3.10	2.87	12.75	11.80	2.80	2.59	7.80	7.22	3.42	3.17
84	0.8573	3.20	2.74	12.80	10.97	2.90	2.48	7.85	6.73	3.49	2.99
85	0.7938	3.25	2.58	12.90	10.24	3.14	2.49	7.90	6.27	3.51	2.79
86	0.7350	3.30	2.42	12.92	9.49	3.20	2.35	7.92	5.82	3.53	2.59
87	0.6806	3.40	2.31	12.93	8.80	3.25	2.21	7.95	5.41	3.60	2.45
88	0.6302	3.50	2.20	12.94	8.15	3.32	2.09	7.98	5.03	3.62	2.28
89	0.5835	3.57	2.08	12.95	7.56	3.40	1.98	8.00	4.67	3.70	2.16
90	0.5403	3.63	1.96	12.95	6.99	3.50	1.89	8.00	4.32	3.76	2.03
91	0.5002	3.74	1.87	12.95	6.48	3.60	1.80	8.02	4.01	3.80	1.90
92	0.4632	3.76	1.74	12.98	6.01	3.69	1.71	8.05	3.73	3.85	1.78
93	0.4289	3.92	1.68	12.99	5.57	3.75	1.61	8.10	3.47	3.90	1.67
94	0.3971	3.99	1.58	12.99	5.16	3.81	1.51	8.12	3.22	4.00	1.59
95	0.3677	4.08	1.50	13.00	4.78	3.90	1.43	8.15	3.00	4.08	1.50
96	0.3405	4.13	1.40	13.00	4.43	4.00	1.36	8.18	2.78	4.13	1.40
97	0.3152	4.22	1.33	13.00	4.10	4.10	1.29	8.20	2.58	4.22	1.33
98	0.2919	4.31	1.26	13.00	3.79	4.20	1.22	8.22	2.40	4.31	1.26
99	0.2703	4.40	1.19	13.04	3.52	4.25	1.15	8.24	2.23	4.40	1.19
00	0.2502	4.49	1.12	13.07	3.27	4.32	1.08	8.27	2.07	4.49	1.12
01	0.2317	4.58	1.06	13.09	3.03	4.40	1.02	8.31	1.92	4.58	1.06
02	0.2145	4.68	1.00	13.11	2.81	4.50	0.96	8.35	1.79	4.68	1.00
03	0.1987	4.78	0.95	13.14	2.61	4.60	0.91	8.38	1.66	4.78	0.95
04	0.1839	4.88	0.90	13.16	2.42	4.65	0.86	8.42	1.55	4.88	0.90
05	0.1703	4.98	0.85	13.18	2.24	4.75	0.81	8.46	1.44	4.98	0.85
06	0.1577	5.08	0.80	13.20	2.08	4.80	0.76	8.49	1.34	5.08	0.80
07	0.1460	5.18	0.76	13.23	1.93	4.90	0.72	8.53	1.24	5.18	0.76
08	0.1352	5.29	0.72	13.25	1.79	5.00	0.68	8.57	1.16	5.29	0.72
09	0.1252	5.40	0.68	13.27	1.66	5.10	0.64	8.61	1.08	5.40	0.68
10	0.1159	5.52	0.64	13.29	1.54	5.15	0.60	8.64	1.00	5.52	0.64
11	0.1073	5.63	0.60	13.32	1.43	5.20	0.56	8.68	0.93	5.63	0.60
12	0.0994	5.75	0.57	13.34	1.32	5.30	0.53	8.72	0.87	5.75	0.57
TOTAL:	11.2576		43.36		145.97		41.29		90.94		44.73
LEVELIZED FUEL COST:		3.85		12.97		3.67		8.08		3.97	

APPENDIX B
RETROFIT COSTS

The following are retrofit costs for the average residential home and commercial building in El Centro.

Residential

(1978 \$)

Estimate 1

Manufacturer "A" fan-coil unit 47,000 BTUH @ 1600 CFM	\$ 535
Labor and Materials	291
Control Valves, other valves	436
Hot water heater tank	150
	<u>\$1,412</u>

Estimate 2

Manufacturer "A" coil 48,000 BTUH @ 1600 CFM	\$ 167
Manufacturer "B" fan two-speed, 1500-2000 SCFM	206
Labor and Materials	242
Control valves, other valves	436
Hot water heater tank	150
	<u>\$1,201</u>

Estimate 3

Manufacturer "B" coil	\$ 291
Manufacturer "B" fan two-speed, 1500-2000 SCFM	206
Labor and Materials	242
Control valves, other valves	436
Hot water heater tank	150
	<u>\$1,325</u>

Estimate 4

Manufacturer "C" coil	\$ 475
Manufacturer "C" fan two-speed, 1500-2000 SCFM	740

Residential (Continued)

Labor and Materials	242
Control valves, other valves	436
Hot water heater tank	150
	<u>\$2,043</u>

Estimate 5

Manufacturer "B" fan-coil unit	\$ 626
Labor and Materials	291
Control valves, other valves	436
Hot water heater tank	150
	<u>\$1,503</u>

Average Cost: \$1,497

Commercial

Estimate 1

Manufacturer "B" coil	\$ 720
Manufacturer "B" fan	566
Labor and Materials	242
Control valves, other valves	586
Hot water heater tank	750
	<u>\$2,864</u>

Estimate 2

Manufacturer "B" fan-coil unit	\$1,526
Labor and Materials	291
Control valves, other valves	586
Hot water heater tank	750
	<u>\$3,153</u>

Estimate 3

Manufacturer "C" coil	\$1,310
Manufacturer "C" fan	1,420
Labor and Materials	242
Control valves, other valves	586
Hot water heater tank	750
	<u>\$4,308</u>

Average Cost: \$3,442

APPENDIX C

HEAT FLUX CALCULATIONS

Heat flux through building walls was calculated for four different types of homes. A floor plan for each type of home is included as Figures C-1 through C-4 of this Appendix. A weighted average of the heat flux of the four types of homes was used in the computer analysis. Heat flux for commercial buildings was calculated based on the residential heat flux.

A typical calculation is shown below for a residential building:

Exterior Walls - Gross

100 ft x 8.5 ft	=	850 sq ft
52 ft x 8.5 ft	=	442 sq ft
10 ft x 8.0 ft	=	80 sq ft
		<u>1,372 sq ft</u>

Doors

3 ft x 7 ft	=	21 sq ft
2.5 ft x 7 ft	=	17.5 sq ft
		<u>38.5 sq ft</u>

Windows

4 ft x 1 ft	=	4 sq ft
4 ft x 1 ft	=	4 sq ft
8 ft x 5 ft	=	40 sq ft
6 ft x 3 ft	=	18 sq ft
6 ft x 3 ft	=	18 sq ft
8 ft x 6.75 ft	=	54 sq ft
4 ft x 3 ft	=	12 sq ft
		<u>150 sq ft</u>

Exterior Walls - Net

$$1,372 \text{ sq ft} - 38.5 \text{ sq ft} - 150 \text{ sq ft} = 1,183 \text{ sq ft}$$

Ceiling Area

(50 ft x 25.75 ft)	-	(4 ft x 5.5 ft)	
1287.5	-	22.0	= 1,266 sq ft

Floor Area

$$= 1,266 \text{ sq ft}$$

Volume

$$1,266 \text{ sq ft} \times 8 \text{ ft} = 10,128 \text{ ft}^3$$

Perimeter

$$(50 \text{ ft} + 50 \text{ ft} + 25.75 \text{ ft} + 25.75 \text{ ft}) + 5.5 \text{ ft} + 5.5 \text{ ft} = 162.5 \text{ ft}$$

Wall "U" Heat Transfer Coefficient BTU/hr-sq ft-F

		<u>R</u>
1/2 in. sheet rock	=	0.45
2 in. fiberglass w/foil	=	8.00
7/8 in. stucco	=	0.17
1-1/2 in. air space	=	2.55
air inside	=	0.68
air outside	=	0.17
		<u>12.02</u>

$$U = 1/R = 1/12.02 = 0.083$$

Ceiling "U" Factor

		<u>R</u>
1/2 in. sheet rock	=	0.45
5-1/2 in. fiberglass	=	18.00
air inside	=	0.92
air outside	=	0.43
		<u>19.80</u>

$$U = 1/R = 1/19.80 = 0.50$$

Floor "U" Factor

$$= 0.81 \text{ BTU/hr-linear foot-F}$$

$$= 0.81 \frac{\text{BTU}}{\text{hr-linear ft-F}} \times 163 \text{ linear ft}$$

$$U_0 = 132 \text{ BTU/hr - F}$$

Door U

$$= \frac{1}{2.19} = 0.45$$

Window U

$$= 1.10$$

Total U_T Heat Transfer Coefficient

$$\begin{aligned} U_T &= (U_{\text{wall}} \times \text{wall area}) + (U_{\text{door}} \times \text{door area}) \\ &+ (U_{\text{window}} \times \text{window area}) + (U_{\text{ceiling}} \times \text{ceiling area}) \\ &+ (U_{\text{floor}}) + \text{infiltration} \\ &= (0.083 \times 1183) + (0.46 \times 38.5) + (1.10 \times 150) \\ &+ (0.05 \times 1266) + (132) + (0.018 \times 10,128 \times 2) \\ &= 841 \text{ BTU/hr - F for 1266 sq ft house} \end{aligned}$$

The Complete List of the Heat Flux for Various Size Residences

<u>BTU/hr-F</u>	<u>sq ft</u>	<u>number of units</u>
841	1,266	1,203
699	1,101	4,060
854	1,354	1,364
475	638	1,260
TOTAL number of units in City		7,887

To Obtain the Weighted Average Heat Flux:

$$((841 \times 1203) + (699 \times 4060) + (854 \times 1364) + (475 \times 1260))/7887 =$$

712 BTU/hr-F-bldg. for residential home

The average heat flux for a commercial building was estimated as follows:

$$\frac{\text{Total Residential Annual Heat Load}}{\text{Number of homes}} = \frac{0.152 \times 10^{12} \text{ BTU/yr}}{7887 \text{ bldgs.}} = 1.92 \times 10^7 \frac{\text{BTU}}{\text{yr-bldg.}}$$

$$1.92 \times 10^7 \frac{\text{BTU}}{\text{yr-bldg}} \times \frac{\text{yr}}{8760 \text{ hrs}} \times \frac{\text{hr-F-bldg}}{712 \text{ BTU}} = 3.08\text{F}$$

$$\frac{\text{Total Commercial Annual Heat Load}}{\text{Number of Commercial Buildings}} = \frac{0.903 \times 10^{11} \text{ BTU/yr}}{950 \text{ bldg.}} = 9.50 \times 10^7 \frac{\text{BTU}}{\text{hr-F-bldg}}$$

$$9.50 \times 10^7 \frac{\text{BTU}}{\text{yr-bldg}} \times \frac{\text{yr}}{8760 \text{ hrs}} \times \frac{1}{3.08\text{F}} = 3521 \frac{\text{BTU}}{\text{hr-F-bldg}} \text{ for commercial building}$$

C-4

HOUSE - 1287 SQUARE FEET
(EXCLUDING GARAGE)

Figure C-1.

HOUSE - 1100 SQUARE FEET (EXCLUDING GARAGE)

Figure C-2.

C-6

HOUSE - 1354 SQUARE FEET
(EXCLUDING GARAGE)

Figure C-3.

APARTMENT - 638 SQUARE FEET

Figure C-4.