Geothermal Industry Assessment

MASTER

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FOREWORD

This examination of the geothermal industry is one of a series of industrial assessments of alternative energy sources carried out by Booz, Allen & Hamilton for the Department of Energy. The overall objective of this study was to determine industry's perspective of government programs and to gain an understanding of the strategies utilized by various sectors of industry in their development of geothermal energy.

The study was carried out in five tasks as follows:

- . Analysis of legislation pertaining to geothermal energy
- . Survey of government perceptions of the geothermal program
- . Determination of the industry's structure, its perception of the government program, and its future plans and strategies
- . Review of state planning with respect to the development of geothermal industry
- . Assessment of the technological problems confronting the geothermal industry.

These tasks were addressed in a series of interrelated subtasks carried out in approximately the following sequence. After the completion of a literature survey, a detailed examination of applicable legislation was undertaken. In concert with this analysis, various key government officials were interviewed to register representative viewpoints related to the goals and objectives of the Government's geothermal program. In parallel with this effort, extended interviews were held with leaders of the geothermal industry to determine the structure of the "industry" and its perspective of the future of geothermal energy. As a result of these interviews, a representative construct of the geothermal industry, as it exists today, was developed; in

addition, the trends discerned provided an index to the future structure. In the course of this analysis, the technical problems inhibiting geothermal development were identified and made the subject of a detailed technology assessment.

In a separate and parallel task, a summary of findings was presented to the states of Region IX for input into the development of state geothermal operating plans. As part of the last task, a system to track the changing attitudes and perceptions of industry with regard to geothermal energy was conceived. This conceptual system is described in Appendix B, Volume 2.

Although the studies began with no preconceived ideas about this resource or its affiliated industry, it soon became clear that the "geothermal industry," as it exists today, consists of a rather small number of companies that are active in the development of this resource; and, consequently, it was thought possible, in the limited time of this study, to interview representatives from most of the major components of the industry. And indeed, interviews with senior executives of the major companies of this industry were carried out in the course of the study. As a result, the conclusions reached were derived from an inductive process with a high degree of validity—reflecting the completeness of the sampling.*

It became equally apparent that most of the geothermal resources of current and near-term potential lie in the western part of the U.S.; and, therefore, the industrial interviews performed in the course of this study were focused upon industries located in western states. In addition, current and near-term activity in geothermal development—comprising spontaneous and unsubsidized programs—is, to a large extent, oriented around the development of the limited geothermal resources suitable for the production of electricity. It follows then that direct heat applications represent the currently unstructured, and largely speculative, future of the industry.

* It is worth noting that of the sixty-five representatives of the industry interviewed, all agreed to make time and personnel available to periodically update their views and perspectives of geothermal energy. The respondents had been impressed with the seriousness of the Department of Energy's effort to hear industry's views and were very much aware of the opportunity afforded them to air their views to the senior levels of the Department.

These basic assumptions and early conclusions essentially shaped this effort—in that they focused the study's attention upon major developers and utilities generally located in the western states. The analysis leading to these preliminary observations as well as the later, more detailed analyses of industry interviews—and their conclusions—are provided, along with the overall findings, in the report that follows. The analysis leading to these preliminary observations will be addressed in the following sections of the report, along with the overall findings. This volume of the study was presented for review in November 1979. Final internal review was completed in April 1980.

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 -Rogers Engineering Co.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Government interest in the development of geothermal energy resources--taking specific form in the Geothermal Steam Act of 1970--was accelerated as a result of the 1973 oil embargo. Following the Geothermal RD&D Act of 1974, rapid and substantial development was anticipated. However, in spite of growing concern about fossil fuel supply and increasing prices, geothermal development has not proceeded at the pace anticipated in the early 1970's.

The Department of Energy Office of Policy & Evaluation contracted with Booz, Allen & Hamilton to conduct an assessment of the geothermal industry, focusing on industry structure, corporate activities and strategies, and analysis of the technological, economic, financial and institutional issues important to government policy formulation. The study is based principally on confidential interviews with executives of 75 companies active in the field as summarized in Exhibit 1, and draws six major conclusions:

- . Structure: The geothermal industry is dominated by a core group of traditional companies with well-defined programs oriented toward electricity generation, and a distinct emerging collection of companies and joint ventures attracted by opportunities in direct heat applications.
- . Technology: There are no insurmountable technological problems presented by geothermal development. However, the remaining problems strain the state-of-the-art of gas and oil technology, and require substantive attention. The industry is specific in identifying technology improvement requirements, although divided on the question of government involvement.
- . Financial factors: Geothermal energy can be--within the bounds of optimistic and pessimistic scenarios of operation--economically competitive with oil and gas for power generation, and economically attractive for direct heat applications when compared to all fossil fuels.

EXHIBIT 1
Types of Companies Interviewed for the Study

NUMBER OF COMPANIES	TYPE OF COMPANY
4	Large Energy Companies
8	Small Energy Companies
5	Geothermal Companies
4	Engineering Companies
13	Utility Companies
13	Direct Heat Users
10	Municipalities
2	Trade Associations
3	Drilling Companies
3	Financial Institutions
10	Promoters/Developers of Direct Heat Applications

- . Government incentives: There is wide diversity in the industry with regard to incentives. The loan guarantee program is considered a substantial disappointment as implemented. New incentive options suggested by industry include reservoir insurance, tax incentives, subsidies for exploration/development and direct government project funding in some cases.
- . Institutional factors: Beyond financial risk, the government-related institutional requirements are considered the major class of constraint to geothermal development, including denial of access to public lands, a virtually unworkable permitting and licensing process, environmental concerns, acreage limitations which restrict competition and development opportunities, lack of interdepartmental coordination, and aggravations caused by multi-level Federal, state, and local government involvement. Industry recommends attention to two key issues: revisions to the Wilderness Act and the permitting system.
- . Corporate strategies: The historical record of U.S. industrial activity indicates an erratic pattern of corporate interest, closely tied to government stimulus and subsequent constraint—as shown in Exhibit 2. A number of major players in the industry have recognized the formidable constraints in the U.S. and shifted emphasis to foreign opportunities. Direct heat applications have attracted new entrants with uncertain business prospects.

As a result of the corporate, institutional, and governmental situation, projections of geothermal energy for electric generation by the year 2000 have been reduced from 600,000 megawatts (1973) to less than 10,000 megawatts (1979), as shown in Exhibit 3.

The body of the report provides detailed analysis of the findings from interviews with each segment of the industry with respect to the technological, economic, financial, and institutional factors surrounding geothermal energy development in the U. S. The report's length is necessitated by the exceedingly complex environment of the industry. Readers are cautioned to expand the full range of corporate viewpoints on the conclusions summarized in this Executive Summary, and it is hoped that readers will proceed into those sections of the report which interest them most:

Exhibit 2 Past History: Industry Entrance and Exit Events/Exhibit 3 Projections: Comparison of Recent Geothermal Electric Energy Utilization Projections for the Year 2000

EXHIBIT 2
Past History: Industry Entrance and Exit Events

Source: Industry interviews conducted by Booz, Allen & Hamilton

EXHIBIT 3
Projections: Comparison of Recent Geothermal Electric Energy Utilization Projections for the Year 2000

SOURCE OF FORECAST/PROJECTION

- Bechtel Corp., "Geothermal Technology Assessment Study," Dec. 7, 1973, in A Technology Assessment of Geothermal Energy Resource Development, National Science Foundation, Government Printing Office, Apr. 15, 1975, pp. 278-284 (Normal).
- Project Independence, Geothermal Energy, National Science Foundation/FEA, Government Printing Office, Nov. 1974, pp. 3-4 (Crash).
- Program Definition for Geothermal Energy, Background and Program Definition Summary, Jet Propulsion Laboratory, California Institute of Technology, Vol. 1, Aug. 29, 1975, pp. 1-11.
- ERDA-86: Definition Report, Geothermal Energy Research, Development, and Demonstration Program, Oct. 1975, pp. 1-2.
- U.S. Energy Through the Year 2000 (Revised), Bureau of Mines, Department of the Interior, Dec. 1975, p. 36.
- The Mitre Corp., Analysis of Benefits Associated with the Introduction of Advanced Generating Technologies, Mar. 1977, pp. xxxv-ii.
- Geothermal Prospects for the Next 50 Years, EPRI, ER-611SR, Feb., 1978, pp. 3-16.
- EPRI Utility Survey 1978 in "EPRI Geothermal Program - Overview," Vase! W. Roberts, in Proceedings of the Second Geothermal Conference and Workshop, EPRI WS-78-97, Oct. 1978.
- DOE Commercialization Task Force, June 15, 1978.
- EPRI Utility Survey 1979, in "Perspective on EPRI's Geothermal Program," Vase! W. Roberts, at the Third Annual Geothermal Conference, June 25-29, 1979, Monterey, California.
- Booz, Allen interviews with Electric Utilities.

- . Industry structure: Chapter I
- . Detailed technical assessment: Chapter II
- . Financial analysis: Chapter III
- . Institutional situation: Chapter IV
- . Industry decisionmaking process: Chapter V
- . Industry strategies: Chapter VI

This study is one of a series conducted under the overall title: "Industry Assessment: Status and Objectives of Private Sector Energy Technology Development."

INTRODUCTION

INTRODUCTION

Most of the early initiatives in the development of geothermal energy were taken by private industry on private lands—starting with the Geysers' development in the 1950's. Interest in public lands was discouraged by their withdrawal from exploration in 1967, and the general lack of government interest in this energy source at that time.

1. GOVERNMENT INTEREST IN THE DEVELOPMENT OF GEOTHERMAL RESOURCES, TAKING CONCRETE FORM IN THE ENACTMENT OF THE GEOTHERMAL STEAM ACT OF 1970, WAS ACCELERATED AS THE RESULT OF THE 1973 OIL EMBARGO AND THE GENERAL RECOGNITION OF AN ENERGY-SCARCE FUTURE

- . Before 1970, the Federal Government's interest in geothermal energy was centered on research and development, which received minimal funding; other than the development of the resources at the Geysers by private industry, geothermal energy was not considered a major alternative to fossil fuels.
- . As a result of earlier price rises in petroleum, new interest by industry in geothermal energy was seen in the late 1960's, and a new seriousness with respect to this energy source was demonstrated by the Federal Government in its enactment of the 1970 Geothermal Steam Act.
- . By 1974, against a background of the 1973 Oil Embargo, the full implementation of the 1970 Act was effected and the Geothermal RD&D Act of 1974 was enacted.
- . In an effort to improve the environment for geothermal energy development, an attempt was made to rectify the weaknesses of earlier legislation by the development, in 1979, of different versions of an Omnibus Act for Geothermal Energy. The following provides a comparison of the major features of this legislative effort with respect to the earlier legislation.

COMPARISON OF GEOTHERMAL LEGISLATION

GEOTHERMAL STEAM ACT

GEOTHERMAL R&D ACT

OMNIBUS BILL

Leasing

- . Acreage Limitation
- . Royalties
- . Rent
- . Term
- . Limitation
- . Renewal
- . Extension
- . Unit Plan

Geothermal Energy Coordination and Management

- . Program Definition
- . Resource Inventory
- . R&D

Loan Guarantees

- . Terms & Conditions
- . Limitations
- . Interest Payment

Leasing

- . Acreage Lim-
itation
- . KGRA Redefi-
nition
- . Leasing Com-
mittee
- . Cooperative
Agreements
- . Information
Dissemination
and Management
Procedures
- . Conditional
Development
Lease
- . Small Business,
Form Lease
- . Expedited Lease
- . Interagency
Coordinating
Council
- . Nonelectric
Applications
Assistance

2. IN SPITE OF GROWING FOSSIL FUEL ENERGY SHORTAGES AND RISING PRICES—AS WELL AS GOVERNMENT PROGRAMS TO PROMOTE ALTERNATIVE ENERGY RESOURCES—GEOTHERMAL DEVELOPMENT BY INDUSTRY HAS NOT PROCEEDED AT THE PACE HOPED FOR BY THE GOVERNMENT

- . The number of applications for Federal leases for geothermal development has been dropping off.
- . The number of new drillings has leveled off in recent years.
- . The amount of available venture capital for geothermal development has diminished—even for electricity generation.
- . Few programs of significance have developed in direct heat applications of geothermal energy outside of the government-sponsored and-funded demonstration projects.

3. THE QUESTION REMAINS: WHY, IN VIEW OF THE SPATE OF FEDERAL LEGISLATION AND THE EVIDENT NEED FOR ENERGY ALTERNATIVES TO FOSSIL FUEL, IS THE DEVELOPMENT OF GEOTHERMAL ENERGY LAGGING?

Current industrial programs provide little indication that geothermal development will reach its geological potential in the near future. It must be remembered that the tempo of the development of this resource is determined by U.S. industry. The development strategies formulated by corporate management determine the availability of capital, the allocation of resources, and the selection of programs from those envisioned, supported, and regulated by the Government. Whether or not geothermal energy is selected for development by the various companies is a function of its attractiveness to industry—as compared to other investments or programs that might be pursued. The attractiveness of the option is, in turn, a function of the various incentives and constraining factors intrinsic to the resource itself and, to some extent, a result of the interaction of industry with the programs of the Federal Government. As important as the actual physical realities of the technological limitations, the economics, and the institutional barriers to this resource's development—is industry's view of these factors—exerting an influence, more implicit than explicit, on corporate decisions related to geothermal energy development.

4. INDUSTRY'S PERSPECTIVE OF THE FEDERAL GEOTHERMAL PROGRAM—OFTEN QUITE DIFFERENT FROM THE GOVERNMENT PERSPECTIVE—STEMS FROM ITS ANALYSIS OF

- . TECHNOLOGICAL CONSIDERATIONS
- . FINANCIAL CONSIDERATIONS
- . INSTITUTIONAL CONSIDERATIONS
- . PROGRAM TRADE-OFFS
- . CORPORATE GOALS AND OBJECTIVES

AND, AS A RESULT, THE GREATER PART OF THE GEOTHERMAL INDUSTRY—AS IT IS NOW STRUCTURED—HAS BEEN INHIBITED OR INSUFFICIENTLY MOTIVATED TO UNDERTAKE AGGRESSIVE DEVELOPMENT AND UTILIZATION OF THE NATION'S GEOTHERMAL ENERGY RESOURCES

* * * * *

Industry's analyses of these factors, as reflected in their responses to in-depth interviews conducted in the course of this study, are assessed in the chapters that follow.

I. STRUCTURE OF THE GEOTHERMAL INDUSTRY

I. STRUCTURE OF THE GEOTHERMAL INDUSTRY

The existence of geothermal energy has been known for centuries and utilized for power generation around the world for decades. However, other than some small-scale uses of this resource for heating in a few western locations, it remained a geophysical curiosity in the U.S. until the mid-fifties—when the exploitation of the Geysers was initiated. The development of this resource, as it evolved at the Geysers, left its imprint on the industry that was spawned by this pioneer effort. The major characteristics of this initial project shaped and focused subsequent efforts. The Geysers can be characterized by the fact that

- . Its objective was electrical power generation.
- . Its developers were energy companies and "geothermal" companies—companies specifically organized for the development and utilization of geothermal energy.
- . The development took place on private lands with private funding.

As more opportunities for geothermal development were recognized and the need for alternatives to fossil fuel became more critical, expansion of the industry continued—but fitfully—and, to a large extent, with the features of the original development. Gradually, other uses for the resource were recognized and addressed—giving rise to a new and emerging pattern of development. As a result, the now-familiar framework of the geothermal industry has emerged.

1. THE GEOTHERMAL INDUSTRY IS COMPRISED OF TWO COMPONENTS

- . THE CURRENT STRUCTURE
- . THE FUTURE EVOLVING STRUCTURE

(1) The Current Structure of the Geothermal Industry Is Well-defined with Well-Recognized Industrial Components, Well-defined Roles in Industry, Accepted Technological Objectives, and Limited Geographical Orientation

- . The roles or phases of geothermal development in the current structure are distinct, although

at times overlapping, and reflect a sequence of operations oriented around the generation of electricity and developed by the traditional energy companies. The development of the geothermal industry, as currently structured, proceeded in generally four distinct phases illustrated in Exhibit I-1. As depicted, these phases included

- Ownership or leasehold of the resource
- Exploration of the leasehold
- Upon successful exploration, development and/or operation of the resource
- Final use of the geothermal resource.

These phases correspond to the roles of the various companies associated with the geothermal industry—as illustrated above. Principal roles in the resource development are played by energy companies, companies specifically organized to develop geothermal resources, engineering companies, and, in the present industrial structure, users of electricity. Most of the companies have assumed more than one role and have thus been engaged in the development of the resource in more than one phase. Various financial institutions, drilling companies, and equipment suppliers have played ancillary roles—supportive to the resource development—but not determinative roles. The actual strategies adopted by the various industry components in the various phases of development will be discussed later, but first their participation in the development of the resource at each phase will be reviewed.

- Land Ownership/Leasehold

The owners of geothermal energy sites, and more particularly, the leaseholders, vary in their composition. They range from private speculators, using the

EXHIBIT I-1
Phases of Geothermal Development

ownership of such sites as tax shelters and possible sources of future windfalls, to large energy companies with extensive holdings, and companies formed primarily for the purpose of developing geothermal resources. In the present industrial structure, these holdings have been acquired with a view toward their eventual exploitation for the production of electricity.

- Exploratory Operations

Of the many leaseholders and outright owners of geothermal resources, a somewhat smaller number has undertaken the subsequent phase of the overall development—exploration. Many of the small speculators have neither the means nor the intention to do so; but, rather, have decided to hold on to these resources for later bargaining—or have sold their rights to companies bent on initiating exploration in the near term, in the areas concerned. Some large holders, unconvinced of the feasibility of geothermal energy under present conditions, have continued to hold exploratory and development rights to large areas—without actually undertaking such exploration. Finally, there remains the segment of landowners or leaseholders who have undertaken the exploration of the sites themselves. In some cases, these exploration programs have been undertaken with a view toward later development of confirmed resources. In other cases, the companies' plans are limited to developing favorable indications of the geothermal potential—at which time the holdings are offered for sale to those companies with sufficient resources for development.

- Development/Operation

Some of the companies, successfully completing the exploratory phase, have opted

to go on to the development and/or operational phase of this resource's exploitation. In some companies, organized for geothermal development, this action followed their overall plan for a complete and integrated geothermal resource development program—extending from leasehold to land use. In others, the decision was made only after achieving the first exploratory success. On the other hand, a large number of companies, because of their greater resources, were invited to join in the development and operational phases without having participated in earlier exploratory activities. In many instances, this action followed the original strategy of the companies conducting exploration; in others, it was necessitated by the overextension of their companies' resources. In still other cases, users—particularly utilities—recognizing the need for alternative energy sources, invited companies with sufficient capital and expertise to undertake the development and operation of the geothermal resources to which they had access.

Uses

In the current structure of the geothermal industry, the significant users of this resource are those companies involved in the development of geothermal energy for the eventual production of electricity. Although, as a result of the Federal Government demonstration programs, some significant direct uses for geothermal energy are underway, they are generally without industry structure or pattern at the present time. The potential of direct heat applications is associated more with the future than with the present structure of industry. Consequently, the major component of the current industrial user structure is a small group of utilities in the western states and, to a lesser extent, some companies specifically organized for the development of geothermal energy

(known throughout this study as geothermal companies) who have not only acquired leases, undertaken exploratory activities, and developed the geothermal resources; but have actually produced electricity and sold it to utilities for distribution.

The presently structured industry is composed of a small number of companies—the most significant of which are the energy companies and the utilities whose resources and strategies are known to one another, and who occupy influential, if not controlling, positions in the industry.

Because the interviews conducted in the course of this study were carried out in a double iteration, it was possible to utilize the results of the early interviews in planning the latter portions of the study. Thus, in the early interviews, the respondents were questioned regarding the composition of the geothermal industry so that subsequent interviews could be more effectively planned. Their answers indicated that the current industry was composed of approximately nine energy companies with active programs, and perhaps another half-dozen that are observing the industry with a view toward later entrance if the resource proves a feasible energy alternative; nine or ten geothermal companies that have been organized specifically for participation in the development of geothermal energy; three major engineering companies and perhaps a half-dozen lesser companies with active programs in geothermal energy; and perhaps 15 utility companies that either have active geothermal programs or are considering the use of geothermal energy in the future. This description of the industry served as a guide for the subsequent round of interviews.

All of these companies know one another, are very familiar with one another's plans, and in many cases, have formed joint ventures for the development of this resource. While it is true that many other companies are participating, to some extent, in the development of geothermal energy, in industry's

opinion, the center of gravity of the industry rests with the companies identified by them and generally described above. In fact, ninety percent of the companies selected by the respondents in the initial 20 interviews as composing the "industry" were selected by the respondents of the subsequent 50 industrial interviews as well. In Exhibit I-2, a generic description of the companies interviewed by Booz, Allen during the course of this study is provided. It is obvious, in view of the structure of the industry suggested by industry itself, that the Booz, Allen sample is sufficiently large and selectively diverse to accurately reflect the composition of the industry. Based on these interviews, the following construct of the industry, by industrial segment, was developed.

- Energy Companies

Most of the energy companies are involved in the development of geothermal energy, in one form or another, as an extension to their general mission of energy suppliers. Moreover, the industry is aware of the monitoring efforts of the remaining energy companies (especially the very large companies) and the availability and sufficiency of their resources to move into the market, if the development of geothermal energy proves feasible and a suitable opportunity presents itself. The major objective of the energy companies is the production of steam for electrical power. Currently, they show no interest in direct heat applications—because of the present low profitability and limitation of scope of these applications. Historically, the early entrance of some of these companies into the development of geothermal energy vis-a-vis their competitors who deferred their involvement was a result of their western location—proximate to the most significant geothermal resources.

EXHIBIT I-2
Types of Companies Interviewed in Study

NUMBER	TYPE
4	Large Energy Companies
8	Small Energy Companies
5	Geothermal Companies
4	Engineering Companies
13	Utility Companies
13	Direct Heat Users
10	Municipalities
2	Trade Associations
3	Drilling Companies
3	Financial Institutions
10	Promoters/Developers of Direct Heat Applications

- Geothermal Companies

These companies have been generally formed for the express purpose of developing geothermal energy. In general, they are small companies—but some have developed affiliations with very large energy companies. Their current role ranges from providing exploration support—to the production of steam—and ultimately, to the production of electricity. They are often the promoters of joint action between energy companies as operators, and utilities as users.

- Engineering Companies

These companies are generally seen as small, special-purpose engineering companies that are pioneering certain plant design concepts or components thereof, but are often large architect/engineering firms that design and build geothermal plants in the same manner as other energy-generating plants. These companies see themselves as the technical bridge between the developer/operator and the final user of the geothermal energy resource. Although they prefer to limit their role to design and construction, they often find themselves marketing geothermal energy to users (most frequently utilities) and even underwriting the project risk.

- Electric Users

This class of users—and in the current industry structure the most significant users—is comprised of regulated and nonregulated utilities, municipalities, and some large industries with a substantial need of electrical power. Because of the greater significance of the geothermal resources of the western states, these users are currently located almost exclusively in the West—generally near major geothermal resources.

The interface between these companies and the developer/operator is often determined by the companies' financial health. Those companies with the strongest financial positions have a tendency to move the interface toward the resource and include in their purview the construction and control of the steam plant, and, in some cases, the development of the resource. On the other hand, those companies with weaker financial positions tend to move the interface in the opposite direction and limit their participation to buying steam, and, in some extreme cases, to buying electricity from the developer for distribution within their own systems.

In addition to the utilities, there are other electric users of geothermal energy. They include municipalities that intend to develop geothermal resources for public use, and some large industrial users of electricity that own or have leased land containing sources of geothermal energy and are evaluating those resources as possible alternative means for generating electricity to meet their industrial needs.

(2) The Evolving Expansion of the Geothermal Industry—
that Portion of the Industry Involved in Direct
Heat Applications—Is Currently Unfocused, Unstruc-
tured, Geographically Scattered, and Generally
Undefined in Strength and Extent of Development

The evolution of the expansion of the direct heat use applications industry is proceeding in phases somewhat analogous to the earlier development for power generation—but with variations reflecting the different composition, technology, and markets of this segment of the industry. As previously depicted in Exhibit I-1, these phases include

- Ownership or leasehold of the resource
- Exploration of the leasehold

- With successful exploration, development, and/or operation of the resource
- Final use of the geothermal resource.

Although the phases of the direct heat use augmentation of the geothermal industry address the same problems as the electricity generation segment, the manner in which these new companies carry out their roles in development differs widely in some cases. Principal roles in the industry development are played by engineering companies or companies formed as general promoters/developers of the resources, the owners, and the end-users of the resources. As in the earlier development of the industry, financial institutions, drilling companies, equipment suppliers, and various consultants play ancillary roles. The similarities and differences in the roles of companies involved in geothermal development in the current and evolving structure of the industry can be seen in a review of the companies' participation in direct heat use.

- Ownership/Leasehold

The holders of geothermal leases or outright owners of the resources usually fall into one of three categories. The first is the municipality, the second is an industrial entity with large landholdings co-located with geothermal resources (for example, a lumber industry located in and above the region of extensive geothermal resources), or an individual owner with small landholdings containing a resource of geothermal energy. The involved owners or leaseholders in these categories have undertaken the development of their holdings for specific applications, or have been approached by resource promoters to make their resources available for specific direct heat applications.

- Exploratory Operations

Some of the owners or leaseholders of land containing geothermal resources

will have sufficient capital and incentive to undertake the exploration of the areas of geothermal potential themselves. Sometimes, this exploratory effort will be undertaken as the first phase of an overall developmental program by the owner; at other times, it will be undertaken for the purpose of determining its worth for later sale or leasing to developers. Other owners, lacking the resources for exploration, will invite developers to join them in joint ventures, sell their holdings to the developers in direct sales, or maintain their holdings as future investments. In most cases of direct heat use, unless the exploratory effort is undertaken by the Government (for example, the Bureau of Reclamation), the exploration of the site will be carried out as part of the developmental program for the owner.

Developers/Operators

It is in the area of development that the first major difference is seen between the use of geothermal energy for electric production and direct heat applications. Because of the smaller scale and reduced profitability of direct heat use, the large energy companies, and even geothermal companies, have chosen not to pursue direct heat applications, but, rather, to focus their efforts and resources on applications leading to the production of electricity.

Other than the individual development of small, private holdings, most of the direct heat applications have resulted from the efforts of intermediaries or general promoters. In some cases, the promoters have been engineering companies that have undertaken management of the resources' development programs and the engineering of their applications; in other cases, the promoters have taken their efforts a step further and included in their roles as promoters,

the securing of venture capital as well. In addition, new companies have been formed for the express purpose of developing overall programs for the resource owners; and these companies will develop complete financial packages—including the securing of venture capital—as part of the program's integration. The member companies of both groups very often are the initiators of the program—they do not respond solely to the solicitations of the resource owners.

Users

Of course, it is in the use of the resource that the two segments of the geothermal industry basically differ. Unlike the specified use (the generation of electricity) and its specific market (generally the utilities) identified with the current segment of the geothermal industry, the markets for direct heat use cover a wide spectrum of applications in widespread areas of this country. These applications may range from agriculture to process industry to district heating. And, unlike electricity generation, the direct heat applications segment of the geothermal industry is generally unstructured, undefined, and non-localized. Consequently, the form of this future development must be inferred from the distribution of the resources and its conjunctive location with industries that could use geothermal energy for direct heat applications. Studies of potential direct heat applications have been completed for most of the western states, and to some extent, for some of the eastern states as well. (The distribution of significant resources is seen in Exhibit I-3.) The typical approach in such studies usually takes the form of

- .. Location of resources
- .. Determination of the nature
(temperature, salinity, etc.)
of the resources

Overview of existing potential industry sectors

Determination of industry fit.

The inferred potential of these resources is assessed by overlaying possible industrial use upon the evaluated resources. The use of this technique is seen in a typical study for the State of California. In Exhibit I-4, zones of existing geothermal resources are identified and grouped according to temperature. Overlayed on the source location maps (Exhibit I-5) are depictions of the distribution of major industrial applications. The conjunction of resources and industry provides "natural" candidates for the application of geothermal energy beyond the obvious generation of electrical power—especially at the lower temperatures. Similar analyses were conducted for Nevada, Wyoming, Utah, and Idaho.

The results of these analyses were examined by the study team to determine logical respondents for the second round of interviews concerned with direct heat applications of geothermal energy. Major industry sectors thus identified included

- Food and kindred products
- Lumber and wood
- Paper and allied products
- Chemicals and allied products
- Petroleum and coal products
- Rubber and miscellaneous plastics.

2. MAJOR PROGRAMS OF THE EVOLVING DIRECT HEAT SEGMENT OF THE INDUSTRY REMAIN ORIENTED AROUND GOVERNMENT-SPONSORED AND -FUNDED PROGRAMS

From the analysis of direct heat application studies, Booz, Allen selected for interview, respondents from the direct heat use segment of the geothermal industry in order to ascertain their perspectives of the nature and potential of geothermal energy. An early perusal of the opinions of respondents involved in direct heat use resulted in the conclusion that

EXHIBIT I-4
California Resource Zones
for Overview Analysis

Source: SAI

the current major direct heat applications of geothermal energy were the subjects of DOE demonstrations. Consequently, most of the interviews in the direct heat portion of this study were focused on the individuals associated with the DOE demonstration programs. Because of the small number of respondents in the direct heat use area, when viewed in the perspective of the large number of potential users, the sample size is not nearly so significant as it was in the electrical generation segment of the industry. Nevertheless, it does represent a substantial proportion of the major participants in the most significant uses of direct heat applications of geothermal energy currently—the DOE-sponsored demonstrations.

II. TECHNOLOGICAL CONSIDERATIONS

II. TECHNOLOGICAL CONSIDERATIONS

From the technological standpoint, there is little question that geothermal energy is a feasible alternative for a variety of applications. Geothermal energy has been known and utilized by many nations in a variety of locations and under differing operational conditions, with substantial success. Whether it presents an economically attractive alternative to other fuels is a question impinging upon the degree of difficulty of its implementation and the associated costs of resolving these difficulties.

1. GEOTHERMAL ENERGY PRESENTS NO INSUPERABLE TECHNOLOGICAL IMPEDIMENTS TO ITS USE; WILLINGNESS TO UNDERTAKE ITS DEVELOPMENT DEPENDS PRIMARILY ON THE RELIABILITY OF THE RESOURCE

The basic features to be evaluated in determining whether to go ahead with the implementation of a specific resource are its extent and duration. The determination of the sufficiency of the resource is, in turn, a function of its intended use. The resource needed to provide hot water for a small industrial park is an order of magnitude smaller than that needed for even a small electricity generating plant, or a typical pulp and paper industry complex.

Since the reliability of the reservoir can be determined much more easily after the first 6 months of operation, and with still greater precision after the first year, most of the uncertainty felt by the end user and the involved financial institutions regarding the feasibility of investing in a resource's implementation—is a front-end concern. To overcome this major impediment to a particular site's implementation, promoters and developers have advanced reservoir insurance and developed a modular approach to implementation to limit the project risk until the resource is proved in the single module. In the event the resource does not prove adequate, the module can be dismantled and moved to another site.

2. ALTHOUGH THE PRODUCTION OF GEOTHERMAL ENERGY UTILIZES OIL AND GAS TECHNOLOGY, AND THE TECHNICAL PROBLEMS ENCOUNTERED ARE SIMILAR TO THOSE OF THE PETROLEUM INDUSTRY, THEY ARE MORE SEVERE—AND THEIR SOLUTIONS STRAIN THE STATE-OF-THE-ART OF THE OIL AND GAS INDUSTRY TECHNOLOGY

Even though the basic approach to geothermal production resembles that of oil and gas, the medium through which the drilling must proceed is hot, hard rock, and the fluid it must transport is hot, corrosive, and solid-laden brine. Thus, all the problems encountered in the oil and gas industry are met in geothermal development—but in a highly aggravated form. A detailed description and assessment of the technical problems associated with geothermal energy production are provided in Appendix A. The major problems include the following:

- . Inadequacy of drilling technique
- . Lack of adequate drilling fluids at high temperatures
- . Marginal drilling materials and equipment
- . Lack of long-lived drilling bits
- . Insufficient and unreliable well instrumentation
- . General limitations on drilling technology.

None of these problem areas constitutes an insurmountable hindrance to the development of geothermal resources. The extent of difficulty encountered at the particular development site in terms of these technical problems and the consequent cost of their resolution will determine the economic feasibility of the resource's development.

3. ALTHOUGH THE UTILIZATION OF GEOTHERMAL ENERGY EXPLOITS TECHNOLOGY ALREADY DEVELOPED, THE ECONOMIC FEASIBILITY OF ITS ADOPTION VARIES WITH THE CONDITIONS OF ITS IMPLEMENTATION

The technological problems associated with geothermal energy development are both resource constrained and market limited: They are resource constrained in that they are a function of their physical state, either vapor-dominated or liquid-dominated; they are market limited in that the production of electricity, a major user concern, is a

function of the resource's state, and, in case of liquid-dominated resources, the temperature of the resource.

(1) The Vapor-Dominated Resource—Essentially Dry Steam Presents Little in the Way of Serious Technological Problems Today

This statement is true for the following reasons:

- . As dry steam, the resource is in the form desired for use with turbine generators.
- . The number of such resources is limited.
- . Successful operation of such resources has been carried out for two decades, and the major technological problems connected with their operations have been addressed, and to a large extent, resolved.
- . The remaining technological concerns—environmental requirements for reinjection, and nondissolvable gases—are not unique to the vapor-dominated resources and must be addressed in all programs.

(2) In Contrast, the Liquid-Dominated Resources Present Unique Problems Associated With the High Content of Dissolved Solids in These Hot Fluids and the Need to Convert These Fluids Into a Suitable Working Medium for Electricity Generation

The hot fluids must be flashed into steam or their heat value transferred to a flashing medium compatible with electrical generation. Moreover, not all of the liquid-dominated sources are of sufficient temperature to allow them to be flashed into steam; however those with temperatures too low for steam production, and hence electrical generation—can be used with advantage as thermal sources for direct heat applications. The thermal characteristics of the liquid-dominated systems comprise a temperature range from about 190° F to 650° F, with an average of about 300° F—almost 100° less than the average temperature of vapor-dominated systems.

In addition, dissolved solids also vary considerably. Extremes of 26 to 35 percent of dissolved solids are found in geothermal wells drilled near the Salton Sea in California. The potentially high solids content of the liquid-dominated resources present new and expanded operational difficulties not encountered in the vapor-dominated resources.

The hot water systems are usually grouped into three categories—based on the temperature of their natural working fluids.

- A high-temperature system
(greater than 300°F)
- Intermediate-temperature systems
(190°F to 300°F)
- Low-temperature systems
(less than 190°F).

These systems may be further divided by characteristics affecting their performance (e.g., level of salinity, dominant chemical constituents, rate of rechargeability, structural and stratigraphic environments, and the presence or absence of permeable reservoirs and insulating cap rocks). These characteristics are important in the determination of the commercial feasibility of a hot water system—either for electricity production or other purposes.

In the use of the hot water system for electricity generation, essentially two systems are used. First, is flash steam; second, is a binary system (or heat exchange process).

Flash Steam

This technology, depicted in Exhibit II-1, takes advantage of a process that occurs naturally in some hot water systems; that is, the hot fluid in the reservoir is usually under much higher pressure below the surface than at ground level. As the water is withdrawn and nears the surface, the pressure decreases, causing a portion of the fluid (approximately 20 percent in high temperature fields) to boil and "flash" to steam upon reaching the surface. The steam is captured, passed through separators to remove particulates, and used to drive turbines in an electrical power plant. The remaining water and condensed steam are disposed of through reinjection or surface drainage; noncondensables are vented to the air. Energy efficiency of this system is low; only 2 to 5 percent of the original stored heat of the hot water system is actually converted to usable energy. This conversion efficiency drops to 1 percent if the steam is required to be passed through a separator. To extract all the heat available in the fluid, the process is sometimes repeated in multiple flashes.

EXHIBIT II-1
Flashed Steam Cycle Power Plant

Source: Pacific Northwest Laboratory

Binary Cycle

In this process, depicted in Exhibit II-2, the reservoir is used to heat a second fluid (freon or isobutane) having a lower boiling point than the original working fluid. The vapor thus generated by boiling the second fluid is used to drive the turbine. Once used, the vapor is condensed and recirculated through the heat exchanger enclosed system, in which it may be heated and used again. This system appears to be the preferred method for developing high-temperature, high-salinity reservoirs.

As will be seen from the interviews of the various companies throughout the geothermal industry, a high degree of interest in this process is seen in all segments of the geothermal industry interested in electricity generation. In addition, advanced systems that would enhance the efficiency of the various processes have been mentioned from time to time, but they require extensive development. The most frequently mentioned is the total flow system—the least developed of the three liquid-dominated systems—which utilizes the heat and natural pressure of the steam and water in one generating process, combining the principles of the steam turbine and the water wheel. Another approach envisages the operation of the heat exchanger being carried out at the bottom of the well—with only the secondary fluid reaching and being handled on the surface.

As a result of discussions with the various industry groups, it was decided that this study would address only the difficulties associated with systems that are presently technologically feasible—but whose commercial feasibility has not yet been completely established. These are the flash system and binary systems previously described. As indicated, the vapor-dominated system has already been commercialized and does not present unresolvable technological difficulties.

EXHIBIT II-2 Binary Cycle Power Plant

Source: Pacific Northwest Laboratory

The flash system and the binary system—identified as currently feasible systems with applications to most of the remaining resources in the United States—were discussed by industry and will be the subject of the economic analysis undertaken in Chapter III. These two systems, to a large extent, are impacted by most of the institutional considerations discussed in Chapter IV, are the subject of trade-off analyses in Chapter V, and serve as the basis for most of the future planning and corporate strategy formulation discussed in Chapter VI.

In Appendix A a discussion of the technical considerations associated with the development of geothermal energy is presented in detail—to provide a framework for the discussion of the viewpoint of industry with regard to the technological considerations of geothermal development, which follows.

4. INDUSTRY, THOUGH OPTIMISTIC WITH RESPECT TO ITS CAPABILITY TO SOLVE THE TECHNOLOGICAL PROBLEMS OF GEOTHERMAL ENERGY DEVELOPMENT, STRESSED THE NEED TO ADDRESS THE PROBLEMS OF RESOURCE UNCERTAINTY, BINARY SYSTEM VALIDATION, AND THE PROPER ROLE OF GOVERNMENT IN THE DEVELOPMENT OF TECHNOLOGY

Although the concern with technological inadequacies diminished with the responding company's distance from actual development, most of the companies interviewed were most concerned about the reliability of the reservoirs with which they were associated. Utilities and their developer/operators, facing the prospect of electricity generation outside The Geysers, were most interested in a commercially demonstratable binary plant for use with low-and moderate-temperature resources. It became apparent very soon in the interviews that Corporate Management was almost completely critical of the government role in technology development—as they perceived it; but this consistency of viewpoint was not without ambiguity. As would be expected, the assessment of technological impediments to geothermal energy development was a function of the resources the responding company was able to bring to bear on their resolution. A summary of the following discussion of the technical concerns of the respondents is presented in Exhibit II-3.

SUMMARY OF TECHNICAL CONCERNS BY INDUSTRY SEGMENT

INDUSTRY SEGMENT	TECHNICAL PROBLEMS		MAJOR PROBLEMS		INHIBITING PROBLEMS		GOVERNMENT PROGRAMS				COMPANY APPROACH		GENERAL PHILOSOPHY		MAJOR NEEDS	
			MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY		MINORITY		MAJORITY	MINORITY			MAJORITY	MINORITY
							DEMOS	R&D	DEMOS	R&D						
ENERGY COMPANIES LARGE			Since steam resources are limited; chief technical problem concerned with utilizing and extracting heat from large volumes of hot water.	No major problems.	Problems of reinjection.	Need for cooling water; subsidence. Silica precipitation with resultant well and line plugging. Surface and subsurface environmental problems.	Government demonstrations too costly and seldom necessary. Government demonstrations seldom answer technical needs; they often demonstrate commercial applications.	Government should get out of development; industry will develop what is required. Government promise of participation slows down program - industry will wait for government. Requirements for government - industry joint development frequently causes industry to delay and sometimes abandon its participation.			Undertaking its own development program - to solve its problems.	Wait and see. Wait for government funding.	Government programs causing private industries that have invested to lose their technical advantage resulting in decreased incentive for aggressive strategy. In addition, government often subsidizes projects incompatible with its own program. Government has supported politically motivated projects instead of technically needed projects - after sometimes enticing private industry to invest in the needed projects and then withdrawing support or choosing politically acceptable alternatives. If industry develops solution with all or part of their own funding, they want a proprietary position.		Binary system for low and medium temperature water.	Improved heat exchange equipment.
ENERGY COMPANIES SMALL			Ability to determine size and reliability of resources. Current drilling and measurement techniques inadequate - borrowed from O&G industry.	Insufficient number of discoveries.			Too much emphasis on programs like hot dry rock and geopressure geothermal.	Winners of government competitions often incompetent amateurs.		Sandia doing good job regarding its drilling development program. Government should develop hot dry rock programs - and similar programs - stay out of development. Present technology transfer working; communication with industry is very good.	Undertake company-funded R&D programs.		Would like to see the government develop mechanisms whereby R&D could go to competent companies - not to amateurs, students, or to pay political debts. If government insists on continuing in R&D, it should concentrate on long term projects - like hot dry rock, etc.; however, its research can be concentrated on a single project - hot dry rock survey is not a feasible research objective.		Improve drilling and logging equipment and techniques for high temperature, hard rock drilling (strata packs, bits, turbo drills).	High temperature cements and muds. Elastomers for down-hole pumps.
GEOTHERMAL COMPANIES			Current drilling and measurement techniques inadequate for high-temperature, hard rock drilling.	Existing down-hole pumps inadequate.				Too much emphasis on geo-pressure geothermal programs.	DOE demonstrations helpful in demonstrating to potential investors that technology is economically feasible. Have no faith in government ability to transfer technology.	Sandia development work in drilling techniques good. Government should continue hot dry rock program - as secondary extraction method. DOE should reactivate down-hole pump development program.	Have undertaken government-funded R&D.	Have maintained company-funded R&D programs as well as implementing government-funded R&D.			Need binary system for low and medium temperature water - for generating electricity.	Need double flash system.
ELECTRIC USERS			Ability to determine size and reliability of resource - and uncertainty re integration with power plant.	Risk of early reservoir depletion overstated.		H ₂ S abatement equipment approaching complexity of a chemical processing plant. Land use requirements - substantial. Diminishment of cooling tower noise may not be feasible or economical. Increased induced seismicity. Control of corrosion, scaling precipitation and pipe plugging. Reinjection problems and effects on ground water.	Current programs aimed at demonstration of commercial technology - not technologically significant projects. Demonstration programs politically motivated with little technological application.		Demonstration of second generation technology.	Federal R&D program misdirected. Get out of R&D business and leave it to EPRI.		Have maintained vigorous R&D programs.			Need binary plant to make low temperature systems competitive (almost unanimous). Government exploratory drilling.	Environmental control equipment must be improved. Transmission line decision and implementation. Down-hole pumps needed.
ENGINEERING COMPANIES			Determination of well life.		Preservation of reservoir after reinjection. Scale formation and reduction of permeability by silica precipitation.			Government program competitive with industry or misdirected and irrelevant to technological problems.	Demonstrations needed to convince utilities of opportunity and cost.		Maintain substantial R&D program - bid on and implement government R&D programs.	Extent of R&D is limited by government funding.			Low cost-corrosion resistant materials. Precipitate inhibitor in brine. Binary plant.	Improved drilling technique and reduction of drilling costs. Modular plant. Direct conduct heat exchanger. Down-hole pumps. Economic well-head generator.
NONELECTRIC USERS			Determination of resource.	No major technical problems.			Major programs would not have been implemented without government demonstration program.		Have no need for government support; find demonstrations a waste of time and money.	Need to develop process technology.		Minor development programs.			Federal exploratory program.	Down-hole pumps.
PROMOTERS-DEVELOPERS			Determination of resource and its reliability.	Nothing crucial.		Maintenance of well permeability. Control of discharge.					Provide engineering support and project management services only.	Provide project management, financial organization for equity position.				Down-hole pump. Binary cycle for dual use.
OTHERS DRILLING COMPANIES			Drilling technology is not a constraint.			Completion restraints: erosion and slide control.										Long-lasting bits; improved fracturing techniques. Drilling muds, cements. Hi-temperature turbo drills.
INDUSTRIAL ASSOCIATIONS			Determination of resource reliability.	External cooling water.							Stress dual use of resource.				Binary system.	
FINANCIAL ASSOCIATIONS			Risk of reservoir depletion.								Use only current technology. Have independent assessment of resource.					

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(1) The Major Technical Concerns of Industry Centered on the Problem of Reservoir Reliability, Utilizing Lower Temperature Resources and Inadequate Drilling Technique

Specific viewpoints of the various segments of the industry are as follows:

. Large Energy Companies

To a significant extent, the larger companies felt that there were no serious technical problems inhibiting the development of geothermal energy. However, most of these companies were aware of the fact that, in view of the limited remaining steam resources, all companies intending to develop new geothermal resources for electrical generation would have to be able to develop solutions for the problems inherent in utilizing lower temperature liquid-dominated resources.

. Small Energy Companies

A majority of the small energy companies identified two major problem areas: The first, and more serious, is concerned with the ability of the developer to determine the size and reliability of the resource; the second is concerned with the present inadequacy of drilling and measurement techniques—all of which were essentially borrowed from the oil and gas industry. The first of the major problems identified is particularly inhibiting because it encompasses the major area of risk identified by the utilities—the natural market of the developers. In addition, some of the smaller energy companies pointed out that the whole industry suffers from the lack of new discoveries, which, in turn, is somewhat the result of the rather limited drilling program by both government and industry.

. Geothermal Companies

Most of the geothermal companies echoed the concerns of the small energy companies in that they felt the current drilling and

measurement techniques are inadequate for the high-temperature, hard-rock drilling requirements of geothermal energy. Some of the companies, anticipating the problems of maintaining pressure on the lower temperature hydrothermal resources, identified the inadequacy of existing down-hole pumps as a major technical problem to be solved—if geothermal resources would constitute a feasible alternative energy source.

Electric Users

As anticipated by a majority of the small energy companies, the electric users are most concerned with the capability of current technology to determine the size and duration of the resource and the possible difficulties in integrating this resource with standard power plant operation. Utilities are, of course, most concerned about the reliability of the resource, since it represents their greatest single risk in their assessment of the financial feasibility of utilizing geothermal resources as alternative energy sources. On the other hand, at least one of the utility companies indicated that it felt that the risk of early reservoir depletion was overstated.

Engineering Companies

The majority of the engineering companies interviewed identified the ability to determine well life as their greatest single need in geothermal development. This is, of course, another way of saying that the reliability of the resource is a major technical problem.

Nonelectric Users

Although a few of the small direct heat users stated that there were no major technical problems facing the industry, most of these users joined other segments of the industry in stating that the determination of the resource life and reliability constituted the major technical problem in geothermal development.

Promoter/Developer

Again, although a small number of promoters stated that there were no crucial problems facing them in their geothermal development programs, the majority of the promoters identified the ability to assess the reliability of the resource as the major technical problem.

Others

- Drilling Companies

The large drilling companies stated that geothermal drilling was not so different from oil and gas drilling that any special problems were anticipated. On the other hand, although most of the developers agreed that the technical requirements of geothermal drilling did not preclude the success of the resource development, they felt that, since drilling constituted a major cost item in the development program, improvement in drilling techniques would go far in reducing development costs—perhaps to the point at which geothermal would be more competitive with some alternative forms of energy. They pointed out that, although major drilling companies assured the industry that they would be able to meet every technical challenge, these same companies were almost bereft of research and development investments to improve current techniques. To a large extent, advances in geothermal drilling technique have been made as a result of government programs—especially the development programs at Sandia Laboratory.

- Industrial Associations

The majority of the involved industrial associations agreed with the rest of the geothermal industry in that the determination of resource reliability

was probably the major problem facing industry today. A small minority of these associations listed, in addition, the availability of cooling water for use in geothermal operations as a possible major technical problem.

- Financial Institutions

The financial institutions, to a large extent, focused their feelings of uncertainty with respect to the technological feasibility of geothermal energy, on the risk of resource depletion—thus, echoing or prompting the concerns of the utilities and small energy companies that are most concerned with project funding.

(2) In Addition to the Major Impediments to Geothermal Energy Development, Several Technical Problems Inhibiting the Development of This Resource Were Identified

Although not considered major problems of sufficient dimension to preclude or delay the development of geothermal energy appreciatively, most of the segments of the geothermal industry interviewed identified a set of problems that they felt inhibited the resource's development or impacted the economics of this development so as to make its competitive position less certain vis-a-vis other energy alternatives. Listed below are the comments of the various categories of respondents with respect to the second group of technical problems.

. Large Energy Companies

Most of the large energy companies listed the problem of fluid in injection as one of the factors affecting the overall economics of specific development projects. A smaller number of companies listed, in addition, the need for cooling water, the possible difficulty with subsidence, silica precipitation resulting in well plugging, and surface and subsurface environmental impact problems—both real and statutory.

Electric Users

Some of the electric users, reflecting their experience in plant operation, listed hydrogen sulfide abatement as a major problem for plant operators. This technical problem, they point out, is even present in dry steam operation because of the increasing stringency of environmental standards. They pointed out that the complexity of present abatement equipment is approaching that of a major chemical processing plant. Other general inhibiting problems listed by some of the electric users included the substantial land-use requirements; the cost for diminishing cooling tower noise; possible increased induced seismicity; and the problems concerned with the control of corrosion, scaling, precipitation, and pipe plugging; and the general technical and economic problems involved when injection is involved as well as its effect on groundwater.

Engineering Companies

Most of the engineering companies interviewed included in the problems inhibiting the development of geothermal energy—the preservation of a reservoir after fluid reinjection, scale formation, and the possible reduction of the permeability of the resource area as a result of silica precipitation.

Promoters/Developers

Some of the promoters listed the maintenance of the well permeability and control of the fluid discharge as possible inhibiting problems in the development of the resource.

Others

Some of the drilling companies were concerned with the difficulties of finishing off drilling programs. They listed among the factors causing escalation of drilling costs: completion restraints and erosion and slide control.

(3) In Addition to Identifying Technological Impediments to the Development of Geothermal Energy, Industry Listed Specific Technological Advances Needed for Efficient Production and Effective Utilization of Geothermal Energy—Especially the Low-and Moderate-Temperature Resources

On the basis of their concerns with technical problems impacting the feasibility of geothermal energy as an energy alternative, the various segments of the geothermal industry identified, in the course of their interviews, the particular technical developments they thought necessary for geothermal energy to become a strong competitor in the energy market. Sometimes the technical requirements directly reflected the need for solutions to the identified problems. At other times, the respondents listed technical innovations that would improve the economics of the resource development as well as broadening the base of potential usable resources. The technical needs identified by industry are discussed below by industry segment.

Large Energy Companies

In view of the comments of the large energy companies regarding the limited amount of steam-dominated geothermal resources available and their consequent future dependency on water-dominated resources, it is not surprising that the majority of these companies listed as a major technical need the development of a binary system for utilizing low to medium temperature water. In addition, some of these companies also mentioned industry's requirement for improved heat exchange equipment.

Small Energy Companies

The majority of the smaller energy companies, especially those involved in major operations, reflecting their concern with the inadequacy of the present drilling techniques, listed as needed developments the improvement of drilling and logging equipment and techniques for high-temperature, hard-rock drilling. Included in these developments are stratopack bits and turbo drills. In addition, some of these companies specified other needed improvements in drilling

technology—including high-temperature cements and muds and elastomers for down-hole pumps.

Geothermal Companies

The geothermal companies identified technological needs for the industry directly related to the generation of electricity—focusing on their company objectives. Since most of these companies felt that the single and multiflash systems were in an advanced stage of development, they listed as a requisite technological advance for the industry, the development of a low- and medium-temperature binary system suitable for the generation of electricity. Some of the companies, not so optimistic regarding the operational advantages and economics of the present flash systems, listed their improvement as an industry need—with emphasis on the double flash system.

Electric Users

The utility companies were almost unanimous in indicating their need for workable binary plants to make low- and moderate-temperature systems competitive. And, returning to their concern with respect to the reliability of the resources, they listed as a high priority—expanded government exploratory drilling. In addition, some of the companies, farther along in their operational programs, mentioned that environmental control equipment must be improved for future operations to be acceptable to state and local governments. They also pointed out that the lower temperature resources that would probably be developed in the future would require down-hole pumps. Finally, some of the users, contemplating the development of new areas, were concerned about the institutional complications associated with the definition of wilderness areas. They were especially concerned about possible difficulties of getting transmission lines across these areas—even if the technical difficulties of electricity generation were

overcome. They foresaw extended delays in making the decisions to build transmission lines, and even longer delays before programs are implemented.

Engineering Companies

The majority of the engineering companies joined the rest of the industry in identifying the binary plant as a necessary technological development for the industry. In addition, they indicated that low-cost, corrosion-resistant materials were needed as well as an anti-precipitant for use in geothermal production. This latter consideration reflected their earlier concern with scale formation and silica precipitation. A smaller number of the engineering companies, conscious of the large portion of the overall cost attributable to drilling, listed the improvement in drilling techniques as a technological need of the industry. In addition to the need for down-hole pumps and direct contact heat exchangers, some of the engineering companies suggested that the industry needed some innovative approaches, technologically, to become more competitive. Among these innovations mentioned were a modular approach to plant design and an economic well-head power generator.

Nonelectric Users

The technological needs identified by this segment of the industry, to a large extent, reflected their concern with resource reliability on the one hand, and the necessity of dealing with low temperature resources on the other. Consequently, the majority of the direct heat users indicated a need for a Federal exploratory program—with the hope that resource reliability would be improved with increased exploration. And a smaller number of companies indicated the desirability of the development of workable down-hole pumps—making operations possible at lower temperatures.

Promoters/Developers

This group of companies, working with low-temperature resources, predictably indicated the desirability for down-hole pumps; but, in addition, opted for the development of binary cycle systems for possible dual use—electricity generation and subsequent direct heat use. This latter innovation reflected this segment's realization that the site-specific nature of the resource very much limited the market, and the successful development of a resource for one purpose would significantly increase the economics of additional uses.

Others

The need for a binary system, already indicated by most of the segments of the industry, was seconded by the majority of industrial associations as well.

It was interesting to note that the drilling companies that had indicated that geothermal operations presented no major drilling difficulties, listed as critical needs: long-lasting drilling bits, improved fracturing techniques, drilling muds and cements, and high-temperature turbo drills.

(4) Industry's Views Were Contradictory With Respect to Government Participation in R&D Programs Designed To Solve the Technological Problems and Meet the Needs They Had Identified

A clear dichotomy is seen in industry's view of government participation in geothermal research and development. The currently structured industry, chiefly composed of energy companies and geothermal companies and oriented around electricity production, shows little enthusiasm for government participation. The direct heat users and promoters, on the other hand, find government programs in research and development a basic requirement for the successful exploitation of this resource. The specific comments of industry with regard to government participation in research and development and demonstration projects, and industry's overall philosophy with respect to the government role in geothermal energy development are described.

Large Energy Companies

The majority of the large energy companies concluded that government demonstration programs were seldom necessary, and moreover, represented the most costly way of implementing projects—often scaring industry by providing inflated indices of development cost. They stated, in addition, that it was their opinion that government demonstrations seldom answered technical needs; more often than not, they were aimed at demonstrating commercial applications. These companies emphasized that, unlike demonstrations of technical principles, projects involved in improving commercial application suggested to industry, government-subsidized competition.

Similarly, a majority of the large energy companies indicated that, in their opinion, the government should get out of development altogether; they felt that industry would develop what is required under the pressure of market requirements. Further, they pointed out that a government promise of joint participation more often than not results in program delay—for industry will often be required by management to wait for the government-funded program—rather than undertaking the funding themselves. In addition, government requirements—the concomitant of government funding—in joint government-industry development frequently result in program delays and, when the requirements are major, the abandonment of the program by industry.

The majority of large energy companies elaborated their philosophical viewpoints with regard to government programs by pointing out that, in their view, these programs often resulted in private industries losing the technological advantage they had gained by their own investment. They stated that this was the result of competitive and/or duplicative government projects or by the government's insistence on patent rights in joint industry-government programs that

eroded company-developed patent positions. As an overall result, these companies claimed that there was decreased incentive in industry for aggressive technological strategies.

They stated that it was industry's position that government programs often subsidized projects that were incompatible with the objectives of their own program. Moreover, these companies felt that the government support was politically motivated and projects of little technical value were funded for political reasons—instead of competitive programs of greater technical worth.

These funding selections were often made after enticing private industry to invest in the needed and competitive projects. The overall view of this segment of the geothermal industry is that if industry develops a solution to a technical problem with all or part of its own funds, a proprietary position in its exploitation is warranted.

Small Energy Companies

The majority of the small energy companies expressed the opinion that there was too much emphasis in the government demonstration program on projects that are still in the research phase—for instance, the hot dry rock program and the geopressure geothermal projects. Moreover, with regard to the research and development programs, the majority of these companies agreed with their larger colleagues that the procedures used by the government in conducting its competition often resulted in contracting with incompetent amateurs.

Some of these companies, however, in contrast to the views of the majority of large and small energy companies, felt that some of the government development programs were of great value to the industry. However, these same companies reiterated their views concerning other government participation in development programs and, with the exception

of the Sandia Laboratory effort, stated that the government should stay out of development and concentrate on research—perhaps the hot dry rock program if confined to a single research site and not intended as a developmental project. In general, the minority of companies felt that the present technology transfer program of DOE is working, and the communication between government and industry is good.

As an overall viewpoint, these companies echoed the views of the larger energy companies and stated that they would like to see the government develop procurement mechanisms whereby research and development projects would be awarded to competent companies, not to amateurs and students or to pay political debts.

They maintained that if the government insists on continuing in research and development, it should concentrate on long-term projects; and, again, the hot dry rock program in which industry has little interest or hope for success. In summing up their position, these companies again made the point that even in the hot dry rock program, the research should be concentrated on a single project; these companies felt that a survey of hot dry rock resources not an appropriate research objective.

Geothermal Companies

Some of the geothermal companies, singling out the current geopressure geothermal program, felt that the Federal Government was going too fast too soon in this area—and they relegated the whole project to research. As such, they felt there was too much emphasis by the Federal Government on what they considered was a long-range opportunity.

A small number of geothermal companies stated they felt that the demonstrations sponsored by the Department of Energy were helpful in demonstrating to potential investors that the technology is economically

feasible. Such demonstrations helped these companies to raise the capital for their projects. However, in contrast to the view of the small energy companies, the geothermal companies did not feel the Federal Government was very successful in its program of technology transfer. However, some of the geothermal companies singled out (as did some of the energy companies) the development work at Sandia Laboratory in drilling techniques as beneficial to the industry.

An interesting comment was made by a small number of companies concerning the government research and development program, and the hot dry rock program in particular. These companies suggested that it might represent a feasible secondary extraction method—after the primary geothermal fluids were exhausted. In addition, a small number of these companies stated that the Department of Energy should reactivate the down-hole pump development program.

Electric Users

Most of the electric users echoed the view of the large energy companies—stating that current demonstration programs seemed to be aimed more at the demonstration of commercial technology than at addressing technologically significant projects. They further agreed with the energy companies that, in their opinion, the demonstration programs were politically motivated with little technological application. In spite of this view, a small number of electric users felt that the demonstration of second generation technology by the Federal Government was necessary to the industry.

With regard to R&D, some of the companies felt that most of the Federal research and development projects were misdirected and that it would be better to turn these tasks over to EPRI.

Engineering Companies

Most of the engineering companies felt that the government research and development programs were competitive with industry on the one hand, and were misdirected or irrelevant to technological problems on the other. Still, a small number of engineering companies stated that Federally sponsored demonstrations were needed to convince utilities of technological feasibility and to establish costs of the technology.

Nonelectric Users

The majority of the nonelectric users stated that current programs would not have been implemented without the government demonstration programs. It becomes clear that most of the direct heat use projects of any significant scale have been implemented because of, and to the extent of, government funding. This phenomenon, perhaps, distorts the view of the commercial acceptability of direct heat use applications of geothermal energy.

On the other hand, a small number of the nonelectric users indicated they felt there was no need for government support and found that the demonstrations were a waste of time and money. These latter companies are not involved in the Federal demonstrations—even though some of them successfully competed in the program.

Another group of direct heat users indicated that, in their view, there was a need for the Federal Government to help develop a process technology. This group pointed out that the use of geothermal fluids for direct heat applications constitutes a classical problem of industrial processing, and they felt that it was not being addressed in that manner. They contended that the heat transfer of the fluid and the engineering analysis of heat loss versus distance traveled were not being addressed in a scientific manner.

Promoters/Developers

The views of the nonelectric users most frequently coincided with those of the promoters/developers; and, in fact, the spokesmen for the projects were more frequently the promoters than the final users.

- (5) Although Some Companies Maintained Vigorous Company-Funded R&D Programs Related to the Development of Geothermal Energy, the Approach Taken by Many Companies of the Industry Essentially Limited Their Activities to Government-Funded Projects

The various sectors of the geothermal industry have formulated their approaches to the technology involved in geothermal development based on their recognition of technical problems and the technical developments required to overcome them. The approaches of these companies take into account the funding available under the auspices of the government demonstration programs and research and development projects. The following is a description, by industry category, of current company approaches to the technological problems of geothermal development.

Large Energy Companies

Most of the large energy companies indicated that they have undertaken development programs, and in some cases long-range research programs, to address and solve the problems that have arisen in their geothermal development projects. A small group of the large energy companies, on the other hand, have not initiated any substantial technology research or development programs—reflecting either the companies' general lack of interest in geothermal energy or their decision to continue monitoring the feasibility of that energy source before making investments. A small number of these companies indicated that, although they would be interested in addressing government research and development programs, they had no plans to invest their own funds in geothermal development programs at this time.

Small Energy Companies

Most of the small energy companies, especially those with active geothermal development projects, have undertaken company-funded research and development programs.

Geothermal Companies

Most of the research and development effort of the geothermal companies has been government funded. A small number of these companies have maintained their own company-funded research and development programs as well as competing for and implementing government-funded projects of both a research and a development nature.

Electric Users

Some of these companies, in addition to participation in joint government/company-funded demonstrations, have funded and implemented vigorous research and development programs within their companies aimed at determining the feasibility of, and developing the means to exploit, the potential of the geothermal resources located within their areas of interest.

Engineering Companies

The majority of the engineering companies, especially the large ones, have developed and maintained substantial research and development programs within the companies. In addition, these same companies have competed for and implemented government-funded research and development projects as well. The small engineering companies, however, have limited their involvement in geothermal research and development, for the most part, to government-funded projects.

Non-electric Users

A small number of direct heat users have formulated minor development programs—usually with government financial support.

• Promoters/Developers

The majority of the promoters/developers, although providing engineering support and management to the projects with which they are involved, have undertaken little independent development—outside of government-funded projects. Some of these companies have formulated financial approaches to projects and undertaken, on their own funds, the overall technical assessment of the projects, but have funded little internal research and development in the field of geothermal energy.

• Others

In the course of interviewing some of the ancillary components of the geothermal industry, an almost complete lack of research and development effort related to geothermal energy on the part of the drilling companies was noted.

The industrial associations neither funded nor carried out research and development themselves, but expressed certain views on technological needs—based on their association with the various companies in the industry. They stressed the importance of dual use (electrical generation and direct heat application) of potential resources as a feasible approach to justify the development of geothermal resources beyond the premier and limited dry steam resources.

It was interesting to note that the financial institutions that ultimately must make a judgment on the feasibility of geothermal projects before investing their funds—not only have very definite opinions with respect to geothermal technology—but actually undertake, with the help of their consultants and technical advisors, their own assessment of the resources in question before investing. To a large extent, these institutions limit their investment to projects that are based on current and proven technology—rather than second generation approaches to

geothermal development. Such limitation of viewpoint raises the question of availability of venture capital for new or improved techniques, and, ultimately, returns to the question of the government's role in geothermal technology development.

* * * *

Overall, industry has concluded that although geothermal development is impacted by technological constraints, none precludes its development. However, respondents from industry indicated that some specific technical developments could improve the economics of the use of this resource and, consequently, enhance its potential as an alternative energy source. Exhibit II-4 provides a relative assessment of the seriousness with which industry views these technological constraints and needed developments of in the industry.

EXHIBIT II-4
Technical and Economic Constraints to
the Commercialization of Geothermal Energy
for Power Generation and Direct Heat Utilization

CONSTRAINTS	TYPE OF FIELD						
	STEAM	WATER > 450°F		450°F > WATER > 300°F		WATER < 300°F	
		HIGH SALINITY	LOW SALINITY	HIGH SALINITY	LOW SALINITY	HIGH SALINITY	LOW SALINITY
Production							
Reservoir Capacity	8	8	8	8	8	8	8
Well Stimulation	8	8	8	8	8	8	8
Scale & Corrosion Control	2	6	1	4	1	7	2
High Temp. Drill Muds & Cement	2	4	4	4	4	2	2
High Temp. Drill Bits	7	7	7	7	7	4	4
Downhold Inst. & Equip.	7	7	7	7	7	4	4
Disposal	5	7	4	7	4	7	4
Seismicity	3	3	3	3	3	3	3
Utilization							
A) Power Generation							
Binary	1	4	1	9	9	1	1
Flash	1	7	7	7	7	1	1
DH Pumps/HXCH	1	4	4	7	7	7	7
DC HXCH	1	4	1	7	7	7	7
NC Gas Abatement	8	8	8	8	8	6	6
Water Management	6	8	8	8	8	4	4
Scale & Corrosion Control	6	8	8	8	8	4	4
Total Flow Turbine	1	5	5	5	5	8	8
B) Direct Utilization							
DH Pumps	1	2	2	2	2	9	9
NC Gas Abatement	1	6	6	6	6	8	8
Scale & Corrosion Control	1	5	2	5	2	7	3
Water Management	1	4	4	4	4	4	4
Materials of Construction	1	5	5	5	5	5	5

EXHIBIT II-4 (continued)

SCALE	DESCRIPTION
1	Technology is not needed to exploit resource.
2	
3	
4	Technology will allow a minor cost saving or improve plant efficiency if developed.
5	
6	
7	Technology will allow a major cost saving or major improvement in plant efficiency if developed.
8	
9	
10	Resource will not be developed without this technology.

III. FINANCIAL CONSIDERATIONS

III. FINANCIAL CONSIDERATIONS

The geothermal industry, as described in Chapter I, is composed of two major components. The first, reflecting the current structure, is oriented around the generation of electricity; the second, the emerging component, encompasses direct heat applications as well. From the analysis of the technological considerations performed in Chapter II, it was concluded that there are but two currently feasible systems for geothermal production of electricity: the flash steam and the binary cycle systems. The use of the lower and moderate temperature geothermal resources for direct heat applications was also considered to be technologically feasible. Other advanced concepts to meet current and future energy demands were examined, and it was concluded that substantial development was required before they could be considered realistic technological alternatives to the current flash and binary cycle systems. The economic realities of producing power from geothermal energy and the use of its thermal properties in direct applications must be considered in order to determine whether or not geothermal energy represents a feasible alternative to other available forms of energy.

1. THE ECONOMICS OF GEOTHERMAL ENERGY IS DETERMINED BY ITS INHERENT PHYSICAL PROPERTIES AND THE UNIQUE ASPECTS OF ITS USE

Geothermal energy is a capital-intensive energy resource for which costs of production are primarily fixed. The total projected capital investment for a geothermal power plant can exceed \$800 per kilowatt, with associated owning costs representing 80 to 90 percent of the busbar cost of electricity. Remaining costs of 10 to 20 percent are variable costs associated with equipment operation and maintenance.

In addition, geothermal resource development represents an investment with appreciable inherent risks, particularly for the supplier. For example, the costs for exploration, planning, engineering, testing, operating, and maintaining a producing field are substantial before any revenues are received. If the field is commercially developable, these costs and negotiated profit are eventually passed on to the user in the selling price of steam which, in the case

of power generation, is estimated to account for approximately 55 to 60 percent of the busbar cost of electricity. The remaining 40 to 45 percent represents capital and variable costs associated with the installation and operation of turbine-generator and switchyard equipment.

In addition to producing electricity via dry steam, flash steam, and binary cycle systems, geothermal energy can be utilized in direct heat applications for space and process heat. In these potential applications, geothermal energy is competing with

- . Conventional electric power generation alternatives including coal-, oil-, and gas-fired systems
- . Primary fuels such as coal, oil, and gas in production of space and process heat.

Thus, the geothermal industry—as represented by both developers and users—will commit the capital funds necessary to finance the development of geothermal energy if it can compete with alternative sources of energy and provide a reasonable return on investment. The competitiveness of geothermal energy, in turn, is dependent on several sets of circumstances, including

- . The cost of competing energy alternatives
- . The cost of field exploration and development
- . The cost of steam production
- . The installation and operating cost of power plant or direct user equipment
- . Power plant performance—in the case of electricity generation—on which to base project economics and expected returns on investment
- . The potential impact of development and investment risk as a result of such issues as
 - Uncertainty with regard to reservoir lifetime
 - Drilling success
 - Timing between project initiation and cash returns

- . The investment criteria of potential users of geothermal energy
 - Moderate but assured rates of return to utilities
 - Prospective returns that compensate for development risks in the case of resource companies.

The impact of these economic and financial constraints to widespread application of geothermal energy resources is assessed by

- . Developing representative economic comparisons of geothermal and available energy supply alternatives
 - . Evaluating the effect of the uncertainties identified above on the economics of representative geothermal projects from the perspective of
 - The resource developer
 - The electric utility
 - The direct heat user.
 - . Describing the technologies, economic incentives, and institutional developments that are available or are required to resolve the above uncertainties, where they have potentially significant impacts.
2. AN ANALYSIS OF GEOTHERMAL ENERGY USE, BOUNDED BY BOTH OPTIMISTIC AND PESSIMISTIC SCENARIOS OF OPERATION, YIELDS THE CONCLUSION THAT IT IS COMPETITIVE WITH OIL AND GAS FOR POWER GENERATION—BUT NOT COAL—IN THE ABSENCE OF ECONOMIC INCENTIVES

The cost of geothermal energy for representative applications was evaluated to determine its market potential under "stand-alone" conditions (i.e., without significant additional Federal incentives).

Each case takes into account the investment criteria and tax policies—presented in Exhibit III-1 that apply to the various participants in geothermal projects. Because these cases are generic, they did not include project-specific risk. Risk is taken into account by

constructing plausible scenarios, reflecting possible conditions, and analyzing the operating and resource factors that will have the greatest potential impact on geothermal economics.

Because potential investors in geothermal projects deal in probabilities based on a limited amount of information, several scenarios were developed for each case in order to evaluate plausible resource development conditions. These scenarios are labeled optimistic, most likely, and pessimistic, and the input assumptions for each is presented in Exhibit III-2. Additionally, two sensitivity analyses were conducted to evaluate the two most significant risks that were identified as constraining geothermal development:

- . Short project life
- . Poor success in drilling.

Required prices for steam/hot water and electricity were then determined using a discounted cash flow (DCF) model. DCF models are in wide use in industry to provide information for investment decisions. DCF models allow the economics of alternative capital projects to be comparatively evaluated in order to optimally allocate resources available in a firm's capital budget. The model then calculates the expected cash benefits that will result from each project based on the timing of cash outlays, cash returns, and an assumed minimum rate of return.

(1) The Economics of Electricity Generation by Geothermal Energy Is Based on Currently Available Technology

Three basic technologies exist for the production of electricity from geothermally heated water. Based on the characteristics of the reservoir (amount of steam and temperature), a potential user could select one of the following system designs:

- . Dry steam
- . Flash steam
- . Binary cycle.

Dry steam plants are already a proven technology and are in commercial operation. At present, the condition limiting dry steam power production is the size of the resource base. Pacific Gas and Electric

EXHIBIT III-1
Financial Parameters Used in the
Financial Analysis of Geothermal Energy

FINANCIAL PARAMETERS	RESOURCE DEVELOPER	UTILITY	DIRECT HEAT USER
• FINANCIAL STRUCTURE	20% DEBT AT 9% 10% PREFERRED STOCK @ 10% 70% EQUITY @ 20%	50% DEBT @ 9% 10% PREFERRED STOCK @ 10% 40% EQUITY @ 12%	20% DEBT AT 11% 10% PREFERRED STOCK @ 12% 70% EQUITY @ 20%
• DEPRECIATION	11-YEAR DOUBLE DECLINING BALANCE	20-YEAR DOUBLE DECLINING BALANCE	10-15-YEAR DOUBLE DECLINING BALANCE
• INTANGIBLE DRILLING COST	EXPENSED (55% OF EXPLORATION COST 25% OF DEVELOPMENT COST)	NA	NA
• DEPLETION ALLOWANCE:	YEAR % OF REVENUE* 1980 22 1981 20 1982 18 1983 16 1984+ 15 *NOT TO EXCEED 50% OF TAXABLE INCOME.	NA	NA
• FEDERAL INVESTMENT TAX CREDIT	20% IF USED BEFORE 1982, OTHERWISE 10%	10%	20% IF USED BEFORE 1982, OTHERWISE 10%
• FEDERAL INCOME TAX RATE • STATE INCOME TAX RATE • PROPERTY TAX RATE • ROYALTY PAYMENTS • INSURANCE RATE • INFLATION RATES: - REVENUE - O&M - CAPITAL • ECONOMIC MEASURE	48% 9% 2% 10% 0.75% 3% 7% 7% ROI	48% 9% 2% NA 0.75% 4% 7% 7% FIRST YEAR POWER COSTS	48% 9% 2% NA 0.75% 0% 7% 7% ROI

SCHEDULE AND COSTS	RESOURCE DEVELOPER			UTILITY		DIRECT HEAT USER	ALTERNATIVE UTILITY GENERATING PLANTS	
	FOR DIRECT HEAT	FOR BINARY	FOR FLASH STEAM	BINARY PLANT	FLASH STEAM	INDUSTRIAL	DIRECT FIRED, LOW SULFUR COAL WITH SCRUBBER	COMBINED CYCLE OIL/GAS
COST: OPTIMISTIC MOST LIKELY PESSIMISTIC	\$40/ FT OF WELL \$50/FT OF WELL \$60/FT OF WELL	\$100/FT OF WELL \$115/FT OF WELL \$135/FT OF WELL	\$100/FT OF WELL \$115/FT OF WELL \$135/FT OF WELL	\$525/kW \$675/kW \$825/kW	\$375/kW \$575/kW \$675/kW	DRILLING AS % OF COSTS: -50 -65 -80	\$600/kW \$660/kW \$730/kW	\$360/kW \$440/kW \$440/kW
EXPENSES: OPTIMISTIC MOST LIKELY PESSIMISTIC	0 0 0	3 MILLS/kWh 3 MILLS/kWh 3 MILLS/kWh	3 MILLS/kWh 3 MILLS/kWh 3 MILLS/kWh	1.5 MILLS/kWh 1.5 MILLS/kWh 1.5 MILLS/kWh	1.5 MILLS/kWh 1.5 MILLS/kWh 1.5 MILLS/kWh	5¢/MMBTU 12¢/MMBTU 20¢/MMBTU	3-5 MILLS/kWh	2 MILLS/kWh
REPLACEMENT WELL	10%/YEAR	10%/YEAR	10%/YEAR	NA	NA	NA	NA	NA
WELL ACTIVITY: OPTIMISTIC MOST LIKELY PESSIMISTIC	3X10 ¹¹ BTU/YR 2X10 ¹¹ BTU/YR 1X10 ¹¹ BTU/YR	4 MW 3 MW 2.5 MW	5 MW 4 MW 3 MW	NA	NA	NA	NA	NA
AVG WELL DEPTH: OPTIMISTIC MOST LIKELY PESSIMISTIC	700 FT 1500 FT 3000 FT	5000 FT 6500 FT 8000 FT	5000 FT 6500 FT 8000 FT					
FACILITY SIZE:	4X10 ¹¹ BTU/YR	50 MW	50 MW	50 MW	50 MW	4X10 ¹¹ BTU/YR	50 MW	50 MW
OPERATING FACTOR: OPTIMISTIC MOST LIKELY PESSIMISTIC	NA NA NA	NA NA NA	NA NA NA	.7 .65 .6	.7 .65 .6	0.4 0.4 0.4	.7 .65 .6	.7 .65 .6
SCHEDULE OF CAPITAL COST (FRACTION OF TOTAL PER YEAR)	YR FRACTION 1 .35 2 .65	YR FRACTION O ML P 1 .25 .10 .10 2 .35 .25 .25 3 .40 .30 .30 4 - .35 .35	YR FRACTION O ML P 1 .25 .10 .10 2 .35 .25 .25 3 .40 .30 .30 4 - .35 .35	YR FRACTION O ML P 1 .10 .05 .05 2 .25 .10 .10 3 .30 .25 .25 4 .35 .30 .30 5 - .30 .30	YR FRACTION O ML P 1 .10 .05 .05 2 .25 .10 .10 3 .30 .25 .25 4 .35 .30 .30 5 - .30 .30	YR FRACTION 1 .35 2 .65	YR FRACTION 1 .10 2 .15 3 .20 4 .20 5 .20 6 .15	YR FRACTION 1 .05 2 .10 3 .25 4 .30 5 .30
PROJECT OPERATING LIFE: OPTIMISTIC MOST LIKELY PESSIMISTIC	NA	NA	NA	30 YEARS 25 YEARS 20 YEARS	30 YEARS 25 YEARS 20 YEARS	15 YEARS 15 YEARS 10 YEARS		

Blank

presently has over 600,000 megawatts of geothermal dry steam capacity in operation at "The Geysers." While moderate development of this resource will continue, its potential as an energy contributor is limited in comparison with other geothermal resources. Although a small number of potential steam resources exist, their number is small; thus, dry steam plants are not evaluated in this section. It is assumed that a limited number of dry steam plants will continue to be constructed and operated without any need for economic incentives. In the following sections, flash steam and binary cycle plants—the two remaining geothermal electric production technologies—are compared and evaluated with alternative electric energy supply systems from the economic standpoint. This evaluation will take the form of an assessment of a

- . Base Case
- . Pessimistic and Optimistic Cost Scenario
- . Binary Cycle Geothermal Plant Economics
- . Impact of Major Uncertainties
- . Potential Solutions to the Impact of Major Uncertainties.

(2) The Base Case Analysis Is Postulated on the Most Technologically Feasible System Under the Most Probable Operating Conditions

The base case for electricity generation consisted of a flash steam power plant project using representative values for key technical or cost parameters. These values were chosen because of the significance of their contribution to the cost of producing geothermal energy, and include:

- . A well depth of 6500 feet
- . Drilling costs of \$115 per foot of depth
- . Well productivity sufficient to operate on average, a 4 MW plant
- . A project lifetime of 25 years
- . A power plant capital cost of \$525 per kilowatt.

These costs are in 1979 dollars. Combining these cost parameters with the appropriate financial parameters presented in Exhibit III-2 results in a required selling price of steam of 18.4 mills per kilowatthour (m/kwh). This compares with

- A price of 16.5 m/kWh for dry steam at the Geysers. These dry steam costs have escalated considerably in recent years because the price of dry steam is tied, in part, to the price of fuel oil.

- A price of 35 m/kWh for fuel oil burned in West Coast power facilities.

- A price of 7.5 m/kWh for coal burned in power plants located in the Southwest United States.

While the cost of all fuels for electricity generation are expected to rise considerably by 1985, Exhibit III-3 shows that only coal will remain cheaper than geothermal energy on a Btu basis.

(3) The Development of Pessimistic and Optimistic Case Scenarios Provide Bounds to the Analysis

Although any energy supply project is characterized by both supply and demand uncertainties, this is particularly true for emerging technologies such as geothermal energy development. On the supply side, production costs are impacted by inflation, labor productivity, process development, delays, and operational efficiency. Price is impacted by the availability and competitiveness of alternative fuels and by any existing mismatch between current demand—which includes both existing consumption and latent demand—and current production of the energy form under consideration.

The magnitude of uncertainty surrounding geothermal projects are greater than for conventional fuels because the geothermal industry is young, and the technology is not yet fully commercialized. As such:

- Costs are less well-known.

EXHIBIT III-3
Cost of Fuels for
Electricity Generation in 1985

* Does not include surcharge for low priority use

SOURCE: BOOZ•ALLEN & HAMILTON BASED ON ENERGY INFORMATION
ADMINISTRATION DATA.

- There is no detailed data base with respect to process engineering or operations and maintenance requirements.
- Reservoir evaluation and engineering is much more rudimentary for geothermal than for conventional fuel resources such as oil and gas.

In order to determine more fully the uncertainties and risks surrounding the comparative economics of geothermal energy with regard to coal and oil, two scenarios were postulated as variants from the most likely or base case. These scenarios consist of

- An optimistic scenario, in which the key parameters cited above are adjusted to determine the potentially achievable results under plausibly optimistic conditions
- A pessimistic scenario, in which these same parameters are adjusted in the opposite direction from the base case to determine the impacts under adverse conditions.

The following values were selected to provide a realistic range and to reflect these scenario conditions of occurrence. The values are based on a review of the most recent geothermal technical analyses.

Parameter	Most Likely Value	Optimistic Value	Pessimistic Value
Well depth	6500 ft	5000 ft	8000 ft
Drilling cost	\$115 per ft	\$100 per ft	\$130 per ft
Average well productivity	4 MW	5 MW	3 MW
Project life	25	30	20
Power plant capital cost	\$525 per MW	\$275 per MW	\$675 per MW

Exhibit III-4 shows parametrically the results of the scenario analysis. Superimposed on this exhibit is a band of expected costs for electricity from alternative fuels for new generating plants

EXHIBIT III-4
Effect of First Year Electricity Cost
on Varying Selected Parameters

coming on line in the mid-1980's. It should be noted that varying most of the geothermal parameters through realistic ranges does not change the comparative economics of a flash steam power plant with respect to either coal or oil. Under most conditions, then, coal is expected to remain cheaper than geothermal energy, which, in turn, will be cheaper than oil.

Optimistic Scenario Results

The optimistic scenario is based on the following parameters:

	<u>Value</u>	<u>Deviation From Base Case</u>
Well depth	5000 ft	-23%
Drilling cost	\$100 per ft	-13%
Well productivity	5 MW	+25%
Project life	30	+20%
Power plant capital cost	\$375 per kW	-29%

Results show that the cost of electricity can be expected to be as low as 26 m/kWh in 1979 dollars. This is lower than the lowest cost anticipated for a new low sulfur coal plant startup at the same time. However, it must be mentioned that this optimistic scenario represents the lower bound of achievable results on all key technical and cost parameters, and, as such, has a low probability of occurrence.

Pessimistic Scenario Results

The pessimistic scenario is based on the following combination of values for key parameters:

	<u>Value</u>	<u>Deviation From Base Case</u>
Well depth	8000 ft	+23%
Drilling cost	\$130 per ft	+13%
Well productivity	3 MW	-25%
Project life	20	-20%
Power plant capital cost	\$675 per kW	+29%

Results indicate that the cost of electricity from geothermal energy under this scenario

(48 m/kWh) would exceed even the highest postulated cost for oil in a combined cycle plant (47 m/kWh). However, this cost will still be substantially less than the cost of power produced from an oil-fired single cycle combustion turbine.

(4) Binary Cycle Geothermal Plant Economics Represents an Additional Alternative to the Base Case

Binary cycle power plants are projected to produce power at costs of 3 to 10 m/kWh above those for flash steam plants. This cost disadvantage is due to the higher capital or fixed costs of this type of facility. While the competitiveness of these plants vis-a-vis coal plants is questionable at best, it appears that, in many cases, binary cycle plants will still be competitive with oil plants. It is doubtful, however, that binary cycle plants will enjoy as clear an advantage over oil-fired generation as flash steam plants.

(5) The Evaluation of the Impact of Major Uncertainties Provides Greater Definition to the Bounds of the Analysis

Early Reservoir Depletion Risk Analysis

Most developer and user firms interviewed stated that some sort of insurance against early reservoir depletion is vital. Because of the nascent state of the industry, resource developers and utilities claim they do not have a reservoir data base that is adequate to support investment decisions. Since utilities are concerned with the availability of fuel for their major generation projects, they will opt against construction of geothermal projects unless they can be assured of long-term supply, or some technique for minimizing investment risk. In order to measure the economic impact attendant with this risk, a sensitivity analysis was conducted of the impact on project economics of a 10-year (nominal) reservoir lifetime for a project initially designed for a 25-year life. This reservoir lifetime was chosen as a boundary because several participants stated that such a lifetime would make any geothermal project uneconomic.

Exhibit III-5 shows that if the economics are based on a 10-year project, the required selling price of both steam and electricity are significantly affected. This occurs because the substantial capital investment in wells and power plant must be amortized over a considerably shorter time period. Thus, each unit of production carries a heavier burden of capital-related charges than under the most likely scenario case. Under these conditions, it appears that geothermal economics are adversely impacted, for example:

- Neither a flash steam nor a binary cycle plant can be made competitive with a coal-fired plant.
- A flash steam plant may still be competitive with oil-fired plants, although results appear to be marginal.
- The competitiveness of a binary cycle plant with oil becomes questionable at best.

If instead, the project was amortized over a nominal 25-year operating lifetime, the utility would have an investment remaining at the end of 10 years approximately equal to its initial investment, thus suffering significant loss. This contingent liability has been pointed out in industry interviews as a major source of risk. In addition, the resource developer would achieve a rate of return too small to compensate him for the large risks he takes in a venture such as this. In fact, the uncertainties attendant with this risk, the investment required, and the length of the construction period have been offered as explanations for the fact that independent drilling companies have not become a major factor in the industry. For example, the perception of risk and reward compared to conventional petroleum drilling had led many major industries to shy away from geothermal projects.

**EXHIBIT III-5
Sensitivity Analyses**

	FLASH STEAM		BINARY CYCLE	
	COST ¹ (m/kWh)	Δ^2 (%)	COST ¹ (m/kWh)	Δ^2 (%)
BASE CASE				
STEAM	14.3	—	14.3	—
ELECTRICITY	28.2	—	30.8	—
10-YEAR PROJECT LIFE				
STEAM	23.6	+65%	23.6	+65%
ELECTRICITY	41.6	+47.5%	46.3	+50.3%
1:2 DRILLING SUCCESS RATE				
STEAM	15.5	+8.4%	15.5	+8.4%
ELECTRICITY	29.4	+4.3%	32.0	+3.9%
1:4 DRILLING SUCCESS RATE				
STEAM	17.7	+23.8%	17.7	+23.8%
ELECTRICITY	31.6	+12.1%	34.2	+11.0%

¹ LEVELIZED COST IN 1979 DOLLARS.

² CHANGE FROM BASE CASE.

Drilling Success Ratio Risk Analysis

Exhibit III-5 also shows the effect of a drilling success ratio less than that assumed for the base case. Ratios of 1:2 and 1:4 were applied to the base case exploration effort, since technical experts indicate that the fraction of successful wells could be reduced by a factor of four in virgin fields. Whereas the resulting price of steam is increased greatly (approximately one quarter), the effect is to increase the price of electricity by only 12 percent. It does not change the relative standing of geothermal energy vis-a-vis coal or oil.

The major effect then is on the financial stability of the driller who may incur costs up to four times those expected and delays of 2 years beyond nominal plant startup. When combined with current tax treatment of excess profits on disposal of geothermal properties and operating income (versus capital gains), the effect may be to depress geothermal activity among small drilling companies. Thus, it is doubtful under the set of assumptions postulated here whether many small or independent drilling companies will pursue geothermal development as long as alternative investments, e.g., oil and gas exploration and production, show promise. The decontrol of new gas fields and the expected phase-out of price controls on petroleum can depress geothermal drilling activities for the next several years unless special financial incentives are offered. It is clear that there is critical need for some mechanisms or processes that will be capable of accelerating the cash flows or profitability associated with geothermal development, and minimizing the risk associated with these investments.

(6) Potential Solutions to the Impact of Major Uncertainties Can Further Refine the Economics of the Base Case and Its Alternatives

Early Reservoir Depletion

A potential solution to the risk associated with early reservoir depletion may be found in the substitution of a gradual development

of the geothermal field with modular equipment, for the more traditional rapid, large-scale development (50 MW and larger). Since utilities generally think in terms of large blocks of incremental power when planning generation alternatives, due consideration may have to be given to the smaller, modular, development concept.

With this suggested approach, modular units of between 1 and 10 MW would be installed initially while a geothermal field is being tested. These units would be of moderate cost, and certainly would be affordable to any utility of significant size. Upon the test's providing indications of a resource of sufficient extent and duration—large-scale development could begin. This modular development concept could potentially benefit the utility and developer in two ways:

- If the field warrants further development after additional field testing, additional units could be quickly moved onto the site. In the interim some power is already being produced.
- If the field does not prove out commercially and undergoes rapid depletion, at least some power has been obtained; and the unit, because of its modularity, could be moved to another potential site.

Drilling Success Risk

The solution to the mitigation of the risks associated with drilling may lie in simply taking advantage of the financial incentives already available. These incentives include

- A 75 percent loan guarantee
- A 20 percent investment tax credit.

Thus, currently available government programs provide coverage of 95 percent of all investment costs.

What is likely to be of even greater importance to the driller is the compression of the time frame within which he can expect to achieve some cash return. Independent drillers tend to run small, highly leveraged operations. Thus, achieving a positive cash flow at the earliest possible time is a consideration of the highest priority. An early cash flow requires two conditions:

- The ability to install small modular generating units—to take advantage of whatever steam flows can be achieved, both during and after field testing.
- A siting and licensing environment that allows the field developer to minimize the time between the identification of potentially commercial geothermal sites, and the first cash returns from these fields.

A more compressed development timetable will also allow drillers to quickly ascertain the risks associated with the development of any single site, and to determine the feasibility of moving the operation to another site, thus

- Minimizing the investment in a potentially unprofitable site
- Minimizing the time and effort associated with investing in any particular site
- Accelerating the time frame in which the developer can move to additional sites.

(7) Summary of Scenario and Technology Analysis

Exhibit III-6 summarizes the major cost assumptions and quantitative results of the previous analysis. Exhibit III-7 compares the expected first-year costs of geothermal electricity under the range of scenarios considered, and arrays these costs against alternatives. This exhibit illustrates that the cost of conventional hydroelectric power will always be cheaper than geothermal power, and nuclear

EXHIBIT III-6
Comparison of Geothermally Generated Electricity
with Alternative Methods

	FLASH STEAM	BINARY CYCLE	LOW SULFUR COAL	COMBINED CYCLE
CAPITAL COSTS,* \$ PER KM	375-675	525-825	600-730	360-440
O&M COSTS	1.5-3	1.5-3	3-7	3
FUEL COSTS \$/MMBTU	1.5-2.3**	1.5-2.3**	1.5-2.3	2.5-3.1
TOTAL FIRST YEAR COSTS MILLS/kWh	26-48	29-58	29-36	38-47
TOTAL LEVELIZED COSTS MILLS/kWh	21-40	23-48	25-32	39-48

ALL ENTRIES IN 1979 DOLLARS.

***EXCLUDING INTEREST DURING CONSTRUCTION.**

****COST OF STEAM PURCHASED FROM RESOURCE DEVELOPER.**

EXHIBIT III-7
First Year Cost of Electric Power From
New Generating Plants in 1985

and coal power can be expected to be cheaper than geothermal flash steam under most scenario conditions.

The comparison with nuclear and hydro power may not be particularly relevant, since:

- . It appears that few nuclear units will be ordered during this time period because of environmental, regulatory, legal, and sociopolitical constraints.
- . The most advantageous hydro sites have already been developed and environmental and siting issues may prevent development of the remaining underdeveloped hydro resources.

Nevertheless, geothermal power may be cheaper than both coal or nuclear power under a selected set of conditions. This price advantage can occur if the cost parameters of the geothermal plant approach those assumed under optimistic scenario conditions, and the large coal and nuclear plants are delayed, require costly retrofits, or incur operational problems. This development scenario will assume the ability of drillers to rapidly develop a geothermal site, and achieve cash returns at an early date. However, the most likely case is that flash steam power will be at least 10 to 20 percent more expensive than either coal or nuclear power. Finally, new geothermal power plants should continue to enjoy some economic advantage (possibly 10 percent) over oil- and gas-fired units. This analysis is predicated on the continued real escalation of these fuel prices above general inflation--a likely scenario given existing conditions. Thus, if load continues to grow in the West Coast, and nuclear, coal, and hydro resources are not capable of or allowed to satisfy those requirements, geothermal energy will appear to be a feasible economic alternative to the installation of oil-fired power generation.

3. THE ANALYSIS OF THE ECONOMICS OF DIRECT HEAT APPLICATIONS OF GEOTHERMAL ENERGY SHOWS SUBSTANTIAL COST ADVANTAGES WITH RESPECT TO FOSSIL FUELS

A comparative analysis of geothermal energy vis-a-vis conventional fuels in direct heat applications was also conducted. The application selected was a hypothetical

industrial process that would require up to about 50 million Btu of heat per hour. Food processing (e.g., drying, blanching) would be a representative application of this type of process.

Typical parameters for direct heat use of geothermal energy were chosen based on a review of publicly announced projects and interviews with selected users. The base case was developed as an average of those projects, and includes the following parameters:

- . Well depth - 1,500 feet
- . Surface facility cost - 65 percent of downhole cost
- . Average well productivity - 2x10" Btu/year
- . Development time - 1 year
- . Project lifetime - 15 years.

(1) The Base Case Analysis Is Postulated on Available Technology and Well Depths Under 3000 Feet

Base case results and a sensitivity analysis of key technical and cost parameters are presented in Exhibit III-8. These results indicate that

- . Geothermal energy is considerably less expensive than fossil fuels (\$0.81 per MMBtu versus \$3.50 to \$4.50 per MMBtu for oil or natural gas).
- . The only significant factor that appears to bear on the cost of geothermal energy is well depth. Presently, direct heat geothermal projects are utilizing only the most advantageous sites, and well depths for the foreseeable future are not expected to reach 1000 feet. However, even at depths of 3000 feet, geothermal energy may be cheaper than alternative energy sources.
- . Extrapolation indicates that geothermal energy may even be competitive at depths of about 4000 feet—if all other base case conditions remain the same.

EXHIBIT III-8
Sensitivity Analysis of Direct Heat Use
Economics

Because varying single parameters did not sufficiently alter the competitiveness of geothermal energy, an additional scenario was postulated. These scenarios take into account a combination of events that could realistically occur. The adverse scenario is discussed in detail in order to identify the conditions under which incentives may be needed— if geothermal energy development is to be accelerated.

(2) An Adverse Scenario Was Developed To Bound the Analysis

As in cases of geothermal electric projects, participants in a geothermal direct heat application may not have the necessary information at the beginning of a project for realistic decisionmaking. Consequently, although the most likely scenario may show favorable economics, a wide range of future conditions can occur.

The adverse scenario was developed to test the full range of comparative economics that may result from commitment to a project, and is based on the following key parameters:

- . Well depth - 3000 feet
- . Drilling cost - \$60 per foot
- . Surface facility cost - 85 percent of downhole cost
- . Average well productivity - 1x10 Btu/year
- . Operating and maintenance cost - \$0.20 per MMBtu
- . Project lifetime - to be determined.

Exhibit III-9 projects that under this scenario, geothermal energy could cost about \$4 per MMBtu. This compares with natural gas at \$3.50 per MMBtu and No. 2 fuel oil at about \$4.40 per MMBtu. Thus, under this scenario, geothermal energy would be about 10 percent more expensive than natural gas and 10 percent less expensive than fuel oil. Interpolation suggests that geothermal energy would be competitive with natural gas if well depth was about 2500 feet under this scenario.

EXHIBIT III-9
Cost of Fuels to the
Industrial Sector in 1985

Exhibit III-9 also compares the fuel cost of coal with geothermal energy. While this comparison indicates that coal has a distinct economic advantage, comparison on a straight cost of energy basis (\$/MMBtu) is not necessarily warranted in this analysis. Coal is not the fuel of choice in light industrial applications because of its handling costs and pollution effects (e.g., soot deposition). Thus, although coal may compete effectively in heavy industrial applications (especially for steam generation), it is not expected to compete in light industrial applications or direct heat applications.

(3) Critical Nongothermal Issues Affect the Economics of Geothermal Development

Although geothermal direct heat may constitute a practical application of this energy source to a certain industry--food processing, for example; unlike electric power production, energy economics is not the only consideration affecting geothermal development. Other significant considerations involve the activities associated with operating the basic business on a day-to-day basis. Such operations require highly motivated people knowledgeable in the prospective business, and interested in taking advantage of low-cost energy.

In addition, since these types of businesses are fairly small in scale, their inherent competitive advantage rests with their ability to flexibly respond to business opportunities. Thus, institutional constraints on the development of direct heat applications represent factors inhibiting these businesses from making appropriate use of this inherent advantage. The lengthy licensing and siting process presently associated with geothermal development is the most significant factor constraining direct-heat geothermal applications.

Finally, these small operations are also heavily dependent on achieving cash returns as early as possible in order to maintain liquidity. Thus, the longer the geothermal siting and licensing process ties up capital in nonrevenue-producing investment, the greater the risk and the disincentive to invest in businesses attempting to utilize geothermal energy.

4. IN GENERAL, WITHOUT ECONOMIC INCENTIVES, GEOTHERMAL ENERGY REPRESENTS A FEASIBLE ALTERNATIVE FOR DIRECT HEAT USE, BUT IS MARGINAL FOR POWER GENERATION AT MOST SITES WITH CURRENT TECHNOLOGY

The preceding financial analysis has shown that

- . Under certain conditions geothermal electricity may be as inexpensive as coal-fired electricity.
- . The most likely case is that geothermal energy will cost at least 10 percent more than coal.
- . Geothermal energy under base case conditions can be expected to cost 10 percent less than an oil-fired combined cycle plant.

However, large uncertainties in future costs exist because of the lack of a detailed geothermal data base to support decisionmaking. Certain contingent events would have a major impact on one or more of the participants in a geothermal project. These events include

- . Early reservoir depletion
- . Poor success in exploratory drilling
- . Low temperature and/or flow from production wells.

These uncertainties have inhibited the orderly development of low temperature geothermal energy in the western United States. If the Federal Government desires to accelerate that development, incentives will be necessary to reduce the uncertainties surrounding geothermal projects.

5. A VARIETY OF DIRECT ECONOMIC INCENTIVES AND OTHER INITIATIVES ARE AVAILABLE, AND NEW ONES HAVE BEEN PROPOSED, TO STIMULATE THE DEVELOPMENT AND ADOPTION OF GEOTHERMAL ENERGY

As a result of renewed interest in geothermal energy, new legislation has been introduced into the Congress—modifying earlier initiatives—with a view toward improving the overall attractiveness of geothermal energy to corporate planners and decisionmakers. The incentives thus incorporated into the current legislative proposals are contrasted with existing legislation in Exhibit III-10.

EXHIBIT III-10
Comparison of Legislative Incentives

ISSUE AREA
Leasing

<u>Geothermal Steam Act (1970)</u>	<u>Geothermal RD&D Act (1974)</u>	<u>Omnibus Development Act S. 1330 (1979)</u>	<u>Omnibus Commercialization Act S. 1388 (1979)</u>
Lease limitation of 2560 acres, per holder limi- tation of 20,480 acres		Lease limitation of 51,200 acres	Lease limitation of 2560 acres, individual limitation of 266,560 in any state, except Alaska
Royalty rates of 10-15 percent per annum for steam; 5 percent for by-products			
10-year lease term can be continued to 40 years			
Known geothermal areas subject to competitive bidding		Withdrawal of KGRA on which no bids have occurred	Known geothermal resource areas offered and no bid are withdrawn
Lands under autho- rity of Interior and Agriculture must be approved for lease by those agencies			

EXHIBIT III-10 (continued)

	<u>Geothermal Steam Act (1970)</u>	<u>Geothermal RD&D Act (1974)</u>	<u>Omnibus Development Act S. 1330 (1979)</u>	<u>Omnibus Commercialization Act S. 1388 (1979)</u>
Leasing			Establishment of coordinators for expedited leasing	
			Time limitations on stages of processing (1 year maximum)	Time limitations on stages of processing (1 year for development; 180 days for exploration)
			Conditional development leases with limited EIS available for exploration	Conditional development leases available
			Leases available for direct use of government entities	Government entities may develop lands under their control
			Requirement for information dissemination prior to application	
			No cost permits for small business and from direct use	
RD&D Programs		Establish geothermal Energy Coordination and Management Project		

RD&D Programs

Loan
Guarantees

EXHIBIT III-10 (continued)

<u>Geothermal Steam Act (1970)</u>	<u>Geothermal RD&D Act (1974)</u>	<u>Omnibus Development Act S. 1330 (1979)</u>	<u>Omnibus Commercialization Act S. 1388 (1979)</u>
	Resource inven- tory and assessment required		
	R&D programs for drilling pre- dictive methods, frac- turing, by- product use, waste disposal		
	Cooperative demon- stration proj- ects authorized		
	Fellowships, train- eeships, estab- lished to train geothermal per- sonnel		
	Loan guarantees established, \$25 million maximum for project, \$50 million maximum for borrower		

EXHIBIT III-10 (continued)

	<u>Geothermal Steam Act (1970)</u>	<u>Geothermal RD&D Act (1974)</u>	<u>Omnibus Development Act S. 1330 (1979)</u>	<u>Omnibus Commercialization Act S. 1388 (1979)</u>
Loan			Development of expeditious process for applications—4-month time limit	
Guarantees			Forgiveable loans for feasibility studies or license applications	Loans for feasibility studies to be repaid by proceeds, may be forgiven on unacceptable sites
Direct Loans				Limit on loans to 50 percent of cost except for direct use 90 percent; absolute limitation of \$3 million
			Water resources interest rate	Water resources interest rate
				Program expires in 1986
				Total authorization of \$150 million
Other			Reservoir insurance program to be established	

EXHIBIT III-10 (continued)

Geothermal Steam
Act (1970)

Geothermal RD&D
Act (1974)

Omnibus Development
Act S. 1330 (1979)

Omnibus Commercialization
Act S. 1388 (1979)

Other

Priority energy proj-
ects subject to
expedited proce-
dures

Review only by Supreme
Court

The degree to which the current available and proposed incentives are capable of skewing the financial assessment previously outlined to a conclusion more favorable to geothermal energy is a function of the mode and extent of the impact of the incentives' implementation.

6. EACH ECONOMIC INCENTIVE OPERATES DIFFERENTLY WITH RESPECT TO FUNCTION, PROBLEMS ADDRESSED, AND ATTRACTIVENESS TO REGULATED VERSUS UNREGULATED INDUSTRY

Quantitative impact on the apparent cost of geothermal energy can be achieved by adjusting the level of various incentives. However, a more significant issue for choosing among incentive options is the degree to which the specific decision variables are affected. The following sections identify the influence of candidate incentives on the investment decision process.

(1) Four Types of Problems Are Addressable by Direct Economic Incentives

The intent of economic incentives is to mitigate barriers to investment, and to encourage decision-makers to take action or to adopt a particular strategy. Underlying this basic intent, various incentives can address four types of barriers:

- . Improve Expected Economics. Revenues may be increased, costs decreased; or the timing of the cash flow may be changed to improve the inherent economics of the investment.
- . Reduce Project Risks. Investors will attach a risk premium or cushion on top of the estimated project return to reflect their perception of the intrinsic technical risk and cost uncertainty. Direct incentives may be offered to reduce or eliminate these risks.
- . Reduce Marketplace Uncertainty. Incentives may be able to provide a buffer against uncertain market prices/conditions. This is an especially important consideration in direct heat use, given the unstructured nature of the present marketplace.

- Facilitate Access to Capital. Assistance may take the form of actually providing capital to the developer for reducing risks to the lender thereby increasing the borrower's likelihood of securing financing.

(2) Economic Incentives Can Be Applied to Regulated or Unregulated Industries and May Be Defined as Front-End or Production Incentives

Incentives can be targeted to regulated and unregulated industries, as shown in Exhibit III-11 and III-12.

- Unregulated Industries. A broad range of tax measures, subsidies, grants, and various guarantees on price, project completion, and debt are applicable.
- Regulated Industries. A somewhat unrestricted set of conventional incentives, plus Construction Work in Progress (CWIP), all-events tariffs, and rolled-in pricing are applicable.

Within each industry group, there are two additional categories of economic incentives that relate to the basic objectives of the incentive legislation:

- Front-end incentives encourage investment by providing or guaranteeing capital, reducing investment requirements, or guaranteeing project completion.
- Production incentives focus on the feasibility of plant operation by improving expected rate of return or reducing the marketplace uncertainties.

Specific findings with respect to the key incentive candidates are presented in the following sections.

EXHIBIT III-11
Incentives Available to
Industry
(Nonregulated)

(NON-REGULATED INDUSTRY)

CATEGORY/INCENTIVE	HOW IT WORKS	IMPACT ON INVESTMENT DECISION PROCESS			
		IMPROVES EXPECTED ECONOMICS	REDUCES PROJECT RISK	REDUCES MARKETPLACE UNCERTAINTY	FACILITATES ACCESS TO CAPITAL
1. FRONT-END INCENTIVES					
• INVESTMENT TAX CREDIT	ALLOWS A CORPORATION TO DEDUCT FROM ITS TAX LIABILITY A SPECIFIED PERCENTAGE OF THE COST OF THE CAPITAL INVESTMENT	● OFFSETS A PORTION OF CAPITAL COSTS	● REDUCES PAYBACK PERIOD BY SHIFTING BENEFITS TO EARLIER YEARS OF PROJECT		● LENDERS RISK REDUCED BY IMPROVED ECONOMICS
• CONSTRUCTION COST EXPENSING	ALLOWS A CORPORATION TO WRITE OFF ALL CONSTRUCTION COSTS AS EXPENSES IN THE YEAR INCURRED, THEREBY REDUCING TAXABLE INCOME				
• ACCELERATED DEPRECIATION	ALLOWS A CORPORATION TO WRITE OFF A GREATER PORTION OF ASSET VALUE AS EXPENSE IN THE EARLIER YEARS OF A PROJECT LIFE REDUCING TAXABLE INCOME	● INCREASES REVENUES IN EARLY YEARS	● REDUCES PAYBACK PERIOD BY SHIFTING BENEFITS TO EARLIER YEARS OF PROJECT		● LENDERS RISK REDUCED BY IMPROVED ECONOMICS
• CONSTRUCTION GRANT	UP FRONT CAPITAL PROVIDED TO DEVELOPER WITH BEST COMPETITIVE BID	● DIRECTLY REDUCES INITIAL COSTS	● REDUCES POSSIBLE LOSS OF INVESTOR'S CAPITAL		● PROVIDES CAPITAL TO DEVELOPER
• DIRECT LOAN	LOANS ARE MADE BY THE FEDERAL GOVERNMENT TO DEVELOPERS ON TERMS WHICH WOULD OTHERWISE NOT BE AVAILABLE				● PROVIDES CAPITAL DIRECTLY TO DEVELOPER
• NON-RECOURSE LOAN GUARANTEE (DEBT PORTION)	THE CREDIT RATING OF THE FEDERAL GOVERNMENT STANDS IN FOR THE MARGINAL CREDIT RATING OF THE BORROWER AND MAKES AVAILABLE CAPITAL ON TERMS OTHERWISE UNATTAINABLE				● FEDERAL GOVERNMENT ELIMINATES LENDERS RISK
• COMPLETION GUARANTEE	FEDERAL GOVERNMENT PROVIDES INSURANCE AGAINST LOSS DUE TO STOPPAGE OF A PROJECT EITHER BY REPAYING LENDERS OR SHARING ADDITIONAL COSTS TO COMPLETE A PROJECT		● GOVERNMENT ASSUMES RISK		● LENDERS RISK IS REDUCED BECAUSE OF COMPLETION INSURANCE
2. PRODUCTION INCENTIVES					
• PRODUCTION SUBSIDY OR TAX CREDIT	A SPECIFIED AMOUNT PER UNIT OF OUTPUT PRODUCED MAY BE DEDUCTED FROM A CORPORATION TAX LIABILITY (E.G., \$3/BBL)	● INCREASES REVENUES ON A PER UNIT BASIS			● LENDERS RISK REDUCED BY IMPROVED ECONOMICS
• NEGOTIATED FIXED PRICE GUARANTEE	FEDERAL GOVERNMENT GUARANTEES A PREDETERMINED PRICE FOR ALL OUTPUT SOLD (E.G., \$28/BBL).	● INCREASES REVENUE STREAM IF MARKET PRICE IS BELOW GUARANTEED PRICE		● LIMITS MARKET PRICE UNCERTAINTY	● LENDERS RISK REDUCED BY IMPROVED ECONOMICS
• NON-NEGOTIATED PRICE GUARANTEE	FEDERAL GOVERNMENT GUARANTEES THE DIFFERENCE BETWEEN THE COST OF PRODUCTION AND THE MARKET PRICE (E.G., E.G., DIFFERENCE BETWEEN COST AND OPEC PRICE)	● INCREASES REVENUE STREAM IF COST OF PRODUCTION GREATER THAN MARKET PRICE	● RISK DUE TO HIGH PROJECT COST REDUCED BECAUSE GUARANTEE TIED TO COST	● REDUCES MARKET PRICE UNCERTAINTY TO NEGOTIATED AMOUNT	● LENDERS RISK REDUCED BY IMPROVED ECONOMICS AND REDUCED PROJECT RISK

LEGEND: ● PRIMARY IMPACT
○ SECONDARY IMPACT

- (3) Investment Tax Credits Provide Cash Flow by Offsetting a Portion of Capital Requirements. Corporations Must Have Sufficient Tax Liability To Utilize an ITC; for Regulated Utilities, Tax Credits Must Be Accompanied by Tax Normalization

Investment tax credits allow corporations to deduct a percentage of capital investment from a tax liability. Current tax credits amount to 10 percent for general industrial investment and up to 20 percent for various energy technology investments.

The key effect is an improvement in expected economics

Secondary effects include a reduction in project risks by shifting benefits to earlier years and a reduction in lender risks by improved economics.

Investment tax credits are not universally applicable, however. Corporations must have sufficient income and associated tax liability to be offset by the credit. For regulated utilities, state utility commissions may require that the tax benefits flow through to customers, rather than being retained to offset capital requirements.

- (4) Construction Costs Expensing Allows the Investor To Depreciate the Plant Before It Begins Operation

Expensing of construction costs increases the after-tax income of investors prior to operation of the facility. In essence, the deduction offsets a portion of capital investment if investors have adequate taxable income.

Based on discount cash flows, the expected project rate of return is enhanced substantially by shifting benefits to initial years of the project.

Project risks will be reduced by shortening the period required to pay back the capital investment accumulated at the time of the plant's startup.

(5) Accelerated Depreciation Is an Effective Incentive for High Risk Investments

Accelerated depreciation allows a corporation to write off a greater portion of asset value as expense in the earlier years of operation. The write off is largest in the early years and decreases over the period of depreciation. It is typically allowed by the IRS to compensate appropriately for asset depreciation in a high risk situation.

The primary impact of accelerated depreciation is to shift the benefits to earlier years of cash flow.

Earlier benefits result in a shorter payback period and less operating risk.

The impact of Federal tax revenues is felt in the timing, and not in the actual dollar differences, over the life of the plant.

(6) Construction Grants Provide Capital and Also Impact Inherent Economic Attractiveness and Project Risks to the Investor

Construction grants may take several forms and include various provisions. Grants have two primary impacts on the investment:

They increase the inherent economics by providing a portion of the capital costs

They directly provide capital to the developer that may not otherwise be available.

Grants may or may not involve equity participation of the Federal Government. Equity participation insures that the government will share in up-side benefits as well as down-side risks. However, equity participation generally is not viewed favorably by industry. Equity participation may involve substantial government involvement in business decision-making processes.

Grants may be structured to be convertible to loans if projects are successful. This provision

allows the government to share in the up-side benefit without equity participation.

(7) Direct Loans Are Not Guaranteed and Though Providing Capital, Have Little Impact on Inherent Economics, Risks, or Uncertainties

Loans without guarantees make capital available at a reasonable interest rate to investors under conditions of risk that are unacceptable to the private capital market. Direct government loans and government guaranteed private loans can be designed with any of three beneficial characteristics:

- . Lower interest rates than required by private sources, considering risk factors
- . Longer maturity term than otherwise required
- . Higher fraction of debt as compared to equity commitment.

Although loan incentives have been used extensively by the Federal Government, the impact of social considerations is becoming apparent. First, increasing Federal loan incentives are crowding out private sector borrowers from available capital. Second, investors may treat nonrecourse loan payments as a variable cost, rather than a financial commitment, and stop operation under adverse conditions sooner than is economically efficient. Moreover, as will be seen, industry is not sure how to use the program, since it requires that companies default on the loan before the guarantee becomes operative.

(8) Completion Guarantees Protect Lenders Against Risk That Projects Will Not Reach Operation

Several variations on this incentive have been suggested, but most attention has focused on a limited guarantee similar to an insurance policy. As suggested in the recent report by the Committee on Economic Development, a fee could be charged to the developer in exchange for a guarantee that the government would reimburse all, or a portion, of the additional costs due to environmental regulations or regulatory delays. Completion guarantees are highly

attractive to industry, which cites regulatory uncertainty as an important barrier to geothermal development. Another variation of this incentive has been suggested in the government's furnishing of resource insurance—a system by which the reliability of a reservoir for a certain period of time would be insured; and, in the event that the reservoir gives out prematurely, the developing or using company would be reimbursed for capital expenditures. Resource insurance is the incentive most frequently suggested by the greatest number of the respondents in this study's interviews.

(9) Production Subsidies Through Direct Cash Outlays or Tax Credits Improve Expected Economics But Would Have Little Impact on Inherent Risks or Uncertainties

Production subsidies improve expected economics by increasing revenues, but do not ensure the profitability or address risk directly. Though subsidies have less administrative complexity, they may not get the most production for the dollars of Federal subsidy

Production subsidies administered through production tax credits have the same problems associated with them as investment tax credit and accelerated depreciation, in that sufficient taxable income is required to benefit from the incentive.

Continued production subsidies may have no influence on the development of a viable, unsubsidized geothermal industry in the long term.

(10) Negotiated Fixed Price Guarantees Have a Powerful Effect on Expected Economics and Marketplace Uncertainties; Though Project Risks Are Not Affected, Access to Capital Is Improved Substantially

Under a negotiated fixed price guarantee, industry weighs its risks against potential profits, or bids for the required price. Negotiation (competitive bids) will improve the chances that the most efficient (least cost) producers will proceed with development, and avoids unnecessary costs to the Federal Government.

- . Negotiated fixed price guarantees involve greater reliance on industry decisionmaking and assessment of risks. The government assumes the marketplace uncertainty, but project risks are carried by the developer.
- . The investor has the potential for both down-side loss and up-side benefits.

A variation on the fixed price guarantee is the pegged price guarantee that is tied to the marketplace (e.g., OPEC world oil price).

(11) Nonnegotiated or Open-End Price Guarantees Have Serious Implications on Federal Budget Exposure and Economic Efficiency

Nonnegotiated or open-end price guarantees are powerful incentives because they are tied to actual future cost of production. Therefore, the producer may be stimulated to provide output but will have no incentive to minimize costs if the market price is below the guaranteed cost. Technical and operating risks, as well as marketplace uncertainties, are borne by the Federal Government.

- . Potential Federal budget exposure is large because of the cost overrun potential and market price uncertainty.
- . Administrative burdens on the government to identify allowable costs would be substantial.

(12) For Utilities, Allowance for Construction Work in Progress in the Rate Base Enhances Overall Company Financial Strength

Financial health of regulated utilities can be enhanced substantially by including Construction Work in Progress (CWIP) in the rate base. CWIP provides additional cash flow and reduces external financing requirements. CWIP does not directly address any of the problems unique to the geothermal industry, but will be beneficial to utilities as geothermal producers. In essence, including CWIP in the utility rate base is a means of raising a portion of capital requirements from rate payer revenues.

(13) An All Events Tariff Ensures That Debt Service Payments and Operating Costs Will Be Passed Through to Customers

All events tariffs are regulatory mechanisms that enable utilities to take acceptable risks with the assurance that costs will be passed through to the rate payers. This incentive will involve no direct Federal expenditure.

- Although the benefits of geothermal resource production accrue to the nation as a whole, the customers of the utility bear the risks and possibly higher costs.

- Economic efficiency is difficult to build into this incentive without significant administrative complexity.

(14) Rolled-In Pricing for Geothermal Energy Producers and Utilities Improves Economic Viability and Mitigates Marketplace Uncertainties

Rolled-in pricing allows a utility to average in the costs of geothermal energy with the costs of other supplies. However, it does not guarantee a full return to the utility as does the all-events tariff. If a public utility commission allows rolled-in pricing, uncertainty due to market price is reduced. If future alternative fuel prices are lowered, the utility will be able to charge the rolled-in price of geothermal energy, but at the risk of losing customers to alternative fuel suppliers.

7. MAJOR FINDINGS OF THIS STUDY INDICATE THAT OF THE GENERIC INCENTIVES PREVIOUSLY DESCRIBED, PARTICULAR INCENTIVES ARE FAVORED BY PARTICULAR SEGMENTS OF THE GEOTHERMAL INDUSTRY; BUT ALL SEGMENTS AGREE THAT INCENTIVES ARE NECESSARY TO STIMULATE GEOTHERMAL DEVELOPMENT AND TO ENSURE ITS COMPETITIVENESS WITH ALTERNATIVE FUEL OPTIONS

Although there are vast differences in viewpoints among the various segments of the geothermal industry with regard to the solution and effectiveness of government incentives for geothermal development stimulation, all segments of the industry agree that incentives are necessary if the tempo of development is to be increased significantly in this century. The basis of this general conclusion stems from the results of trade-off analyses conducted by most of the companies of the geothermal industry. The companies that have undertaken geothermal programs have determined that, in the absence of the opportunity to utilize hot dry steam, the utilization of hydrothermal resources for power production and direct heat use, marginally feasible some years ago, is becoming more competitive as difficulties of licensing nuclear reactors increase. Moreover, the acceptability of the use of gas and oil to meet general energy needs is being thwarted by rising prices and regulation; and the difficulties of utilizing coal in view of limited capacity for increasing production and in the face of new and more stringent air quality requirements are similarly increasing. As a result, most companies have found that geothermal energy would become a feasible alternative if its competitive position is not dissipated by emerging institutional requirements on the one hand, and is stimulated by judicious use of government incentives on the other.

8. RECOGNIZING THAT DIFFERENCES EXIST IN THE INDUSTRY ASSESSMENT OF THE VARIOUS ECONOMIC INCENTIVES AVAILABLE TO THE GOVERNMENT WITH RESPECT TO THE GEOTHERMAL INDUSTRY, FOUR GENERAL CONCLUSIONS EMERGE FROM INTERVIEWS WITH THE VARIOUS REPRESENTATIVES OF THE GEOTHERMAL INDUSTRY

- . Each incentive serves a different purpose with respect to inherent economics, project risks, marketplace uncertainties, and developers access to capital.
- . The type and level of Federal incentives adopted will determine the extent of the impact of the

incentive on the competitiveness of geothermal energy, and will, as well, determine the role of government in industry's decisions.

The subtle nature of business decisions with respect to investment in the geothermal industry suggests the need for direct and continued input from the potential industrial participants in the program before effecting legislation aimed at influencing industrial decisions.

Of the generic incentives previously described, the industrial respondents to the interviews identified four major categories of incentives that were determinative in their decisions to enter, continue, or to leave the geothermal energy development field:

- The Federal guaranteed loan program
- Resource insurance
- Tax incentives
- Direct funding (front-end incentives).

9. THE SUBTLE NATURE OF BUSINESS DECISIONMAKING IN GEOTHERMAL ENERGY DEVELOPMENT INDICATES THE NEED TO CONSIDER DIRECT INPUT FROM POTENTIAL PARTICIPANTS

This study was conducted on a basis of extensive interviews with all segments of the geothermal industry. As discussed in Chapter I (the structure of the industry), the sampling was extensive enough with respect to the current industry structure that the validity of the inductive conclusions can be accepted with confidence. Although this strength is not found in the sampling of the still unstructured and undefined direct heat use segment of the industry, it again provides an index to company attitudes and the impact of incentives on company decisionmaking.

10. INDUSTRY'S ASSESSMENT OF NEW INCENTIVES IS COLORED BY THE GOVERNMENT'S CREDIBILITY WITH INDUSTRY—AND ITS OWN CORPORATE GOALS

Actual decision subtleties extend substantially beyond industry generalizations. Discussions with companies in the geothermal field indicate a reasonable and expected degree of variance among the companies with regard to their decision criteria for investment and, consequently, their

reaction to the programs of the Federal Government. In addition, based on these discussions, it was concluded that the most important element of the decisionmaking process of industry may very well be its degree of confidence in the Federal institutions—their motives, consistency, and reliability. The following discussion of industry's perspective of government incentives is summarized in Exhibit III-13, and reports on the results of the interviews with the companies of the geothermal industry carried out in the course of this study. The construct of the geothermal industry developed in Chapter I and used as a framework for the discussion of technological considerations in Chapter II will be likewise utilized in this analysis of the industrial reaction to suggested incentives for geothermal development.

(1) The Federal Loan Guarantee Provided the Greatest Incentive to Industry—As It Was Conceived—and Its Greatest Disappointment—As It Was Implemented

The Federal Loan Guarantee Program, probably more than any other single piece of legislation, incentivized industry to increase the tempo of its activity in geothermal development. While it is true that the Federal Loan Guarantee Program, as part of the Research and Development Bill of 1974, became available at approximately the same time that the 1970 Geothermal Steam Act was implemented, it was concluded from interviews with various companies of the geothermal industry that the availability of guaranteed loans had constituted the most effective single incentive to industry to develop programs for entering the geothermal field. This was so in spite of the fact that this program was of no great interest or use to some segments of the industry. As will be seen in Chapters IV and VI, this new and heightened interest in the development of geothermal energy was evidenced by the large number of applications for Federal land leases in 1974. However, the enthusiasm with which this incentive was met and the effectiveness of its utilization varied with the various segments of the geothermal industry. Following are the views of the industry with respect to the Federal Loan Guarantee Program—as reported in the in-depth interviews carried out as part of this study.

The Large Energy Companies

The overall evaluation of the Federal Loan Guarantee Program by the large energy companies was that it is worthless. They maintained that any program that had been able to process but four applications in 7 years was of little worth to industry. A minority of the large energy companies was of the opinion that the program was of some use to small companies badly in need of credibility with the financial community to obtain venture capital.

The Small Energy Companies

The smaller energy companies found the Federal Loan Guarantee Program as generally too cumbersome, too expensive, and too time-consuming in its implementation to be of any great use to industry. They pointed out, moreover, that the application for a Federal Loan Guarantee of a single member of a development consortium introduced government regulation into the project—most frequently in the form of new requirements for more extensive environmental impact assessments. The overall result was that development time was greatly increased—not only in the processing time of the application but in meeting the new requirements for environmental impact assessment as well. However, some of the small energy companies agreed that the Federal Loan Guarantee Program may be necessary for high-risk development programs for smaller developers.

These energy companies observed that the original Senate version of the Research and Development Assistance Program (of which the Federal Loan Guarantee Program was part) emphasized support of research and development—rather than the financing of the overall project. In the Senate version, the cost of research and development would have been shared by industry and government. If the research and development had proved successful, the grant would have been

SUMMARY OF ECONOMIC
INCENTIVES BY INDUSTRY
SEGMENT

EXHIBIT III-13
Summary of
Economic
Incentives
by Industry
Segment

INDUSTRIAL SEGMENT	FEDERAL GUARANTEED LOAN		RESOURCE INSURANCE		TAX INCENTIVES		DEFRAYMENT EXPLORATION COSTS		DIRECT FUNDING (UP-FRONT)		MISCELLANEOUS
	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY	MINORITY
ENERGY COMPANIES LARGE	Worthless.	Some use to small companies.	Reservoir insurance needed - especially to support utilities.		Investment tax credit and accelerated depreciation would help industry - espe- cially small companies. Make utilities eligible for tax credits.			Need for government funding - government pays half exploratory costs with- out diluting equity - or government conducts own program.	Up-front loans only aid proliferation of crooked operations or foolish proj- ects - should reward success in tax breaks.		
ENERGY COMPANIES SMALL	Not much use - too cumbersome, expensive and time-consuming implementation.	Prefers Senate R&D ap- proach - for high-risk development projects.	Resource insurance is key to development of geo- thermal energy - especially for utilities -	Do not know how insur- ance scheme could be implemented.	Need tax incentives to indi- vidual users and developers.	Greater amortization for utilities - or, alternatively, let energy companies de- velop resource, produce and sell electricity.	DOE should cooperate with those actually drilling wells - not with resource speculators.	Need government funding - should defray 50% of drilling costs - to advance knowledge and technique.		Need government funding for transmission lines.	Require more demon- strations by DOE - industry cannot go it alone.
GEOTHERMAL COMPANIES		The FLG may be of some use to small operators - but its value depends on the tempo of its implementation. Implementation often frustrates legislative intent. Important in mitigating risk for utilities.			Depletion allowances and favorable tax treatment nec- essary. Requirement that utility tax credit be passed on to consumer strips incentive. Tax incentives required to improve cash flow.	Ten-year depletion allow- ance nearly used up when facility comes on-line - because of 7-year lead time. Because of method of corporate internalization, tax benefits favor small companies. Implementation often frustrates legislative intent. Depletion allowance and deduction for intangibles sufficient - but need assurance that they will not be changed retroactively.			Up front money detri- ment to program - shifts responsibility from entre- preneur to government.	Need up-front funding to improve geothermal eco- nomics vs oil and gas oppor- tunities in view of long lead time of geo projects. Federal Finance Bank should finance waiting time - from discovery to use.	
UTILITIES	Need loan guarantee pro- gram without default clause for developers to reduce their development risks.	Eligibility restrictions need to be modified to favor small developers.	Reservoir insurance abso- lutely necessary for the development of geothermal energy.		Tax incentives to devel- opers needed to reduce their development risk.	Tax incentives to utilities - rapid write-off acceptable to PUCs; CWIP in rate base.				Need front-end funding. Communities need grants - not loans.	Need well defined and reliable DOE program - re- sponsive to utilities' needs. Provide incentives to explore new technologies and encour- age geothermal through pro- grams that have direction and commitment. Enact new Federal Utility Cooperative Agreement.
ENGINEERING COMPANIES	Companies have not learned how to use the FLG - since it requires default to be operative - calling in all loans - and destroying company's financial position.		Government incentive pro- gram must eliminate or reduce primary risk - re- liability of resource - through some kind of insurance. Government exposure would be slight.	Government should allow utilities to build their own power plants without risk of bankruptcy.	Need enlargement of tax credit as well as accelerated depreciation - as incentives to whole industry. Generous depletion allow- ances would be greatest incentives.	The 10% tax credit should be available to utilities. Tax credits often not useful because of need for revenue stream for effective utiliza- tion.				Cost sharing is best contract vehicle to foster development. DOE should fund at least half the cost of a bearing plant.	Need transmission facilities. Need new definition of roles - so excess power can be made available without re- quired wheeling. Could reduce risk by guaran- teeing market or price.
NONELECTRIC USERS	Need a workable loan guarantee program.						There is a need for technical assistance.	There should be emphasis on government program of intensive exploratory drilling to decrease risk - rather than financial incentives.	Need front-end financing.		
PROMOTERS/DEVELOPERS	Present Federal Guaranteed Loan unworkable; but need a workable scheme.	FLG has been some help since it enabled companies to pick up some venture capital.	Resource insurance would be a big help.		Tax incentives needed; would be better than DOE participation - would bring in capital.	Tax incentives will not work for not-for-profit corporations.		Exploratory drilling pro- gram by Bureau of Reclamation badly needed.	Projects need up-front funding to get bank loans.	There should not be up- front government funding - allows irresponsible projects.	
OTHERS											
DRILLING COMPANIES											Need to see clear em- phasis placed on geo- thermal by either public or private sector - so companies can plan market entry and equip- ment acquisition. Greater visibility for geo- thermal needed.
INDUSTRIAL ASSOCIATIONS											
FINANCIAL INSTITUTIONS	Federal Guaranteed Loan necessary because long- term financing must be reasonably assured. Third party financing required because utilities unable to commit risk capital, resource de- velopers unwilling to incur utility cost of service regulation.	Increase guaranteed loan limits to go to 100% and upping total amount.	Development of reservoir insurance and basic need.	Sufficient incentives exist with FLG; reservoir insurance not needed.	Need additional tax credits. Need accelerated or immed- iate depreciation. 10% ITC should be avail- able to utilities - if long- term, standalone industry is to be fostered.					Any offering of Federal government must be balanced against delay of government procedure.	
GOVERNMENT VIEWPOINT	Current FLG ineffective - a forgivable program needed.	FLG is beset with start-up difficulties but needed pro- gram. FLG should have been most effective mechanism pro- vided by legislation - pro- vides confidence to industrial and banking community. Its implementation, al- though not always rapid, has been delayed only for nec- essary investigation. There is a great need to make the FLG program attractive to potential en- trants other than oil com- panies (who don't need it) or the utilities (who can't use it).		Resource insurance needed, but administration of such a program extremely difficult.	Tax incentives needed - probably more effective than guaranteed loans - for developers and utilities as well.	NEP II will give sufficient tax incentives.					

turned into a loan that would have been repaid by the successful developer; if it had not proved successful, the company's development risk would have been halved. These companies felt this approach was more attractive to the more capable members of the geothermal community. However, it was the House version of the bill that was adopted—the version that included the loan guarantee.

The Geothermal Companies

Although, in many cases, these companies were either organized as a result of, or highly incentivized by, the promise of the Federal Loan Guarantee Program, in practice, it did not prove very effective in aiding their efforts. A small number of the geothermal companies have concluded that the Federal Loan Guarantee may be of some value to the smaller operators. Whether or not it is effective depends on the length of time required for the application's processing, however.

These companies selected the Federal Loan Guarantee Program as a prime example of the implementation of a program frustrating the legislative intent of its enactment. The whole reason for this program was to allow riskier ventures by smaller companies with insufficient capital. However, in the implementation of the program, there was a definite effort on the part of the Federal Government to eliminate government risk in guaranteeing the loan. Thus, before the application was acted on favorably, the government required assurances that there was very little chance of default. The companies point out that, in those circumstances, the loans would have been available from commercial banks anyway. Moreover, they stated that this situation was further exacerbated by the fact that the financial community, knowing that Federal loan guarantees were available, insisted upon receipt of the guarantees before issuing the loans—loans that would ordinarily have

been granted—before the availability of the Federal Loan Guarantee.

On the other hand, some of the geothermal companies reported that, in spite of its drawbacks—if the Federal Loan Guarantee Program could be modified to make it more workable—it would be very valuable for mitigating the risk to the utilities.

Utilities

Most of the utilities indicated that, in their opinion, a Federal Loan Guarantee Program was needed; but felt that for it to be useful, it had to be redrafted to eliminate the default clause. They suggested that such a program with the recommended modifications was needed by the developers to reduce their risks.

Engineering Companies

The major engineering companies, in the course of the interviews, indicated that their companies were also very optimistic about the prospects for a surge in the development of geothermal energy in 1973-1974 as a result of the Federal Loan Guarantee Program provision of the 1974 Research and Development Act. But they admitted that they had not been able to determine how to use the program—either for themselves or for their natural customers in the current structure of the industry—the utilities. Since a default on the loan is required for the Federal Loan Guarantee to be operational, the engineering companies are no more willing to undergo that experience—and have all their loans called in—than the utilities. They point out that, like the utilities, they expect to be around for a long time and do not want their record and their credit rating marred by a default—whether their creditors have suffered or not—because of the operation of the Federal Loan Guarantee.

These companies point out that, in practice, the benefits of this program accrue to companies organized for particular programs and plan to go out of existence if they fail. Moreover, the engineering companies have not been able to develop any scheme whereby such programs could be insulated from the parent company by third parties to whom the loan and its guarantee would be made. In any event, these companies anticipate that, in a court action, creditors would be able to reach the utility, the large energy company, or the large engineering company—no matter how the project was organized.

In brief, the geothermal companies feel that the Federal Loan Guarantee Program would be good for utilities; the utilities feel it is needed by the geothermal companies; and the energy companies feel it is of no use to them at all. In fact, on several occasions financial institutions, insisting upon a Federal Loan Guarantee, could not find anyone willing and able to apply for the guarantee. The energy company did not need it and, to avoid government regulation would not apply; the utility company was precluded from undertaking the loan by the PUC; and the small engineering company—willing to sign the loan application—was not considered loan-worthy by the financial institution.

Nonelectric Users

Because many of these companies are new, and have had less experience in the business world than the older companies, their attitude with respect to the Federal Loan Guarantee was generally favorable. They stated that they needed "a workable loan guarantee." Most of these companies were less specific regarding the method of its operation but did not seem to fear the consequences of default as much as the longer-lived and larger companies comprising the current structure of the geothermal industry.

Promoters/Developers

The promoters/developers involved in organizing and managing complete geothermal projects, and in many cases developing the financial packages as well, were much more aware of the complications attendant with the Federal Loan Guarantee Program. The large majority of these companies felt that the present Federal Loan Guarantee Program is unworkable but, at the same time, they also felt that some sort of loan guarantee is needed. In fact, a small number of these companies pointed out that even in its present form the loan guarantee program has been of some use, since it facilitated some companies in gaining access to new capital.

Others

The financial institutions affiliated with the geothermal industry have a major interest in the operation of the Federal Loan Guarantee Program. Not unexpectedly, most of the financial institutions not only felt that the Federal Loan Guarantee Program was useful, but insisted upon its issuance by the government to qualify a borrower for funding, since it was their opinion that long-term financing must be reasonably assured. Further, these institutions indicated a need for third-party financing because the utilities apparently were unable to commit risk capital; and the resource developers were unwilling to undergo the financial risk of the project without receiving an equity position—in fear that such a position might cause them to be subject to regulation. Some of the financial institutions felt that the Federal Loan Guarantee Program should be improved by increasing the limits of the guarantee to 100 percent. They recommended also that the amount of the guarantee be likewise increased.

Government Viewpoint

In interviews with government officials regarding the Federal Loan Guarantee Program,

it was obvious that, with some exceptions, most of these officials interviewed were aware of the difficulties involved in its implementation. Further, they agreed that, as it had operated previously, it was probably ineffective. They suggested that a forgivable program might be an option to explore and are most interested in some of the newer approaches to third-party financing. Some of the officials indicated that, in their opinion, some of the difficulties experienced in implementing the program were merely start-up problems.

All agreed that the program was sorely needed as an incentive to geothermal development. Moreover, they stated that the Federal Loan Guarantee Program should have been the most effective incentive to the geothermal industry furnished by current legislation—since it provided a basis for confidence in projects for both the industrial and the financial communities. They pointed out, in addition, that the implementation of a program insured by public funds necessarily requires proper investigation to determine its eligibility for that funding—and delay, although frustrating, may be inherent in the validation process.

(2) Resource Insurance Is the Economic Incentive Most Frequently Suggested by All Segments of the Geothermal Industry

One of the most frequently suggested incentives for advancing the development of geothermal energy is resource insurance. The frequency of its suggestion correlates directly with the degree of concern evidenced by almost all respondents with respect to resource reliability. Given this concern, the importance of providing some means of compensating companies undertaking the risks associated with geothermal development is clear—in the event that the original estimates of the extent and/or duration of the resources prove inaccurate. The specific comments of the various segments of the geothermal industry with respect to resource insurance are indicated on the following pages.

Large Energy Companies

Most of the large companies maintained that resource insurance was needed, particularly, to support the utilities' position—since the PUCs, as a matter of principle, opposed capital risks for the utilities.

Small Energy Companies

Most of the smaller energy companies—particularly those involved in major geothermal development programs—have concluded that resource insurance is the key to the development of the geothermal energy. They felt that the existence of such insurance was particularly beneficial to utility companies. Although a small number of these firms are not sure how such a scheme could be implemented, some of the companies stated that they had already provided such insurance to those utility companies with which they were associated in joint development programs.

Utilities

The utility companies were almost unanimous in the position that resource insurance is absolutely necessary for the further development of geothermal energy.

Engineering Companies

Most of the engineering companies maintained that a government incentive program must eliminate, or at least reduce, the primary risk to geothermal development—the reliability of the resource—through some kind of government-supplied insurance. Moreover, they felt that the government exposure would be slight and, to a large extent, limited to the cost of the premium. They did not feel that the government had to act as carrier in such a scheme, but merely as the purchaser of the insurance policy.

A few of the engineering companies particularized this opinion by suggesting that the government should develop some concept, probably resource insurance, that would make it possible for a utility to build its own power plant without the risk of bankruptcy. They stated that if sufficient resource insurance were available, the need for the loan guarantee would diminish—since the largest risk to the project is the reliability of the resource.

. Nonelectric Users

Because, at the present time, the ultimate users in direct heat applications are less involved in the mechanics of resource development than the developer, they displayed very little knowledge or interest in resource insurance.

. Developer/Promoter

In contrast to the direct heat users, the developer/promoters were most aware of the benefits of resource insurances; and most of them felt that such insurance would be of substantial value in the future development of nonelectric applications of geothermal energy. However, they pointed out that such insurance was not so important currently, since the major programs involved with direct heat use are government-sponsored demonstration programs and/or have been aided by government exploratory drilling programs. But for the future, the majority of the developer/promoters felt that resource insurance was of critical importance to the success of the projects they were putting together.

. Financial Institutions

Most of the financial institutions interviewed felt that resource insurance would be the most effective incentive that could be developed by the government to increase the likelihood of success of the geothermal program.

Government Viewpoint

Most of the government officials interviewed felt that resource insurance is needed, but they pointed out that the administration of such a program could be extremely difficult.

Representatives of various industry groups cautioned that speculation regarding the administrative difficulties inherent in a program of government-supplied resource insurance must consider not only the experience of energy companies furnishing such insurance to the utilities in joint projects, but the recent programs developed by carriers for this purpose as well.

The point was made repeatedly by various industry representatives that government participation in a resource insurance program does not necessarily mean that the government will play the role of underwriter or even administrator of the program. Insurance policies are currently available, and the government's exposure could be limited to payment of the premium for short-duration coverage—until the resources can be assessed with greater precision.

(3) Although More Limited in Their Application, Tax Incentives Constituted the Best Understood and Universally Accepted Incentive

Of all of the incentive programs discussed by the representatives of industry, tax incentives represented the general area of the most interest and knowledge. However, since most tax advantages really provide a system of profit relief and assume a cash flow, they represent a philosophical position of rewarding success—in contrast to programs aimed at reducing risk. The specific comments of various industrial groups with respect to tax incentives are discussed below.

Large Energy Companies

The majority of large companies felt that tax credit and accelerated depreciation

would stimulate the geothermal industry—especially the small developers. Moreover, these companies maintained that utilities should be made eligible for tax credits currently denied them. At the present time, the 10 percent tax credit, if given to utilities, must be passed on to subscribers; consequently, the financial position of the utilities is not improved by the current program.

Small Energy Companies

The small energy companies agreed with the views of the larger companies in holding that tax incentives are necessary to individual users (utilities) and developers. Some of the smaller energy companies were specific with regard to the form of the tax incentive—indicating a need for a more generous schedule of amortization for the utilities. These companies suggested that energy companies be allowed to develop geothermal resources and produce electricity without becoming regulated industries themselves. However, given the choice between regulation and withdrawal from geothermal development, the energy companies stated that they would unhesitatingly forego the business to avoid the status of regulated industry.

Geothermal Companies

Most of the geothermal companies interviewed stated that substantial depletion allowances and favorable tax credits were necessary for the development of geothermal energy. In addition, they pointed out that the current requirement that utility tax credit be passed on to consumers strips the utilities of development incentives. In general, they felt tax incentives were required to improve the cash flow of this developing industry.

Some of the geothermal companies noted that the 10-year depletion allowance currently available is nearly used up by the time the facility comes on line—in view of the current

7-year lead time. They felt that the present approach to the determination of reasonable depletion allowances should be reviewed.

These companies observed that tax incentives already made available by the Government are not generally being internalized by the large energy companies in the most advantageous way for geothermal development. For example, it was pointed out that these tax incentives are frequently applied at the corporate level—and not particularized to geothermal energy. Consequently, in the competition for resources within the corporation, the geothermal position is not very strong vis-a-vis other fuel options. On the other hand, some of the smaller companies have set up separate profit centers for their geothermal activities, and the tax incentives accorded geothermal energy are applied directly to that energy source. As a result, its position becomes more competitive within the corporation.

This internalization of the tax advantages is practiced by all the geothermal companies and, as a result, it is their opinion that the Federal Government is spawning a new industry of small companies that, with sufficient Federal incentive, can fill the cracks between the programs of the large companies. Moreover, these same companies indicated that depreciation allowances and deductions for intangibles are sufficient incentive for the geothermal companies. More important to them was the assurance that these programs will not be changed retroactively. As with all the companies interviewed, it was emphasized that a basic requirement of industry with respect to the Federal Government is the consistency of the Federal viewpoint. Without exception, all respondents emphasized that they cannot manage in an environment of uncertainty.

. Utilities

Most of the utilities agreed with the rest of the industry that tax incentives are needed for developers—to reduce development risk. Some of the utilities stressed the need for tax incentives for themselves—particularly rapid write-off of costs acceptable to the PUCs and including CWIP in the rate base.

. Engineering Companies

Most of the engineering companies confirmed industry's need for an enlargement of the tax credits as well as an accelerated depreciation schedule—as incentives for the whole industry. It was the opinion of these engineering companies that the depreciation allowance would constitute the greatest incentive to the industry. However, some of the engineering companies felt, in addition, that the 10 percent credit given to developers of geothermal energy should be available to the utilities as well. Moreover, they pointed out that in the smaller companies and those companies involved in the direct heat use, the tax credits were often not as useful because of the need for a revenue stream for their effective utilization.

. Nonelectric Users

The end users of geothermal energy in direct application had little knowledge of interest in tax incentives available throughout the geothermal industry. Their interest was in finding a less expensive energy source; the programs and financial packages necessary to make the source available was of less interest to the users. Their position was: If a less expensive source is available, they will use it; if not, they will use whatever is available.

• Promoters/Developers

For most of the promoters/developers, unlike the direct-heat users, tax incentives are considered absolutely necessary for success in developing this energy source. They much preferred tax incentives to direct DOE participation in either cost-sharing or front-end financing. These tax incentives were particularly needed by the promoters putting together financial packages, for tax relief could be traded off for venture capital—badly needed by the promoters.

• Financial Institutions

Nearly all the financial institutions interviewed felt that the industry needed additional tax credits and accelerated or immediate depreciation schedules. Moreover, the financial institutions stated that the 10 percent investment tax credit available to industry should be available to utilities as well—if a long-term, stand-alone industry is to be fostered.

• Government Viewpoint

Most of the government officials interviewed recognized the need for tax incentives, and felt that they probably would be more effective than the guaranteed loans in fostering the development of geothermal energy—for both developers and utilities alike. Some of the government officials pointed out that NEP II would provide increased tax incentives—and they would probably be sufficient.

(4) The Defraying of the Costs of Development and Exploration Was Considered a Substantial Incentive by Some Segments of the Industry Because Their Implementation Reduced Project Risk

The government's defraying of development costs and/or either funding or undertaking resources exploration were identified as major incentives to the development of geothermal energy by various

segments of the industry. The form and extent of such support generally reflected the problems being addressed by the various components of the industry—as illustrated below.

. Energy Companies

Although the large energy companies felt no need for government assistance in their development programs, since (as was pointed out in Chapter II) they maintained that industry would develop what was necessary for successful utilization of this resource, some of the companies felt that there was a need for government support of exploration programs. They stated further that a joint industry-government exploratory program would be desirable—if industry could cooperate without having its equity position diluted.

. Small Energy Companies

The majority of small energy companies, particularly those with ongoing programs in geothermal development, discussed this incentive more in philosophical than operational terms. These companies felt that the DOE should cooperate with those companies actually engaged in drilling wells—not with organizations merely engaged in resource speculation. A smaller number of these companies indicated the need for government funding—especially in the drilling programs. They hoped that the government would defray 50 percent of the drilling costs in an effort to learn more about the resource and to generally improve drilling techniques.

. Nonelectric Users

Most of the potential users of geothermal energy for direct heat applications thought that there would be a need for technical assistance by the Government, but because of their relatively remote role in the program were not specific with respect to the form of government participation.

However, a small proportion of these companies indicated a specific need for emphasis in the government programs on drilling and exploration—to decrease resource uncertainty. They felt that such a program, if well implemented, would be more effective than many financial incentives.

Promoters/Developers

Some of the promoters/developers interviewed specifically noted the need for government help in exploratory drilling. They singled out the Bureau of Reclamation as an agency that might provide the support.

(5) The Value Placed on Direct or Joint Government Funding of Geothermal Energy Development Varies With Company Perspective

It is in the area of direct funding to companies involved in geothermal development that basic differences in industry views were detected—with respect to the government role in this industry. Although divergence of view was first detected in earlier consideration of the government role in development programs, exploration support, and tax incentives, a basic dichotomy of views is apparent between those companies that have achieved success and are in a strong financial position and those companies attempting to penetrate this energy field or who are having financial difficulties. This basic difference in viewpoint was reflected in the views of the respondents of the interviews—reviewed by industry segments:

Large Energy Companies

The almost unanimous view of the large energy companies was that front-end money only encouraged the formation of companies that were irresponsible and projects that were nonresponsive with respect to DOE's objectives. They felt that the temptation for companies to use the government money in projects with very little chance of success was very strong—when the funding was not a function of technical excellence or project success. They suggested that success could be best rewarded by tax incentives.

. Small Energy Companies

Although the small energy companies generally held the same opinion as their larger counterparts with regard to front-end funding, they felt that funds for some specific purposes were required to further the development of geothermal energy. Among such projects were: the building of the transmission lines and exploratory drilling in new areas.

. Geothermal Companies

A small number of the geothermal companies suggested that front-end funding would be desirable to improve the economics of geothermal energy and make it more attractive to corporations selecting programs to be pursued. Because of the long lead times of geothermal projects—these companies maintained that support was needed to improve this energy's competitiveness vis-a-vis oil and gas development opportunities.

. Utilities

Most of the privately owned utilities did not feel that front-end funding was desirable; however, municipal facilities felt that front-end funding was absolutely necessary. In fact, they made the point that grants, not even loans, should be available to municipalities implementing geothermal programs.

. Engineering Companies

Most of the engineering companies, and all of the large companies, were of the opinion that front-end funding of projects and companies encouraged irresponsibility in the implementation of geothermal programs. On the other hand, a small group of the smaller engineering companies indicated their belief that cost-sharing represents the best contract vehicle to foster development of geothermal resources.

Nonelectric Users

Most of the nonelectric users, in contrast to the utility companies, indicated a need for front-end funding. This need stems from the newness of the technology and their uncertainty with respect to the resource.

Promoters/Developers

The enthusiasm with which the promoters/developers of direct heat applications of geothermal energy looked upon front-end funding was inversely proportional to their success in raising venture capital. Those promoters who were able to trade tax incentives for equity positions and venture capital felt that front-end funding was unnecessary and unwise. They maintained that such funding promoted irresponsible projects. They felt, moreover, that if the project were worthwhile, venture capital could be secured outside of government funding. The promoters/developers that have been unsuccessful in obtaining private capital, on the other hand, maintained that the projects in this new field need up-front funding—if for no other reason than to render a project loan-worthy in normal financing arrangements. In the current capital-scarce environment, those promoters/developers of direct heat applications indicating a need for government up-front funding are in the majority.

Financial Institutions

In general, the position of the financial institutions was ambivalent. On the one hand, they pointed out the front-end funding provided greater credibility to small companies seeking commercial funding from their institutions; on the other hand, they admitted that screening procedures for advancing such government funding were not always rigorously applied and, consequently, some ill-conceived and poorly managed projects were undertaken by

irresponsible companies. In general, they felt that any offering by the Federal Government of direct or front-end funding should be balanced against the aggravated costs of the program resulting from the delays caused, in turn, by the government processing of the funding requests.

Miscellaneous Incentives

In addition to the specific incentives that were the subjects of the interviews, from time to time during the interview process, individual respondents suggested incentives unique to their roles in the geothermal industry or to the fruit of their experience in the implementation of specific programs. Although these viewpoints originated with the respondent being interviewed, they are not necessarily minority opinions; but rather, they represent individual thoughts on subjects that had not come up in previous interviews.

One of the small energy companies, in contradiction to the majority and almost unanimous opinion of the other small energy companies, indicated a requirement for more demonstrations by DOE—stating that industry cannot carry the geothermal program alone.

Some of the utilities were interested in the programmatic aspects of the government effort. They stressed the need for a well-defined and reliable DOE program—not only responsive to utility needs, but one that would provide incentives to industry to explore new technology. The greatest encouragement to the field, they thought, would be a recognized government commitment to the development of geothermal energy. These companies specifically suggested the enactment of a new Federal Utility Cooperative Agreement—within the perspective of the needs of geothermal energy development.

Some of the engineering companies, very conscious of the fact that the industry is market-driven—particularly utility driven—indicated a need for a new definition of

of industry roles—in consideration of the fluidity of the interface between developers and utilities in the current geothermal industry. They suggested that the limited electrical production already undertaken by some of the geothermal companies could be enlarged, and electricity produced as a matter of course by even the large energy companies—if the excess power developed could be made available to the utilities without the currently required elaborate wheeling arrangements.

A few specifics were mentioned by the engineering companies: They proposed a reduction of risk to the developers initially—which would flow to the engineering companies ultimately—by guaranteeing the market price of the steam.

Some of the engineering companies pointed out a critical need to provide transmission facilities. This need goes beyond financing which is substantial, but more important, to a government commitment to electrical transmission—even across some of the Federal land in questionable states of wilderness definition.

Similarly, some of the companies in ancillary roles in the industry suggested incentives they felt would benefit the geothermal industry as a whole. The drilling companies felt that the necessary emphasis had not been placed on this energy source in the public and private sectors. They stated that it was necessary for them to plan market entry and equipment acquisition; consequently, they needed a firm government position and program to furnish direction. Similarly, the industrial associations stressed the need for greater visibility for geothermal energy in the Federal programs.

IV. INSTITUTIONAL CONSIDERATIONS

IV. INSTITUTIONAL CONSIDERATIONS

Although industry's assessment of the technology associated with geothermal energy production and utilization has concluded that there are no significant technological barriers to geothermal development (as discussed in Chapter II), its analysis of the economics of the development suggests that (as discussed in Chapter III) without new incentives the feasibility of geothermal energy as a competitor to alternative energy forms remains marginal. However, some of the major incentives enacted or under consideration in current legislation promise to provide the necessary margin to establish geothermal energy as a feasible competitor; but industry maintains that the promised advantages are frequently being dissipated in inordinate delay in the implementation of those same incentive programs. Of more significance, from the industry's viewpoint, are the institutional barriers erected by Federal, state, and local governments, particularly with respect to environmental protection.

1. CURRENT INSTITUTIONAL REQUIREMENTS THREATEN TO DESTROY THE ADVANTAGES ENJOYED BY GEOTHERMAL ENERGY AND TO FRUSTRATE RECENT FEDERAL LEGISLATIVE INITIATIVES TO PROVIDE NEW INCENTIVES TO INDUSTRY

The Geothermal Steam Act of 1970 had as its intent to "encourage private enterprise to invest in and develop this resource...and make possible the development of presently untapped natural resources of the publicly owned lands of the United States, resulting in new supplies of pollution-free power...." However, because of the atmosphere created by the National Environmental Policy Act of 1969, the overall effect of the Geothermal Steam Act in many cases was something less than an incentive for the development of this resource. Nor was the situation particularly alleviated by the Geothermal Energy Research Development and Demonstration Act of 1974 in spite of its loan guarantee provisions.

Moreover, the operation of the Geothermal Steam Act has been marked by delay. Nearly 4 years lapsed before regulations were promulgated that would allow leasing of the Federal lands; and once promulgated, implementation of the act was fraught with additional delays caused by the many requirements—mostly environmental—inherent in the

operation of the provisions of the act itself. As a result, as observed in the report to the Interagency Geothermal Coordinating Council from the Streamlining Task Force:

The significance of the amount of acreage leased competitively is that even though this land lies on known geothermal resource areas (KGRAs), which should, at least in some cases, be the most attractive to potential developers, only 428,000 acres have been leased since January 1974 out of a total of over 3 million acres of Federal lands theoretically available for leasing in the KGRAs. On lands leased noncompetitively, the statistics are equally condemning as one realizes there are over 95 million acres of Federal land in the Western United States, of which 55 million acres are considered potential geothermal resource areas. Less than 2 million acres are currently under lease.*

In addition to the barriers to geothermal development incidentally growing out of the operating requirements of legislation aimed at encouraging geothermal energy, that development has been critically impacted by legislative and regulatory strictures—mostly of an environmental nature—specifically designed to control the resources development. Currently, the Federal geothermal leasing and permitting program is subject to the requirements of the following regulatory controls:

- . Geothermal Steam Act of 1970
- . National Environmental Policy Act of 1969
- . Federal Land Policy and Management Act of 1976
- . National Forest Management Act of 1976
- . Endangered Species Act of 1973
- . National Historic Preservation Act of 1966
- . Federal Water Pollution Control, as amended
- . Clean Air Act, as amended
- . Resource Conservation and Recovery Act
- . Noise Control Act of 1972
- . Coastal Zone Management Act of 1972
- . Wild and Scenic Rivers Management Act
- . Wilderness Act and other conservation statutes
- . Safe Drinking Water Act.

Moreover, these acts are implemented by a variety of governmental institutions, including DOI, DOA, DOE, EPA, as well as many of their constituent bureaus such as the Bureau of Land Management, Bureau of Indian Affairs, U.S. Geological Survey, Forest Service, and Fish and Wildlife

*Geothermal Streamlining Recommendations, January 1979.

Service. In addition, there exists a full complement of state and local ordinances, restrictions, and regulations impacting the development of the resource, and, ultimately, geothermal programs can be subject to private suits in Federal and state courts.

2. INDUSTRY'S OVERALL VIEW OF THE PROSPECTS OF GEOTHERMAL DEVELOPMENT IS THAT THE BASIC INSTITUTIONAL BARRIERS—DENIAL OF ACCESS TO PUBLIC LANDS, RESTRAINTS ON LEASING AND LICENSING, AND ENVIRONMENTAL RESTRICTIONS—EITHER DENY MAJOR RESOURCES TO DEVELOPMENT OR, BY TIME-CONSUMING LICENSING PROCEDURES, MAKE DEVELOPMENT IMPRACTICABLE OR ECONOMICALLY PROHIBITIVE

The huge front-end investments required and the long delays imposed before return on investment can be realized—as a result of these procedural requirements—can completely vitiate the resource's competitive advantage even with new incentives.

Industry's overall perspective with regard to institutional barriers is seen in their interview responses (summarized by industry segment in Exhibit IV-1).

(1) All Segments of the Geothermal Industry Consider the Procedural Requirements of the Permitting and Licensing Provisions of Legislation Originally Designed To Promote the Development of Geothermal Energy To Constitute the Major Inhibiting Barriers to That Development

Although the Geothermal Steam Act of 1970, as already seen, was enacted to open for development the extensive Federal lands containing geothermal resources, the slow pace of its permitting process has proved the Act to be less a help to the geothermal industry than Congress envisioned. Industry's overall evaluation of the current permitting system is: it is so restrictive and cumbersome that it is to be avoided at all costs. Industry's perspective of this process (which will be discussed later in this chapter) is one of the most significant factors in determining corporate strategy with respect to geothermal energy—as will be seen in Chapter VI. The responses of the various segments of industry with respect to the permitting system are as follows:

Large Energy Companies

Most of the large energy companies focused on problems of uncertainty with respect to the permitting process, as it is currently implemented by the Federal Government. They emphasized in their interviews, repeatedly, that the only thing they cannot manage around is uncertainty. If the permitting requirements are too severe, the companies will simply opt for other energy forms. If the permitting system and other environmental requirements are known and, upon evaluation, are determined to be less severe than those impacting other forms of energy (e.g., nuclear or coal), industry will undertake geothermal development in accordance with the requirements of current legislation. They stress that, to a large extent, much of industry's hesitation regarding their involvement in the development of this resource centers on the indefinite commitments of their capital for indeterminate periods of time under conditions yet to be specified. They do not feel this to be an environment conducive to investment.

The whole DOE implementation of the permitting process, they feel, has been marked by an unpredictability of the bureaucracy and by ever-changing policy, approach, and personnel. Most of these companies interviewed singled out the EPA participation in the permitting process to be disastrous for the industry. They felt that a more reasonable environmental policy was needed—based on technology required, not all the technological innovation available.

Individual companies spoke of the difficulty in obtaining a definition or even a statement of the rules for implementation—as well as the difficulties of conforming to them. On occasion, such difficulties resulted in court action—when companies were brought into court by state action for nonperformance and proceeded to name as codefendant the Federal agency that had failed to provide the rules to which the company was expected to conform.

SUMMARY OF INSTITUTIONAL CONSIDERATIONS
BY INDUSTRY SEGMENT

INSTITUTIONAL CONSIDERATIONS INDUSTRY SEGMENT	POLICY CONSISTENCY		S&L CONSTRAINTS		DOE PARTICIPATION IN PROGRAM		OVERALL VIEW OF INSTITUTIONAL CONSTRAINTS		PERMITTING REQUIREMENTS	
	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY
ENERGY COMPANIES LARGE	Uncertainty in government policy adds to project risk.		State and local agencies even more difficult to work with than Federal agencies.	Some areas have been closed off to development because Federal programs were not coordinated with county plans.		Often DOE participation and concomitant requirements result in industry abandoning projects it would have funded itself.	Institutional requirements of DOE and DOI have caused company decision not to pursue or to curtail geothermal development.		Problem: unpredictability of bureaucracy - changing policy, approach and personnel. EPA's participation in permitting process terrible - need more reasonable environmental policy - based on what is needed, not what is available.	Had difficulty in getting rules for implementation - in addition to following them. Difficulties with Federal leasing program convinced company that it would never do it again.
ENERGY COMPANIES SMALL				California is a terrible state to work in; if there were available resources anywhere else, they would move their operation. Unit block approach in Utah is a serious constraint - because developer on adjacent land can join and dilute holdings of the unit holders.		Government is not used to risk climate; it is not good at funding exploration-type projects - result: spends 10 times amount necessary.	Institutional delays (7-8 yrs. vs 2 years overseas) have convinced management that all new operations in geothermal field will be foreign based. Intervenor action is uncontrolled and adds uncertainty to the already-complex government procedure. Current government environment not very encouraging to investors; therefore they will maintain current effort but will not start any new projects.	Severely critical of regulatory and environmental aspects of geothermal development at all levels of government. Companies will avoid Federal lands whenever possible. Problem with working public lands - it is not possible to get transmission lines across public lands, or roads, into them. Slow pace in government's removal of restraints has resulted in demise of many small companies and lack of activity in the larger companies.	Institutional requirements for leasing, licensing and developing - major barriers to geothermal development.	Federal requirements have slowed development to 1/10 the pace it could have developed.
GEOTHERMAL COMPANIES			State requirements vary widely; in general, worse than Federal requirements - as a result, economics are site specific.	County institutional restraints worst of all.		Companies have no faith in the government technology transfer program - although it is badly needed.	Major barriers are financial and institutional - result: no one is willing to take a risk. Institutional barriers increase cost and lengthen lead times - will result in consolidation of small companies and entry of well-financed companies.	Because of SEC rulings, there is no venture capital - SEC makes prospect unpalatable.	Difficult to understand the workings of the DOE approval process. Leasing program feasible. Companies avoid it by leasing on private land.	
UTILITIES	Changing rules result in added costs, retrofitting, and reoptimization of systems. DOE's environmental policy is inconsistent.	There is no uniform policy - it varies from site to site, making siting requirements unique ... and costly. Industry has problems in the assessment of a project - because of lack of knowledge and uncertain regulatory environment.							There are lengthy and costly delays to secure the necessary permits.	McClure Bill should mitigate some problems. Potential water rights issue. Company decided it will build geothermal plant when economics are equivalent to competitive energy forms - because licensing procedures more favorable.
ENGINEERING COMPANIES						DOE's participation a hindrance, rather than a help. Industry waits for DOE funding instead of going ahead itself.	Government leasing program getting worse, since '70, 50 new pieces of legislation enacted to restrict program.	Government patent and publication policies also hindrances to industry development.	Permitting process costly in time and money it is the largest restraint on development - after resource reliability.	Most of the possible leasehold-site on Federal land, therefore, permitting process required. Sometimes this requires 5-6 years - with money out and nothing being accomplished.
NONELECTRIC USERS				State assumes it owns resource - such determinations sometimes complex and procedure lengthy.			If Federal government serious about developing this resource, it must give access to it in the best circumstances possible for development.	Water rights may become serious hindrance.	If Federal permitting procedure is involved, project will probably not be feasible.	Permits from private land owners required - though procedure not as difficult as Federal.
PROMOTERS/DEVELOPERS			State requirements further delay an already complex Federal procedure.	State organizations are not sufficiently educated regarding this resource; programs are held back by imposition of standards that are not applicable - e.g., water rights, water quality, EIS, etc.		Government involvement should diminish in the years ahead.	Companies have not addressed or given up their public lands options and gone to private holdings. User, and hence the market, will go elsewhere - to avoid interaction with Federal policy.	Unenlightened imposition of institutional requirements/restraints may insure that failure is built into project. Geothermal regulations were written for electricity generation - not direct heat use - and their implementation is costly.	If the project gets involved with Federal leasing/permitting it will render project infeasible. Federal lands are therefore avoided.	Biggest constraint to development - getting permission to drill.
OTHERS DRILLING COMPANIES								Too much bureaucracy.	Should streamline permitting procedure if serious about geothermal development.	
INDUSTRIAL ASSOCIATIONS					Little awareness of Federal programs.					Industries go out of way to avoid Federal lands in order to escape permitting requirements.
FINANCIAL INSTITUTIONS						They see a major role for the Federal government in solving institutional problems.	Financial institutions are not in the business of developing social policy - consequently, will not subsidize industry to compensate for costly institutional requirements.			
GOVERNMENT VIEW			Federal - State and local government coordination badly lacking.		Discussions held - with DOE support - with National Council of State Legislators. Institutional problems being addressed - e.g., heating districts being defined, definition of resource being drafted, etc.	The disbanding of the Geothermal Advisory Council caused some ill will throughout industry.		Direct heat use is marginal proposition; institutional impact could destroy feasibility, e.g., - Volumes too small to threaten environment - but too small to attract venture capital. - Risk of regulation as public utility of more than a few uses involved. - Small companies - resource constrained. - A "reasonable prospect of repayment" (of FLG) must be maintained IAW the law and good sense. - However, as a result, length of time for grant - intolerably long; some delay avoidable, some not.	Time table specified in McClure Bill too stringent to be met. "Goals" more acceptable - as in Church Bill. - Greatest inhibitors to geothermal development are procedural, permitting system complex, time-consuming and to a substantial extent - counterproductive.	Industry must conduct its business in the time frame of the government or take its business elsewhere.

SUMMARY OF INSTITUTIONAL CONSIDERATIONS
BY INDUSTRY SEGMENT
(CONTINUED)

INSTITUTIONAL CONSIDERATIONS INDUSTRY SEGMENT	ENVIRONMENTAL CONCERNS		ACREAGE LIMITATIONS		INTERDEPARTMENTAL POLICY		INSTITUTIONAL NEEDS	
	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY	MAJORITY	MINORITY
ENERGY COMPANIES LARGE		If left alone company could have probably developed feasible project - but will not meet operating expenses because of unnecessary requirement for reinjection.	Federal limitations on geothermal acreage render development of potential impossible - and not worth company investment.	Would require 10-fold increases. Would require a minimum of 50 K acres but would prefer O&G acreage of 246 K acres.	Company is confused and finds confusion in conflicting viewpoints of DOE, DOI, EPA and USGS. Policies of and within departments conflicting; local BLM and Forestry the worst. One department will not recognize the determinations of another (e.g. DOE vs DOI).		Simplification of leasing, permitting processes. Opening of all Federal lands to exploration and development. Modification of environmental regulations to make them reasonable. Streamlining of regulations, in general, would be a tremendous help.	Desire the reinstitution of the Geothermal Advisory Committee.
ENERGY COMPANIES SMALL	Current massive effort government requires prior to original leasing and exploration of government lands ridiculous - suggest drilling first, then an EIS when it is determined that there is something worth developing.	To overcome industry reluctance to accelerate pace of geothermal development, government must clearly define environmental requirements and set up business climate to minimize external factors in business planning.		Inability of companies to secure large enough tracts of land for development has resulted in diminishing corporate interest.		EPA and CEQ moving independently of DOE and DOI. Consequently, geothermal development will never achieve its geological potential.		
GEOTHERMAL COMPANIES	Complying with environmental regulations costly.	Cost in Geysers went up by factor of 5 because of environmental reporting requirements.		Increase in acreage from 20 to 50 acres will not help commercialization.	On Federal lands - at least BLM, USGS, and DOE (thru Federal Loan Guarantee) are involved - and therefore NEP applies. However, the responsibility for prescribing the EIS requirement not determined.	The Federal/state relationship not always clear. Besides EPA, difficulties are encountered with state and local governments.		Need an "Implementing Factors Evaluation Group" - to expedite, to look into bottlenecks - at Assistant Secretary level. Bureau of Reclamation should push expansion of transmission network. The Geothermal Advisory Committee should be reinstated.
UTILITIES	Environmental requirements may impede geothermal development unnecessarily. Environmental requirements are often overstated. Changes to environmental regulations could make geothermal attractive to developers.	Desire that environmental requirements apply to field as a unit. Geothermal research must consider the full range of environmental and testing needs.			There should be different institutional requirements for power generation and direct heat use.		Need a well-defined program with respect to utilities' needs. Reduce the complexity of the DOE regulations. Need licensing and/or siting process that is timely and workable.	Classification of resource - water or mineral. Resolution of conflicting goals of Federal, state and local agencies.
ENGINEERING COMPANIES	Environmental requirements a significant restraint on development - time-consuming and costly.	Government is over-compensating for environmental impact. These problems even worse when dealing with states - can add up to 3 years.	Most of the possible leasehold too limited for commercial development.		Institutional problems especially acute when dealing with BLM, Forestry Service and DOE.	BLM has major effect - in requiring EIS and leasing policy in general - slows down program.		
NONELECTRIC USERS	Environmental impact by direct heat users usually much less serious than developers for power plants.	To reduce government concern, developer can post bond to warrant future conditions.			In developing source project often hindered by institutional squabbles among Federal, state and local governments.	Sometimes user owns surface rights; moreover, if municipality, will be accorded to them by BLM for "fair market value."		
PROMOTERS-DEVELOPERS	Major problem is environmental requirements - especially when EIS specified. In spite of minor impact - institutional requirements may destroy economics. Problem of providing for discharge costly - especially if reinjection specified.	Disposal attitudes difficult to address - forcing reinjection for every application. Environmental requirements on private land not too severe.						
OTHERS DRILLING COMPANIES		Completion restraints critically affect economic feasibility.						
INDUSTRIAL ASSOCIATIONS		Because they have more contacts with Federal government, industry perceives that they have greater problems at Federal level.						
FINANCIAL INSTITUTIONS	Environmental requirement seems less restrictive for geothermal than other energy forms (with exception of subsidence).	Utilities having trouble in getting permission to bring power lines across roadless areas.						
GOVERNMENT VIEW	The other major inhibitor of geothermal development is the requirement of and administration of the Environmental Impact Statement.				Lack of interdepartmental cooperation - major problem - e.g., DOE's requirement for an EIS at East Mesa - when BLM and EPA ruled it was necessary.	Most of the delay in leasing caused by BLM field personnel - especially in California. Forestry officials in field make their own determination requirements for leasing and permitting.	Consideration of special approach to institutional requirements for direct heat use - since impact less severe than power generation. Diminishing length of time to receive a FLG badly needed; shifting approval from Secretary to Asst. Secretary will help; shifting approval authority to field - urged in some quarters.	

EXHIBIT IV-I
SUMMARY OF INSTITUTIONAL
CONSIDERATIONS BY
INDUSTRY SEGMENT
(CONTINUED)

Some companies stated they have been convinced by the difficulties they encountered with the Federal leasing program that geothermal energy is not a program to be pursued.

Small Energy Companies

Most of the small energy companies stated that, in their opinion, the institutional requirements with respect to leasing, licensing, and development constitute the major barriers to geothermal development. Further, they indicated that these barriers were, in many cases, so formidable that they not only succeeded in wiping out the natural advantages of geothermal energy compared to the less environmentally benign energy competitors, but overbalanced the incentives specifically enacted by the Congress for the encouragement of geothermal development. A few of the smaller energy companies attempted to quantify this impact—finally agreeing that Federal regulatory requirements have slowed the development of geothermal energy to one-tenth the pace at which it could have proceeded in a more reasonable institutional environment.

Geothermal Companies

Most of the geothermal companies admitted their difficulty in understanding the intent of the geothermal requirements or the workings of the DOE approval process. In many cases, they felt that the incentives proffered on the one hand were negated by the inhibitory requirements on the other. In general, these companies felt that the Federal leasing program was terrible; and, consequently, they avoided it, when possible, by leasing private lands.

Utilities

A majority of the utilities pointed out that for a segment of industry already suffering from lack of capital, costly delay in securing the necessary permits for development and operation was one of the major factors inhibiting their selection of geothermal energy

in meeting their companies' energy demands. Consequently, most frequently an alternative energy source was selected.

Some of the companies felt that the McClure Bill should mitigate some of these problems but, at the same time, pointed out essentially new institutional problems concerned with the water rights issue.

Despite the evident institutional difficulties associated with geothermal energy development, one company decided that these difficulties still remain less formidable than those associated with nuclear energy; and it felt that rigorous application of the Clean Air Standards with regard to the coal industry would result in geothermal energy's enjoying a competitive advantage over both these forms of energy. However, this company did not find the advantage so overwhelming that it saw a clear-cut case for geothermal energy in view of the marginal economics of its utilization.

Engineering Companies

The net assessment of the permitting process by most of the engineering companies was that it is so costly in time and money, it constitutes the largest restraint on the development of geothermal energy—after the uncertainty associated with the reliability of the resource itself.

Some of these companies pointed out that most of the leasehold sites are on Federal land and that despite their earnest efforts, they have been unable to circumvent the Federal permitting process. Consequently, they have been required to factor into their cost estimates a 5- or 6-year outlay of capital with nothing being accomplished or, alternatively, abandon their geothermal programs altogether.

Nonelectric Users

Most of the final users of geothermal energy in direct heat applications maintained that if Federal permitting procedures were involved

in a project, it would probably not be feasible and, without special Federal fundings or incentives, would be abandoned at the outset. On the other hand, some of the companies pointed out that permits are required for development of sites on private lands as well—although they admitted that the requirements are not nearly so difficult to meet as those associated with development on Federal lands.

. Promoters/Developers

A majority of the promoters/developers interviewed admitted that the Federal permitting procedures rendered most of the direct heat application projects infeasible from the beginning. Consequently, they either sought resources for development on private lands or restricted their development activities to those funded or subsidized by Federal funds.

. Others

The industrial associations indicated that their member geothermal industries went out of their way to avoid developments on Federal lands and their concomitant permitting requirements. The associations and the drilling companies suggested that existing permitting procedures must be streamlined if the Federal Government, particularly the Department of Energy, is serious about the development of geothermal energy. They were aware of, and applauded, the recommendations of the Streamlining Task Force and its report to the Interagency Geothermal Coordinating Council.

. Government Viewpoint

The majority of the government respondents, although sympathetic to the views of industry, felt that the McClure Bill went too far in establishing a specific timetable for the implementation of the permitting process. The limits specified were considered by most of the government respondents as too stringent. The government respondents recommended that, as an alternative, goals be substituted for

stringent time limits—an alternative proposed by the Church Bill. However, the respondents, though varying in their proposed solutions to the problem were nearly unanimous in their view that the greatest inhibitors to geothermal development are procedural rather than substantive. Overall, they declared the current permitting system to be too complex, time-consuming, and, to a substantial extent, counterproductive.

A small group of government respondents, on the other hand, did not feel that current procedural requirements were excessive; and they scored industry for its impatience with government-instituted safeguards designed to protect the environment. They felt that sufficient time for consideration of proposed projects was necessary and desirable. Moreover, they stated that industry must conduct its business in the time frame of the government—or take its business elsewhere.

(2) Environmental Concerns Are Not Only at the Hub of Most of the Inhibitory Procedures of the Permitting System, But Are the Subject of Specific Regulatory Controls in Their Own Right

A pacing item of the current permitting system is the environmental impact assessments required by various agencies at different stages of the procedure. In general, industry finds them to be complex, over-restrictive, and time-consuming. However, they are somewhat divided on the means to improve the situation. Other than asking for less stringent requirements and more simplified procedure, they are far from unanimous in their views on environmental reviews. Although some of the companies interviewed felt that complete environmental impact assessments should not be required for early exploratory programs, other companies felt that they were unwilling to risk exploratory funds and effort for projects that may later be deemed inappropriate for development because of environmental concerns. The following are industry views synthesized from earlier interviews.

Large Energy Companies

Most of the comments of the large energy companies concerning environmental considerations were very specific to individual projects.

One company stated that if it had been left alone, it would have probably been able to develop a feasible project on its own and provide the nation with not only a new operating energy resource but a new proven technology as well. However, because of unnecessary and irrelevant requirements for reinjection at this site, the company will not meet its operating expenses and will probably terminate its program upon completion of this project. The company stressed that the reinjection requirement stemmed less from a recognized environmental danger than from lack of technical understanding on the part of the government authorities.

. Small Energy Companies

Most of the small energy companies with programs of substantial size stated that the current requirement for massive environmental impact studies prior to original leasing and exploration of government lands is ridiculous. They suggested that a more logical sequence would be drilling first, then developing an environmental impact statement—when it is determined that there is something worth developing. Some of the companies outlined their overall philosophy of investment selection with respect to geothermal energy vis-a-vis other opportunities. They suggested that the government must clearly define its environmental requirements and set up a business climate to minimize external factors in overall business planning—if it is serious about overcoming industry reluctance to accelerate the pace of geothermal development. They stated that this consideration was broader than environmental requirements and addressed the whole problem of institutional barriers: the leasing and permitting system, acreage limitation, and environmental restrictions.

. Geothermal Companies

Most of the geothermal companies stated, unequivocally, that compliance with current environmental regulations is so costly that the competitive edge once enjoyed by geothermal

energy has been dissipated. Some of the companies involved in the Geysers development reported that their costs went up by a factor of 5 from their early developments—as a direct result of new and questionable environmental requirements.

Utilities

Utilities were almost unanimous in their feeling that environmental requirements may have impeded geothermal development unnecessarily. They felt that the environmental overkill had somehow to be mitigated to make geothermal energy attractive to developers. They felt that significant changes in environmental regulations are necessary.

Engineering Companies

In general, the engineering companies felt that the present environmental requirements present a significant constraint on geothermal development in that they are time-consuming and costly to the developer, and to the user, ultimately. Some of the companies felt that the government was overcompensating for current environmental concern. Moreover, these same companies indicated that dealing with state and local governments was even more difficult than meeting the requirements of the Federal Government with respect to the environment. This latter burden has become a major item of anticipated escalating costs by engineering companies when estimating overall project costs.

Nonelectric Users

Direct heat users made the point that the environmental impact of direct heat applications is usually viewed as much less serious than that associated with developments for power generation. The volume of the resource used is less; the overall installation is much smaller; and the location is generally farther from wilderness sites and closer to already developed industrial or municipal complexes. Consequently, the concerns of conservationists

are not nearly so great as when considering a major power installation developed in a currently roadless and undeveloped wilderness area. Moreover, some of the direct heat users made the point that the concern of the environmentalists can be mitigated by developers posting a bond against any permanent harm to the site. This technique has been used in the past with other energy development programs.

Others

- Drilling Companies

Some of the drilling companies, considering the completion requirements of the projects with which they have been concerned, indicated that the extent of these requirements is often determinative with respect to the economic feasibility of geothermal development projects.

- Financial Institutions

Most of the financial institutions with long histories of dealing with energy development projects find the environmental requirements for geothermal development less restrictive than some alternative energy sources (e.g. nuclear) —with the possible exception of the requirements and constraints dealing with subsidence. However, some of these institutions have pointed out that some of the utilities, the ultimate users of the geothermal resources, have had trouble in securing permission to bring power lines across some of the current roadless areas. Delay in receiving such permission threatens the overall feasibility of the development of the geothermal resource.

Government Viewpoint

Most of the government officials interviewed in the course of the study agreed with industry that the other major inhibitor (in addition to the permitting requirements) of

geothermal development is the administration of the environmental impact assessment. This requirement, as previously pointed out, affects the permitting procedures and, in lengthening the time for development of the resource, greatly impacts the economic feasibility of the resource's development.

(3) Acreage Limitations, Designed To Protect the Small Developers From Competition by Larger Developers, in Practice Threaten the Small Developers With Early Competition and Cause Larger Developers To Lose Interest in the Federal Program at the Outset

The limitations on leasehold acreage specified by the Geothermal Steam Act of 1970 has been one of the more controversial and most criticized segments of current geothermal legislation. The original intent of this legislation was to provide a means for ensuring the participation in the leasing process by small operators and to shield them from competition by the large developers with substantially greater economic strength. Under the act, a known geothermal resource area (KGRA) is defined as:

" . . . an area in which the geology, nearby discoveries, competitive interest, and other indicia would (in the opinion of the Secretary of the Interior) engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose."

As a result, 47 of the 107 existing KGRAs were designated entirely on the basis of "competitive interest." This term, as defined in the regulations, actually means "competitive overlap" (i.e., the entire acreage covered by the noncompetitive lease applications which overlap is designated a KGRA if at least one-half of the lands are also covered by another application filed during the same 30-day application period). As observed by the Streamlining Task Force, "This situation may or may not constitute indicia of a commercial resource or real competitive interest."

The Act further specifies that geothermal leases can be obtained on a KGRA land only through competitive bidding, regardless of the reason for the KGRA designation. In practice, as the Task Force notes, all non-competitive applications that cover lands in KGRA status will be rejected in whole or in part, depending on whether all the applied-for acreage is KGRA or only part of it. As a consequence, industry alleges that some of the most promising tracts of KGRA land are not being offered. In addition, of the tracts offered, a relatively low number of bids have been received—exacerbating the problem. And, as pointed out by the Streamlining Task Force, when the total bid number is compared with the number of tracts bid, "it can be seen that interest very clearly centered only on specific tracts." Approximately 30 percent of all sales have produced no bids at all, and in some KGRAs, it has taken two or three sales to generate even one bid for parcels offered. In other KGRAs, in which there is intense interest in the lands that are potentially available for lease, the Task Force has observed that there have been no sales at all.

A complicating factor has been the fact that the Geothermal Steam Act requires lands in KGRAs to be leased to competitive bidding but further states:

If the lands to be leased are not within any known geothermal resources area, the qualified person first making application for the lease shall be entitled to a lease of such lands without competitive bidding.

DOI has interpreted this provision to mean that the first qualified applicant is entitled to lease if, after his application is adjudicated, the land applied for is not within a KGRA. The clear listing step—the full determination that the land is not KGRA—is the last step in the leasing process just prior to a lease issuance. During processing time, the applicants are legally entitled to apply for exploration permits. However, as the Task Force points out, they are reluctant to initiate exploration on applied-for adjacent land out of fear that their own exploration, if successful, will trigger KGRA designation. This could occur "because temperature gradient holes and/or other exploration activities could provide sufficient 'evidence' to support KGRA designation." As indicated by

the Task Force previously, if a KGRA that embraces applied-for land is established during adjudication of noncompetitive applications, the applications will be rejected, in whole or in part as the case may be, causing the applicant to lose his land position. In such cases, if and when the land is offered for competitive bidding, the applicant must bid to protect the land positions he was attempting to develop--or risk losing that particular acreage to another bidder. It is pointed out by the Task Force that this would be especially galling if it were his own exploratory effort and dollars that engendered the KGRA. The Task Force finds his reluctance to risk this situation to be thoroughly understandable, and consequently accounts for major delays in exploratory work. The concept of the KGRA is particularly restrictive when the parcels of the lease are limited to 20,480 acres in any one state. Operators complain that their exploration programs are severely inhibited by the current acreage restriction. Proposed legislation to increase the limitation to 51,200 acres per state is currently under consideration by the Department of the Interior and by the Congress. The following is a summary of comments of the various segments of industry with respect to the acreage limitation and the effects of the KGRA concept of competitive leasing--and with respect to a Federal ritual that calls into play the complete panoply of permitting and leasing procedures with the concomitant requirement for an environmental impact statement.

Large Energy Companies

Most of the large energy companies indicated that, in their opinion, the Federal limitation on geothermal energy development acreage hinders development of potential sites because it parcels out the development opportunities into packages too small to be worth the company investment in time and/or resources. These companies point out that even the largest of the geothermal projects is barely equivalent to a small oil field. From the point of view of the large energy company, the choice of the investment would be clear--given the Federal limitations on the size of the geothermal project--they would opt for the oil or gas field. Some of the companies indicated that, to be worth their while, a tenfold increase in acreage limitations would be necessary. At a minimum, these companies

argued that a 50,000-acre limitation would be necessary, but they felt that an oil and gas parceling of 246,000 acres would be preferable.

. Small Energy Companies

Some of the small energy companies and, unfortunately, some of those with major geothermal development programs stated that the inability of their companies to secure large enough tracts of land for geothermal development has resulted in diminishing corporate interest in pursuing projects associated with geothermal energy.

. Geothermal Companies

The geothermal companies that commented on the acreage limitations were generally of the opinion that the proposed increase of acreage limitations from 20,000 to 50,000 acres will not help the commercialization potential of the resource very much. They felt that a much larger increase is necessary in view of the competitive aspects of the KGRA concept and the great uncertainty with regard to the reliability of geothermal resources.

. Engineering Companies

Most of the engineering companies agreed with the energy companies—that most of the leaseholds available today, under the present acreage limitations and the KGRA concept, are too limited for commercial development.

- (4) The Lack of Interdepartmental Coordination, With Its Consequent Lack of Uniformity of Regulation and Concern With Prerogative, Has Not Only Resulted in Confusion in Industry but Has Caused Many Problems of Implementation, Unnecessary Duplication of Effort, and Escalation of Costs

In most of the interviews with the various segments of the industry, the interrelationship among the policies of the various impacting government agencies was stressed. The roles of the Department of Energy, Department of the Interior, the Department of Agriculture, and

the Environmental Protection Agency have already been addressed and their policy inconsistencies, as well as concerns with "turf," have presented major problems to industry in their conception and implementation of geothermal development programs. The following is a summary of the specific comments of the various segments of industry regarding the lack of coordination among various agencies in the government.

Large Energy Companies

Most of the large energy companies confessed to be confused by, and claim they found confusion in, the viewpoints of the Department of Energy, the Department of the Interior, and, particularly, the U.S. Geological Survey and the Environmental Protection Agency regarding industry's obligations. They found that the policies of and within the various departments to be conflicting. Moreover, they stated that very little control is maintained over their local agencies by the Bureau of Land Management and the Forest Service; and, in general, they found these latter agencies to be the most difficult to work with. Repeated examples were given by the respondents to support their impression that one department will not recognize the determinations of another (for example, the Department of Energy versus the Department of the Interior).

Small Energy Companies

Some of the small energy companies stated that the Environmental Protection Agency and the Council for Environmental Quality were moving independently with respect to the programs and objectives of the Department of Energy and the Department of the Interior. Consequently, they felt that policy inconsistency and the consequent confusion in industry will ensure that the development of geothermal energy will never reach its geological potential.

Geothermal Companies

Most of the geothermal companies indicated their overall confusion in dealing with Federal agencies with overlapping jurisdiction. They pointed out that on Federal lands at least the Bureau of Land Management, the U.S. Geological Survey, and the Department of Energy (through the Federal loan guarantee program) are involved—and, consequently, NEP applies. However, these same companies have not been able to determine who has the responsibility for determining the environmental impact statement requirement. They pointed out that the Department of Energy is a particular offender in this regard—using its financial participation to override and duplicate functions of the other agencies.

Engineering Companies

Most of the engineering companies stated that interdepartmental coordination between overlapping jurisdictions is a major problem in attempting to implement geothermal projects; they stated that institutional problems are especially acute when dealing with BLM, the Forest Service, and the Department of Energy. Some of the companies singled out the Bureau of Land Management as an agency that has a major effect on the development of geothermal energy—in its requirements for environmental impact statements in particular and its leasing policy in general—and is responsible for slowing down the pace of the development of this resource.

Nonelectric Users

Most of the companies engaged in developing direct heat application of geothermal energy stated that the development programs with which they have been associated have often been hindered by institutional squabbles between Federal, state, and local governments. Some of the companies have encountered difficulties with respect to agreement by different agencies of the definition of ownership of areas, and particularly the determination of

surface and subsurface rights to resources. Moreover, even when some municipalities have been accorded surface rights by the Bureau of Land Management, a problem has arisen in the determination of "fair market value" for the resource. These companies pointed out that it has been very difficult to find one agency capable of making a determination that will be recognized by the other involved agencies.

Government Viewpoint

Most of the government officials interviewed admitted that the lack of interdepartmental cooperation is a major problem in promoting the use of geothermal energy—for example, DOE's requirement for an environmental impact statement after BLM and EPA ruled it was unnecessary. However, some of the officials indicated that, in their opinion, most of the delay in leasing was caused by BLM field personnel—especially in California. Some of the respondents pointed out that Forest Service officials in the field often make their own determinations with regard to the requirements of leasing and permitting—almost independent of the overall policy of the Department of Agriculture.

(5) A Lack of Policy Consistency Forces Corporations to Manage in an Environment of Uncertainty

From time to time in the course of the interviews with industry, various companies indicated that a major hindrance to their developmental program was the lack of consistency in Federal policy—distinguished from the lack of interdepartmental coordination of policy. Since the interviewer did not ask this particular question, comments were scattered and offered on the initiative of the respondents. These comments by the various segments of the geothermal industry are summarized:

Large Energy Companies

Most of the large energy companies did offer comment on the lack of consistency of government policy. They pointed out repeatedly the problems associated with attempting to manage

in an environment of uncertainty. They specifically indicated that, in their opinion, this uncertainty in government policy adds to the project risk and, ultimately, to the cost of the development of the resource.

Utilities

Most of the utilities brought up the subject of policy inconsistency and stated that "changing rules results in added costs" to initial construction, and even more to retrofitting and reoptimization of systems in place. These companies singled out the Department of Energy's environmental policy as being inconsistent and difficult to accommodate. Some of the companies were more specific—pointing out that there is no uniform policy with respect to institutional requirements: the policy varies from site to site, making siting requirements unique and, consequently, very costly. The overall effect of this inconsistency, these companies point out, has been that industry has had difficulty in assessing the feasibility of these projects—because of the lack of knowledge and an uncertain regulatory environment.

(6) Industry's Difficulty With Institutional Barriers of the Federal Government Is Aggravated by State and Local Government Constraints

Although state and local government constraints are not within the purview of policy change for the Federal Government, the viewpoint of industry with respect to this added burden of inhibitory restraints completes the perspective of industry with regard to the feasibility of the development of this resource. The following is a summary of industry observations, by industry segment, with regard to state and local institutional barriers.

Large Energy Companies

Most of the large energy companies concluded that state and local government requirements and regulations were more difficult to accommodate than their respective Federal equivalents. Some of the companies pointed

out that the lack of coordination between the Federal regulations and state and local requirements have, on occasion, resulted in some areas being closed to development because the Federal programs were not coordinated with county plans.

Small Energy Companies

Some of the small energy companies singled out California as a "terrible state to work in." These companies stated that if the resources were available anywhere else, they would completely move their operations from the state. A couple of the companies also identified a problem unique to Utah—in that its block approach operated as a serious restraint to development. These companies maintained that under this concept, developers on adjacent lands can join and dilute the holdings of the original unit holders.

These companies identified institutional factors that they viewed as inhibiting considerations in corporate decisions with respect to investment in geothermal development.

Geothermal Companies

Most of the geothermal companies observed that the state institutional requirements varied widely; in general, they felt that they were worse than Federal requirements. As a consequence, most of the geothermal companies approached the feasibility of geothermal development as site-specific—in view of the fluctuating economics that are so much a function of the institutional environment of the project's development.

Nonelectric Users

Some of the final users of geothermal energy in direct heat applications had difficulty in determining ownership of the resource. In most cases they found that the state assumes that it owns the resource; but the determination is sometimes complex and the procedure lengthy. The ownership determination is

critical in identifying the agent with whom negotiations for the resources utilization must be carried out.

Promoters/Developers

Most of the promoters looked at state implementation requirements as still another layer of institutional constraints on an already complex Federal procedure—further delaying development of the resource. Some of the promoters pointed out that some of the state organizations were not sufficiently educated with respect to geothermal energy; consequently, programs are held back by the imposition of standards that are really not applicable to this resource (e.g., water rights, water quality, and extended environmental impact statements) while the program is in the exploratory stage.

Government Viewpoint

Most of the government respondents saw the state and local constraints in terms of the lack of Federal, state, and local government coordination. In general, they felt that such coordination was badly lacking. However, some of the Federal Government officials pointed out that discussions have been held as a result of DOE initiatives between the National Council of State Legislators and DOE. As a result, institutional problems have been addressed, Heating Districts have been defined; and definitions of resources have been drafted.

(7) Industry's View of DOE Participation in Geothermal Development Is Ambiguous; It Is Determined by the Degree of Success Achieved, the Proprietary Position Desired, and the Extent of the Support Needed

The interviewed company officials' comments with respect to DOE's place in geothermal program development were more concerned with incentive programs of the Department of Energy than with institutional barriers. The formalized participation of the Department in geothermal development was categorized as an institutional

consideration by industry rather than merely as a government-offered incentive. It was thus viewed by industry and, consequently, is included in institutional considerations in this study. The following is a brief summary of industry's view of DOE participation in geothermal development.

. Large Energy Companies

Most of the large energy companies looked with askance at DOE's participation in developmental programs. This industry's attitude stems from its view that, with government participation, comes certain institutional requirements that impose restraints on the industrial programs. Some of the requirements inherent in the DOE participation in programs of companies interviewed were viewed by those companies to be so severe that they subsequently abandoned projects that they would have funded themselves.

. Small Energy Companies

Some of the small energy companies observed that government participation complicated project implementation—not because of their imposition of new institutional requirements as much as their lack of understanding of the nature of new ventures. They stated the government is not used to the risk climate and is not very competent in funding exploratory-type projects. Consequently, they claimed that government participation generally results in an order of magnitude increase in the project cost.

. Geothermal Companies

The geothermal companies, many of which are rather small and are engaged in leading-edge technological development, indicated the need for government support; but they displayed little faith in the ability of the government to implement a technology-transfer program.

. Engineering Companies

Some of the engineering companies indicated that DOE participation, apart from its imposition of institutional restraints as a concomitant of its support, constituted a hindrance in another way. They felt DOE's promise of support caused most of industry to await DOE funding, with all of its inherent delay, rather than proceed with the program—as originally envisioned and scheduled.

. Promoters/Developers

Most of the developers, although anxious for government support in current programs, felt that government participation in roles similar to the direct funding of the demonstration programs it funds currently—should diminish in the years ahead.

. Others

The financial institutions interviewed considered DOE participation in development programs in a very different light from other segments of industry. They saw a major need for the Federal Government to solve institutional problems—if only refereeing and coordinating interagency policy overlap.

. Government Viewpoint

Some of the officials of the government interviewed in the course of this study pointed out that the disbanding of the Geothermal Advisory Council caused some ill will throughout the industry, for most segments of industry considered the work of the Council to be very beneficial. This view was, incidentally, raised by many of the industrial respondents spontaneously—even though it was not a subject ordinarily presented by the interviewer during discussions with industry.

- (8) Because the Institutional Barriers Are Perceived To Be So Formidable, Major Segments of the Industry Have Decided To Curtail Their Efforts in Geothermal Development in the U.S.

The free-form exchange of views carried out in the course of the discussions with the representative segments of the geothermal industry resulted in an overall philosophical point of view with respect to the current institutional environment. In some cases, the responses were specific, reflecting particular experiences or problems encountered; in others, and more significantly, the responses indicated corporate decisions that have been taken—based on the corporation's evaluation of the feasibility of developing this energy source in the current institutional environment. Some of the decisions reported by industry at this juncture provide an index to the corporate strategies developed. These are discussed further in Chapter VI. The following is a summary of overall viewpoints of various segments of the geothermal industry regarding the current institutional environment for the development of the geothermal energy.

Large Energy Companies

Based on the current institutional requirements of the Federal Government, most of the large energy companies have made the decision not to pursue new programs and/or to curtail current programs of geothermal development by their companies. This was a major finding of this study and is reflected in the corporate strategies that will be discussed in Chapter VI.

Small Energy Companies

The institutional delays encountered by some companies and perceived as possible by others have resulted in decisions by the Management of these companies that all new operations of geothermal development will be foreign based. These companies point out that the difference in program implementation time and, hence, the period of high investment between domestic and overseas programs represents a differential of 5 years (7 years versus 2 years). This time differential militates for the transfer of company effort to overseas

locations. They point out that, in today's environment, intervenor action is uncontrolled and adds a great deal of uncertainty to the already complex government procedures. They state that the current government environment is simply not very encouraging to investors; therefore, they will maintain current efforts but will not start any new domestic projects.

Some of the companies were specific in their attitudes. They were severely critical of the regulatory aspects of geothermal development programs with respect to environmental control—at all levels of government. Even those companies that are continuing domestic geothermal projects have decided that they will avoid developments on Federal lands—whenever possible. Moreover, these companies point out some basic barriers to development: Because of the Wilderness Act provisions and the uncertainty of the outcome of the current wilderness studies, it is not possible to get transmission lines across public land and/or roads into the areas for which development is projected. These are basic institutional barriers that render the whole development strategy uncertain at best, and impossible at worst. Moreover, although these companies are not affected as much as some of the smaller developers because of their financial resiliency, they point out that the slow pace of the government in removing unreasonable restraints has resulted in the demise of many small companies and the lack of interest in the large companies that possess sufficient staying power.

Geothermal Companies

Most of the geothermal companies—organized for the specific purpose of developing geothermal energy as an alternative to current energy sources—identify the major barriers of that development as financial and institutional. They have concluded that the barriers are so formidable that no one is willing to take the necessary risks for successful resource development. Specifically, they point out that institutional barriers increase the

cost and lengthen the lead times; this condition results in the consolidation of small companies and leaves the field open to the entry of well-financed energy companies. They suggest that the only reason the field is not completely dominated by these companies is because of their lack of interest. The same institutional barriers that forced out the small companies make the geothermal area less interesting to the large companies.

Engineering Companies

A large majority of the engineering companies singled out the government leasing program for criticism, pointing out that since 1970, 50 new pieces of legislation have been enacted to restrict geothermal development programs. They have great difficulty in concluding that the government is serious about the need for geothermal development in the face of such concentrated efforts in devising institutional barriers. Some of these companies, reflecting the fact that they are heavily engaged in technology development, point out that the government patent and publication policies also constitute hindrances to industry development. Aggressive technological development will be carried out by these companies only when it results in competitive advantage to the companies investing resources and ingenuity.

Nonelectric Users

Most of the users of direct heat application stated that if the Federal Government is serious about developing this resource, they must give industry access to the resource in the best circumstances possible for its development. A few of the users, reflecting their particular problems, singled out water rights as a possible future serious hindrance to the resource development.

Promoters/Developers

Most of the developers of direct heat applications have either not undertaken or have already given up their public land options,

and have taken their programs to private holdings. They have observed that their market, the users, have gone elsewhere; and, in fact, they advise potential users of geothermal energy to avoid interaction with the Federal bureaucracy by confining their efforts to private lands. Some of the promoters were more specifically critical; they stated that the imposition of government institutional requirements and restraints will ensure that failure is built into small projects associated with direct heat use. They pointed out that geothermal regulations were essentially written for electricity generation—not direct heat use. The imposition of these requirements in a sphere for which they were not designed proves so costly that it precludes direct heat applications on Federal lands unless supported by Federal funding.

Others

Some of the drilling companies indicated in the course of the interviews that there was too much bureaucracy involved in Federal programs.

The financial institutions provided a different viewpoint with respect to the institutional requirements of the Federal Government—from the financial perspective. These institutions stated that they were not in the business of developing social policy; consequently, they do not intend to provide funds to subsidize industry or to compensate for costly institutional requirements.

Government Viewpoint

Most of the government officials interviewed were very sensitive to the possible deleterious impact of institutional requirements. They observed that direct heat applications are particularly vulnerable to ill-advised institutional restraints. They pointed out that direct heat use is a marginal proposition; consequently, institutional impact could quickly destroy the feasibility of projects because:

- The volumes of the resource are too small to threaten the environment but, at the same time, are too small to attract venture capital
- The companies risk regulation as a public utility if more than a few uses of the resource are contemplated
- Small companies are resource constrained.

(9) To Overcome Major Institutional Barriers Inhibiting Industry's Geothermal Development Efforts, Better Definition of the Government Program, Simplification of the Permitting Process, and Enhanced Access to the Resources Are Required

In the course of the interviews carried out as part of this study, the respondents were asked to specify particular institutional changes that might render geothermal development more attractive, from industry's point of view, based on the specific institutional barriers already identified. The following suggestions were offered by the various segments of the geothermal industry:

Large Energy Companies

Most of the large energy companies were in agreement that the following institutional modifications would be desirable, and in some cases necessary, for the development of this energy source:

- Simplification of the leasing/permitting processes
- The opening of all Federal lands to exploration and development
- Modification of environmental regulations to render them more reasonable
- The streamlining of government regulations in general.

Some of these companies indicated a need for the reinstatement of the Geothermal Advisory Council.

. Small Energy Companies

Although generally agreeing with the needs listed by the large energy companies, some small companies indicated their desire to see entrepreneurs involved more heavily. They felt that this group of industry brought with their participation needed ingenuity in organization, financing, and technology. Moreover, the energy companies felt that industrial entrepreneurs were easier to deal with; as a result, in the long run, projects and property were more easily and less expensively managed when they were involved.

. Geothermal Companies

The interviewed geothermal companies talked of institutional initiatives beyond modification of current institutional barriers. They indicated a real need for what they described as "an implementing factor's evaluation group"—essentially a trouble-shooting staff to expedite projects by looking into bottlenecks. To be effective, these companies felt that it should operate at the Assistant Secretary level. An additional recommendation by this group called for a strong initiative by the Bureau of Reclamation to push expansion of transmission networks across public lands. Finally, this group independently suggested that the Geothermal Advisory Committee be reinstated.

. Utilities

Most of the utilities suggested that there was a definite requirement for a well-defined program related to the utilities' needs if they, geothermal's principal market, were to adopt this energy source. The utilities further suggested the necessity of reducing the complexity of the Department of Energy's regulations, and singled out the need for a licensing and/or siting process—that is timely and workable. Some of the utilities pointed to areas of institutional ambiguity and asked for clarification (e.g., basic resource definition to determine whether their use be

governed by water or mineral statutes). In general, these companies were anxious for resolution of conflicting goals of Federal, state, and local agencies.

Nonelectric Users

Most of the users of geothermal energy for direct heat applications repeated their contention that, because of the limited impact of the more modestly scaled operations associated with direct heat use, there should be different institutional requirements for this application than for the large-scale power generation activities.

Others

The industrial associations, commenting on industry's perception of the institutional barriers to geothermal development, observed that most of the segments of the geothermal industry felt that their development programs are inhibited by Federal regulations—simply because they have greater contact with Federal regulations than with the state and local bodies. The association urged greater effort on the part of the Federal government to explain the basis of current regulations; and, particularly, to make an effort to explain the program modifications enacted to stimulate the development of this resource. They pointed out that industry's willingness to periodically update their perspective of government programs in subsequent interviews provided an excellent vehicle for the government to explain its reaction to the industrial perspective—in addition to communicating industry, concerns of their own.

- (10) Two Major Areas of Institutional Concern Were Identified by Industry as Critical to the Future of the Geothermal Industry and Must Be Addressed if Industry Is to Be Persuaded That Geothermal Energy Represents a Feasible, Developable Energy Alternative—the Wilderness Act and the Permitting System

Although the foregoing litany of institutional concerns of the various segments of industry provide,

to a large extent, industry's perspective with respect to current institutional barriers to geothermal energy development, two areas addressed in the preceding discussion are singled out for further consideration because of the importance with which the geothermal industry viewed them as major inhibitors to their undertaking further development. These two areas are the Wilderness Act and the Permitting System.

The Wilderness Act

The first area of concern stems from the enactment of the Wilderness Act of 1974. The Act defines wilderness as: "an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain...an area of undeveloped Federal land retaining its primeval character and influence...and which (1) generally appears to have been affected primarily substantially unnoticeable; (2) has outstanding opportunities for solitude for a primitive and unconfined type of recreation; (3) has at least 5,000 acres of land or is of sufficient size as to make practical its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, and other features of scientific, educational, scenic, or historical value."

The report of the Streamlining Task Force points out that correlation of this definition with the remote location of many geothermal prospect areas indicates that geothermal resources will be competing with wilderness values in a number of areas. The Wilderness Act became law in 1974, but the National Wilderness Preservation System is not yet complete. Both the Bureau of Land Management and the Forest Service, as well as other agencies, are required to make recommendations for additions to the preservation system. The task force notes that the Forest Service's Roadless Area

Review and Evaluation (RARE II) is nearing completion and its decisions and recommendations are due in 1979. The RARE II process will place selected roadless areas into one of three areas:

- Areas recommended to the Congress for designation as wilderness
- Areas to be immediately available for multiuse management
- Areas whose status will be left for further planning for all uses, including wilderness.

The BLM wilderness review, recommendations of which will be submitted no later than October 21, 1991, will locate the roadless areas having wilderness characteristics. Such areas will be identified as wilderness study areas, which will then be subjected to analysis to determine the areas to be recommended as suitable for wilderness designation. The study phase, as this analysis is called, will then be followed by a reporting phase which will provide the Secretary of the Interior's recommendations to the President and to the Congress. In the meantime, the Steamlining Task Force points out that leasing has been sufficiently inhibited on certain forest lands that a suit challenging "de facto" withdrawal of the lands from oil and gas leasing has been filed in Wyoming. The contention is that public access to Federal lands is being denied without the consent of the Congress as required by the Federal Land Management Policy Act. The results of this suit, the task force states, will have a profound effect on the implementation of recommendations under the RARE II process.

The geothermal industry suffers from the same uncertainty with regard to areas of promising geothermal potential as with its definition under the Wilderness Act. Again, its objection is less to the lands being withdrawn as a result of their designation as

"wilderness areas" as to the uncertainty that remains while they have been withdrawn from any substantial development until the study is completed. Roads into areas and transmission lines out of the areas cannot be seriously contemplated until the study has been completed.

The Permitting and Licensing Process

If the institutional barriers to geothermal development represented by RARE II are formidable, they are also considered by industry to be, to a large extent, out of the control of the Department of Energy. In contrast, another set of institutional barriers associated with the licensing and permitting process, though not completely within control of the Department of Energy, are, at least, addressable. Moreover, DOE is in a position to take the initiative in effecting interdepartmental coordination of the whole process. The responsibilities for implementing the Federal Geothermal Leasing and Permitting Program are summarized in Exhibit IV-2. The actual processes for leasing both competitively and noncompetitively in accordance with the Geothermal Steam Act of 1970 are depicted in the activity flows presented in Exhibits IV-3 and IV-4.

However, the industry respondents pointed out that the flow depicted does not approach the reality of the implementation process. Very little is said about a timetable for implementation, and the long delays associated with repeated reviews of the environmental impact assessment and/or intervenor action is nowhere considered. Moreover, the activity flow does not consider the administrative difficulty or lack of skill in the processing of applications which has been exhibited by the various agencies administering the program since the receipt of the large number of applications at the time the 1970 Act was finally implemented in 1973. Industry's view is generally borne out by the statistics presented by the Streamlining Task Force to the Interagency Geothermal

EXHIBIT IV-2
Summary of Responsibility in the Federal
Geothermal Leasing and Permitting Program

BLM - Bureau of Land Management
DOE - Department of Energy
FS - Forest Service
FWS - Fish and Wildlife Service
GS - U.S. Geological Survey
IGCC - Interagency Geothermal
Coordinating Council

Land Management Planning	BLM/FS
Competitive Lease Sale Scheduling	BLM/FS/GS/Industry/ IGCC
Scheduling for Noncompetitive	BLM/FS (Primary) GS/FWS (Consulting)
Prelease Environmental Analyses	BLM and/or FS (Primary) GS/FWS (Consulting)
Postlease Environmental Analyses	GS (Primary) BLM/FS/FWS (Consulting)
Competitive Lease Sales	BLM (Primary) FS/FS/FWS/DOE (Consulting)
Noncompetitive Lease Applications	BLM (Primary) FS/GS/FWS (Consulting)
Development of Lease Stipulations	BLM/FS/GS/DOE
Issuance of Lease	BLM/DOE
Prelease BLM exploration Permit or FS Prospecting Permit	BLM/FS (Primary) GS and FWS (Consulting)
Postlease Exploration Permit	GS (Primary) BLM/FS/FWS (Consulting)

EXHIBIT IV-3
Pre-Lease Regulatory
Process

COMPETITIVE LEASING
PRIMARY RESPONSIBILITY - BLM

NONCOMPETITIVE LEASING
PRIMARY RESPONSIBILITY - BLM

(COMPILED FROM GEOTHERMAL STEAM ACT OF 1970, FEDERAL RULES AND REGULATIONS
43 CFR PART 3000 AND 30 CFR PARTS 270 B, 271, AND MEMORANDUM OF UNDERSTANDING
FOR THE GEOTHERMAL PROGRAM - USGS, BLM, FWS)

ABBREVIATIONS

BLM	- Bureau of Land Management
BLM-DO	- Bureau of Land Management District Office
BLM-SO	- Bureau of Land Management State Office
GS	- U.S. Geological Survey
GS-RCM	- U.S. Geological Survey, Regional Conservation Manager
AGS	- Area Geothermal Supervisor
GS-AG	- U.S. Geological Survey Area Geologist
GS-DG	- U.S. Geological Survey District Geologist
FWS	- Fish and Wildlife Service
FWS-RO	- Fish and Wildlife Service Regional Office
FWS-AO	- Fish and Wildlife Service Area Office
EAR	- Environmental Analysis Record (prepared by BLM)
EA	- Environmental Analysis (prepared by GS)
GEAP	- Geothermal Environmental Advisory Panel
R/C	- Agency Review and Comment
DOE	- Department of Energy

EXHIBIT IV-4
Post-Lease Regulatory
Process

Coordinating Council in its report of January 1979. Not only has the time required to process the application been unconscionable, but the number of applications still pending since their submission in 1974 still represents a majority.

The task force identifies the major critical delay in the process as originating in the interval during which the BLM district office and/or the Forest Service is considering the application. It points out that not only do the actual and median time frames in the process of this state—60 to 81 weeks and 55 to 48 weeks for BLM and FS respectively—greatly exceed the significant lags elsewhere in the process, but the "still pending" numbers are of greater significance. More BLM applications are still pending than acted on (22 to 16 percent), and the percentage of FS applications that have not been acted on is six times the percentage that have been processed. Moreover, the task force reports that these pending percentages would be considerably higher if large numbers of applications had not been withdrawn shortly after they were filed and did not remain in the system. For example, in California, 99 applications, or 28 percent, of the 357 BLM applications filed in January 1974, the first month of the leasing program under the Geothermal Act of 1970, were withdrawn within a year—many of them within 6 months or less. Fifty-six, or 34 percent, of the California Forest Service applications filed the same month were similarly withdrawn during the same period. The task force reports the finding that "the greatest significant delay arises at the BLM District Office/Forest Service Office consideration stage was not unexpected." It is at this point (as seen in the flow diagram) that

- The application is subjected to environmental review if the acreage involved is not already covered by review considered to be adequately up to date

- Decisions are made as to whether the land should be leased and, if so, under what conditions
- Specific stipulations are formulated if they are needed (e.g., stipulations attached to leases to provide for special treatment of all or some portion of the land—to protect an endangered species, for example.

These considerations, the task force points out constitute the "heart" of the leasing process. In addition, the time frames involved in environmental review set up a whole new round of possible delay and opportunities for independent actions for project hindrance. Overall, the average period for obtaining a lease for lands under BLM jurisdiction is 97 weeks, or slightly less than 2 years, with leases issued on only 18 percent of the applications and 30 percent still pending. The average wait for a lease on Forest Service land is under 111 weeks, or nearly 2 years and 2 months with leases issued on only 2 percent of the applications and 56 percent still pending. From the point of view of industry, the number of unacted-on applications is most significant, for capital investment and other costs continue until a decision is made.

Moreover, the activity flow developed in connection with the 1970 Geothermal Steam Act and illustrated in Exhibit IV-3, is not, in the opinion of industry, representative of the real situation faced by developers currently. What is assumed in the flow depicted in the exhibit is that decisions will be made at the nodes of the activity flows. What industry has discovered is that decisions are not necessarily made at those points and often industry is required to go through additional reviews or defend its proposals against attacks by various intervenors. A more realistic activity flow, from the perspective of industry, is depicted in Exhibit IV-5. This depiction of procedural flow resulted from a compilation

EXHIBIT IV-5
Industry's Perception of
Permit Procedures

of the experience of developers and utilities operating in California. The time limits suggested in the flow may not be the maximum delays encountered; it was pointed out that many of the data feedback paths illustrated in the exhibit, could enlarge the time required for completion of the administrative procedure and not anticipated in "normal" procedure. The duration of the complete procedural cycle that was repeatedly suggested in interviews with industry is approximating 7 years from the initiation of the project to the plant start. Whether industry is correct in its assessment or not, it is the figure most mentioned and believed by industry. More importantly, this figure has been generally employed by corporate management in making decisions regarding the feasibility of geothermal development. Consequently, 7 years is the planning figure militating for the transfer of corporate geothermal effort to overseas locations. The results of such decisions will be further discussed in Chapter VI.

As a result of the study of the institutional problem associated with the leasing and permitting system by the Streamlining Task Force, recommendations were made to the Interagency Geothermal Coordinating Council. In this report, a major new approach to the leasing and permitting procedure was suggested—whereby, as an alternative option, "staged environmental reviews," allowed separate environmental assessments of the exploration and development phases. In the opinion of the task force this option is viewed as a means of

- Expediting geothermal leasing exploration and development
- Ensuring adequate Federal control of other resources and leased areas
- Allowing reasonable and realistic implementation of NEPA.

The task force points out the advantages to the developer of phased environmental reviews.

- He can get on the land quickly to develop it and to determine its potential.

- After discovery and testing, the extent of the potential value of the resource is much better known, and positively located in relation to surface values, making management trade-off analysis much more knowledgeable and easier.
- He can protect his land positions in areas of mixed landownership.
- He can protect desired land positions in wilderness, roadless review, RARE II, or land management study areas under the Federal Land Policy and Management Act and the National Forest Management Act until the development/no development decisions are made, and if the development and other uses are not precluded, then the lessee will hold the exclusive right to development.

The advantages to the government are:

- Savings in time, manpower, and financial resources in evaluating the conjectured effects of an unknown resource
- Speeding the pace of environmental assessments in potentially exploitable areas in order to expedite their contribution to the nation's energy supply.

The task force indicates that the principal elements of this recommendation, illustrated in Exhibit IV-6, envision that the U.S. Geological Survey, as lead post-lease agency, will conduct the environmental review upon submission of a plan of operation for development and utilization of a discovered resource. USGS will then be assisted by the appropriate land management agencies in the analysis. Approval of the plan by the land management agency as well as by USGS will be required. If the plan is not approved for legal or a significant environmental reason, it will be rejected with reason or considered for approval with suggested changes. If no approvable revised plans are submitted, development will be denied. This is similar

EXHIBIT IV-6
Principal Element of Proposed Phased
Environmental Review Procedure on Federal Lands

Source: Interagency Geothermal Coordinating Council

to the approach of the State of California geothermal leasing process, which is mandatory.

The task force cautions, however, that the phase review process offers further risk to the developer in an already high-risk business. If, for example, a developer accepts a conditional lease and finds that he has commercial resources, he can (1) be denied the opportunity to develop because of environmental sensitivity to the land, or (2) has such severe restrictions imposed that development in the area is no longer economic. For these reasons, the task force recommends the approach be an elective option on the part of the applicant. The following are other options recommended by the task force:

- The use of regional or area-wide environmental analyses and pre-lease review, and the conduct of site-specific studies only during the post-lease permitting process
- The setting of time limits or time frames (through administrative directives and/or regulations) for issuance of leases and permits
- Improvement in the coordination of all phases of pre- and post-lease activities
- Improvement in the uniformity and consistency of policies and procedures with respect to lease stipulations among the involved agencies
- The institution of formal nomination procedures for KGRA's and noncompetitive areas
- The allowance of no-surface-occupancy leases in wilderness study areas and other special areas where requested
- Modification of KGRA regulations

- Allowance of the issuance of noncompetitive leases unless the area is in a KGRA at the time of application
- The provision of budgets in proportion to workloads, organizational needs, and priorities
- Base leasing decisions on area-wide environmental assessment in combination with land management plan.

* * * * *

It is apparent that many of the recommendations of the Streamlining Task Force directly address the concerns of industry with respect to the use of geothermal energy. The extent that these measures, if taken, will alter industry's perspective of the feasibility of geothermal energy, and hence its future strategies with regard to this resource's development, remains to be seen.

V. TRADE-OFF CONSIDERATIONS

V. TRADE-OFF CONSIDERATIONS

The decisions of Corporate Management with respect to the development and utilization of geothermal energy take into account considerations of the technology, economics, and institutional requirements associated with this energy source, as discussed previously. Within the framework of the basic decision to initiate a geothermal program, more particularized decisions, to a large extent site-specific, are required.

1. A DECISION TO PROCEED WITH THE DEVELOPMENT OF A SPECIFIC RESOURCE IS TAKEN ON THE BASIS OF TRADE-OFF ANALYSES CONCERNED WITH THE NATURE OF THE RESOURCE, ITS LOCATION WITH RESPECT TO ITS NATURAL MARKET, THE TECHNOLOGY REQUIRED FOR ITS EXPLOITATION, THE INSTITUTIONAL CONSTRAINTS IMPOSED ON DEVELOPMENT IN THAT LOCATION, AND THE OVERALL ECONOMIC ENVIRONMENT GOVERNING THE PROJECT'S DEVELOPMENT

These decisions are made by corporations considering these projects in a more or less logical sequence—either explicitly or implicitly following a pattern similar to that illustrated in Exhibit V-1.

The overall criteria used to determine the feasibility of a specific reservoir for development are multifaceted. The more energy-intensive the associated industry with respect to processing and transportation, the greater the savings that are possible from the substitution of geothermal energy for more expensive fossil fuels. One of the most energy-intensive industries in the United States is the utilities; consequently, it represents a most likely candidate to consider the use of geothermal energy. However, because of the wide temperature range of geothermal reservoirs, direct heat applications are more frequently compatible with available resources than power generation.

Given an overall corporate decision to develop geothermal energy, decisions related to the implementation of the specific resource must be made—a suggested flow of which is depicted in Exhibit V-1.

The decision process begins with a review of pertinent geophysical data related to the specific site and continues along the following sequential steps.

EXHIBIT V-1 Decision Flow

(1) Step 1. Formulate Drilling Schedule From Geothermal Information

Once the geophysical data have been reviewed and a commercially attractive site is believed to exist, an exploratory drilling schedule is set up.

(2) Step 2. Determine the Nature of the Resource

Assuming the exploration of the area yields a reservoir of dry steam or water with a temperature greater than 450°F, a total of three wells will be drilled for further reservoir testing. If steam is not found and the temperature of the water is less than 450°F, a separate sequence of decisionmaking will be undertaken and will be discussed later.

(3) Step 3. Test Well Properties

In this step, the resource will undergo a series of tests to determine its suitability for electricity generation. Tests will include both flow rate and well interference analysis. In addition, during this resource analysis, possible geochemical problems associated with the properties of the brine will be analyzed, such as precipitates and corrosives. Based on this analysis of possible precipitates, the resource will be examined to determine whether additives to inhibit precipitation or corrosion will render the resource economically noncompetitive. At this stage in the examination of the resource, a determination will also be made as to whether reinjection problems are expected to occur as a result of possible reduction of the porosity of the injection zone by the precipitates.

In addition to the analysis of the properties of the resource itself, an assessment will be undertaken of the environmental effects anticipated from its development. In this assessment a determination will be made of the extent of possible discharge of noncondensable gases. In addition, the noise abatement requirements will be determined; the potential for contamination of drinking water will be assessed; the need for reinjection to avoid land subsidence will be specified; and the availability of make-up water will be determined.

(4) Steps 4 and 5. Determine Desirability of Field Development

Based on the temperature of the resource and the properties of the well, the economics associated with the resource development will then be examined. The costs of compliance with Federal, state, and local regulations will be determined, in general; and the site-specific requirements with respect to such factors as reinjection requirements, environmental restraints, land-use planning criteria, and other institutional considerations will be specified. These constraints will be analyzed to determine whether their imposition will change the economics of the resource's development. If, at this juncture, the development economics seem acceptable, the development program will continue.

(5) Step 6. Determine Resource Suitability for Electricity Generation

Because the generation and sale of electricity is the most profitable and, to a large extent, the most badly needed form of energy, the suitability of the resource for that purpose—whether steam or water—will be determined. In the initial analysis of the resource, its size and duration will be assessed to determine whether it will be able to support a power plant for a sufficiently long time to justify the development expense. A reservoir greater than 300 megawatts in size and with an expected lifetime of 30 years or more will be very attractive to utilities, the natural market for the resource. A smaller reservoir will be attractive to a utility only if the reservoir's proximity to its subscriber market is such that a modular increment to its generating capacity can be added and still remain cost effective. The latter decision will be influenced by the suitability of the site for incremental development and the existence of facilities and services that can accommodate the incremental expansion. Primary among the facilities that will influence the economic decision will be the existence and convenient location of transmission lines.

(6) Step 7. Assess the Power Market

Based on the analyses carried out in Step 6, a thorough examination of the anticipated electric power market, vis-a-vis the current utilities' capacity, will be made. This market assessment will include the proximate and immediate market as well as the more remote

and long-range electrical demand. If the market appears to be sufficiently strong, the developer and the associated utility will make the decision to continue the development.

(7) Step 8. Set Up Field Development Drilling Schedule

A drilling program will then be initiated as part of the development program. In the course of carrying out the program, an analysis of surface conditions will be performed as well as studies of seismicity, groundwater transport, and other factors impacting the resource's utilization. If these analyses do not result in any unforeseen developments that may suggest that the resource is not adequate for the generation of electricity, the project is in a position for the final decision regarding the design and construction of a power plant.

(8) Steps 9 and 10. Make Final Decision Regarding the Suitability of the Site for Power Development

This step is the last before design and plant construction. Whether the resource is vapor-dominated or liquid-dominated, the final decision with respect to the resource's suitability for electric power generation will be made. If, at this juncture, it is decided that the resource is not suitable for power generation, a determination of its suitability for direct heat use will then be made. This latter consideration will be examined at a later step. If it is decided that the resource is suitable for electric power generation, a basic design approach for plant construction will be developed. At this point, the decision logic then branches, for the design approach is a function of the temperature and characteristics (vapor- or liquid-dominated) of the resource under consideration. Consequently, the development program will follow one of two major paths—the development of a plant for hot dry steam or the development of a plant for hot water. These will be discussed in turn.

(9) Step 11. Evaluate Steam Source

If the reservoir is dry steam, conventional technology will be used in designing the power plant. Reinjection will be virtually trouble free, since the condensate will be clean. In addition, corrosion will also be minimal except for some possible silica plating out on the turbine. In general, no serious technological problems are anticipated in plant design for the

utilization of dry steam, since its use was initiated quite some time ago at the Geysers, and its supporting technology has addressed and generally resolved most of the technological problems inherent in the use of that resource. At this point in the development, the most important consideration is the extent and reliability of the steam source. If the dry steam reservoir appears to be large enough to meet the power requirements with a duration in the neighborhood of 30 years, a dry steam plant will be built on this site.

(10) Step 12. Determination of Feasibility of Double Flash System

In the event that the steam reservoir is inadequate or the source is a liquid-dominated one with water temperature greater than 450°F, the feasibility of flashing the hot water into steam will be examined.

The use of a single flash or multiflash concept will be a function of the brine chemistry, reinjection, porosity, and the cost of treating the brine sufficiently to make the flashing design approach feasible. These design considerations are currently being undertaken in California's Imperial Valley in a number of potential projects. Major among these considerations is the amount of solid precipitate in the brine. Flashing the brines at reduced temperatures—at levels below which precipitation occurs—will greatly alleviate the problem. A trade-off analysis will determine whether the loss of efficiency in the utilization of the brine is of more value than the cost of cleaning the spent brine for reinjection. For greater efficiency, if the temperature is high enough, a multiple flash approach will be taken to extract maximum heat from the resource. If the water temperature and other factors are suitable for the multiflash approach, flash steam generating plants will be built on the site.

(11) Steps 13 and 14. Determine the Feasibility of Utilizing a Single Flash System

In the event that a multiflash approach is not feasible because of water temperature or other factors, the possibility of flashing the hot water into steam in a single flash system will be considered—despite its inherent inefficiency with respect to the multiflash approach. If the single flash system proves feasible and the economics of this approach to power generation is acceptable, a single flash steam plant will be built on the site.

(12) Steps 15 and 16. Undertake Construction of a Suitable Steam Plant

Based on the analysis of competing steam production plants carried out in Steps 12, 13, and 14, a decision regarding the final design approach of the steam generation plant will be made. After selection of the design approach, a detailed design will be carried out within the environmental, institutional, and financial constraints specific to the site and the market of interest.

(13) Step 17. Determine the Utility of Power Plant Effluent

A consideration in the design and operation of geothermal power plants is the possible use of the condensed effluent for direct heat applications. Multiple use of the resource shows great promise for improving the economics of many geothermal projects. If, for example, a plant constructed and operated successfully for the production of electric power can utilize the hot effluent in a series of cascading direct heat applications—extracting the last Btu of heat from the resource—a more energy-intense utilization of the resource will be possible. As a result, the economics of power generation will be improved and a new low-cost source of energy for other industries in the area will be made available. Of course, such considerations are completely site specific: if other industries do not exist in the area, the hot water, unlike the electricity produced, cannot be economically transported for very long distances. On the other hand, in areas of more concentrated industry, secondary uses of the effluent may be possible and even desirable. Moreover, the availability of such sources of heat may be instrumental in attracting suitable industries to the area.

(14) Steps 18 and 19. Determine If Implementation Problems Are Resolvable

If, after analysis, the resource is deemed unsuitable for power generation, it would be evaluated along with plant effluents as a potential source of hot water for direct heat applications. The analyses of direct heat use of the effluent plants in Step 17 are applicable to the assessment of the suitability of the original high-temperature water resource. Exhibit V-2 lists various direct-use applications suitable to

EXHIBIT V-2 **Approximate Geothermal Fluid Temperatures** **for Nonelectric Applications**

Source: The Unesco
 Press, 1973

various brine temperatures. Since individual direct heat uses utilize so little of the resource potential (with some exceptions; e.g., the pulp and paper industry) a more effective approach to direct heat use will encompass a cascade of various processes—with each process utilizing the discharge from the previous plant. Exhibit V-3 depicts the range of temperatures for several different processes that can be accommodated at an industrial site.

(15) Step 20. Determine Compatibility Between Resource and Use

After reviewing the possible applications of direct heat use of the plant effluent or the original resource, the suitability of the resource for specific industries existing at the site will be assessed. If there exists sufficient industry to provide a natural market for the resource, a direct use industry can be developed.

(16) Step 21. Assess the Probability of Industry Migration

If, on the other hand, sufficient industry does not exist in the proximity of the resource site, an assessment will be undertaken of the probable success of a campaign to attract suitable industry to the area. The promoters/developers, as well as the host state and local governments, will figure prominently in such assessments. The actual formulation of a development plan, the raising of venture capital, and the engineering management of a project will probably be undertaken by the promoter/developer, who will present a complete package to the resource owner or interested governmental or industrial entity for development.

(17) Steps 22 and 23. Implement or Discard Direct Heat Applications

The success of the promoter/developer and/or the host government in attracting new industry to the site or converting existing industry to geothermal energy will determine whether the resource will be developed for direct heat applications at this site, or whether its use will be limited to power generation.

EXHIBIT V-3
Approximate Range of Subsystem Temperatures

Source: International Engineering
 Company, Inc.

(18) Step 24. Determine the Extent of Low and Moderate Temperature Water

If in Step 2, hot dry steam or water greater than 450°F is not found in quantity, a determination will be made of the existence and extent of lower temperature water. If sufficient quantities are not found, the resource will be considered infeasible for further development. On the other hand, if extensive quantities of low and/or moderate temperature water are found, a determination will be made with respect to the feasibility of the resource as a source of heat for power. This determination will be similar to the previously described procedure for hot dry steam and hot water resources. It will, however, differ in some aspects, and to some extent require more comprehensive analysis. Before proceeding with the development of the resource, a series of technological assessments is required.

(19) Step 25. Determine Whether the Hydrological Pressure Is Sufficient

A determination of the hydrological pressure of the resource at reservoir temperatures will initially be required. Above 450°F, the flashing of the brine and the overall high temperatures of the fluid help maintain well production. However, below 450°F, it is possible for a cold slug of water to collect on top of the reservoir, inhibiting the lifting of the expanding brine. A typical example of this phenomenon is seen at Arizona's Chandler site—with a reservoir temperature in the 300° to 350°F range. If sufficient hydrological pressure is found to exist, however, the procedure used previously—beginning with Step 3—will be undertaken and will be continued through Step 7, when a decision will be made with regard to the suitability of the resource for power production.

(20) Step 26. Determine the Utility of Down-Hole Pumps

If sufficient hydrological pressure does not exist, an in-situ or down-hole pump will sometimes be used. These pumps provide lifting action at depths of between 800 and 1000 feet, but their reliability is questionable. Thus, to exploit reservoirs similar to Chandler, down-hole pumps that can be effectively used at greater depth with improved service factors are necessary. If, however, the use of the down-hole pump is able to provide sufficient pressure to lift the brine at the site in question, the procedure will continue.

(21) Step 27. Assess the Utility of Down-Hole Heat Exchangers

At sites lacking sufficient hydrological pressure, even with the use of down-hole pumps, the possibility of effecting the heat exchange in situ with the use of a down-hole heat exchanger will sometimes be considered as an alternative. However, these heat exchangers are still in the experimental stage, but they may provide a feasible technological alternative in the future.

(22) Repeat Steps 3 to 10

If the moderate to low temperature resource possesses sufficient hydrological pressure for lifting naturally or as the result of mechanical augmentation, one or two additional wells will be drilled for reservoir testing. The factors determining its suitability for power generation will be considered in this sequence as well. Particular attention will be given to the solid content of the brine because, as brine temperatures fall below 300°F, corrosion problems tend to decrease. However, as the brine temperature decreases, reinjection requirements are aggravated. Also, as in California's Imperial Valley, land subsidence becomes a particular problem because of the extensive number and dependence of the area on irrigation canals. As a result, local ordinances require 100 percent reinjection of the fluids. Consequently, cooling tower make-up water must come from independent surface sources. These conflicting requirements, to some extent unique to the lower temperature resources, require a new set of trade-off analyses to determine the feasibility of the resource's development—impacting the economics of the resource.

Once the economics of field development have been assessed, and if considered favorable, the decision procedure will be identical to that followed for dry steam and hot water resources.

(23) Steps 28 and 29. Determine the Nature and Extent of the Low to Moderate Temperature Resource

Important in the decisionmaking process with respect to the lower temperature resources is the determination of their properties and extent. This information will provide the basis for deciding on a general design approach for the steam production plant.

(24) Steps 30, 31, and 32. Develop a Specific Design Approach

Three types of plants are theoretically adaptable to the generation of electricity with a moderate temperature (between 450° and 300°F) resource. These are the single flash, the multiflash, and the binary cycle systems. The choice of plant concept will be determined by the economics of the plant and its operation, which, in turn, are most frequently specified by the temperature and the amount of dissolved solids in the brine. The following general design principles are used in the selection of the design approach:

- . Typically, a double flash plant will be used only with brines of higher temperatures and low dissolved solids content.
- . A single flash system will be used with brines of lower temperature and lower dissolved solids—or higher temperatures and higher dissolved solids content.
- . The binary system will be used in this temperature range only if the reservoir is in the lower part of that range and contains a high concentration of dissolved solids. A trade-off will be required: exchanging increased costs of brine cleaning for the greater heat extraction potential.
- . For reservoirs with temperatures of less than 300°F, electrical power can be extracted only with the binary system.

(25) Steps 15, 16, and/or 33. Construct a Suitable Generation Plant

Based on the selection of the plant design carried out in Steps 30 to 32, a suitable steam generating plant will be built. If the reservoir cannot be utilized for power generating, even with a binary plant, because of the low temperature of the water, the possibility of its use in direct heat applications will be considered.

2. DECISIONS CONCERNED WITH THE DEVELOPMENT OF SPECIFIC RESOURCES ARE MADE WITHIN THE CONTEXT OF THE OVERALL CORPORATE STRATEGY—WHICH, IN TURN, IS INFLUENCED BY THE RESULTS OF THE INDIVIDUAL SITE-SPECIFIC PROJECTS

This description of the decisionmaking sequence is provided to emphasize the rather complicated choices that industry must make in implementing corporate strategies with regard to individual geothermal projects. Once the overall strategical decision—for example, that the company will undertake a geothermal development program—has been made, decisions with respect to specific opportunities (the tactical decisions) will be required. The various decision factors, their interrelationship with the externalities of the geothermal industry, and the specifics of the site—described as parts of a logical decision scheme—must be addressed. However, this depiction of a logical decision process does not imply that each company follows this procedure without deviation in arriving at its tactical decisions. Although this process is valid, many of its steps will be made by companies according to a methodology that is more implicit than explicit. Because of a company's familiarity with the site and its knowledge of appropriate technologies, some of the decision steps outlined will be passed over or quickly resolved. Nevertheless, most of the issues identified will be resolved by corporations in implementing their basic strategies with regard to specific projects. In Chapter VI, the overall strategies of the various segments of the geothermal industry are outlined—providing the framework for the decisions described in this chapter.

VI. CORPORATE STRATEGY

VI. CORPORATE STRATEGY

The geothermal industry, as it is currently structured, is oriented around the generation of electricity; and the strategies of the most significant companies in the field reflect this preoccupation with power generation. On the other hand, as previously mentioned, the new and the emerging portion of the industry, related to direct heat use, though still ill-defined, is developing new strategical concepts centered on new applications of geothermal energy.

This chapter extends the analysis of industry conditions—that is, the business factors—to an assessment of strategies. This assessment of strategies, based on executive interviews, is summarized in three major sections:

- . Development of the recent historical context for corporate strategies
- . In-depth analysis of current strategies in resource ownership, exploration, development, and end-use
- . Overview of industry strategies by type of company.

Information presented in the initial section is vital to an understanding of the driving forces in the geothermal industry.

1. THE STRATEGIES FORMULATED BY INDUSTRY HAVE BEEN GREATLY INFLUENCED BY EXTERNAL EVENTS AND GOVERNMENT PROGRAMS, AND ITS RESPONSE IS SWIFT AND READILY DISCERNIBLE

The overall impact of the technological, financial, and institutional considerations upon the formulated strategies of the various corporations comprising the geothermal industry was the specific subject of inquiries with the representatives of corporate management. Of great interest was the effect of external events on the formulation of corporate strategies. Although some of the representatives of Management could not point to any specific event that marked the entrance or exit of their corporations from the field of geothermal development, surprisingly, the majority of respondents in the various companies could point with a good deal of specificity to particular events that governed the decisions made within the corporation with regard to their undertaking

the development of this resource. Exhibit VI-1 depicts the results of those inquiries. In this graphical representation, the specific events identified by the respondents as influential in the formulation of their corporate geothermal strategies are indicated as well as their relative chronological order. The ordinate of the exhibit represents the relative number of companies actively pursuing geothermal programs—of those respondents that have indicated that they initiated their geothermal programs in response to specific and identifiable external events. Thus, it is seen that from the early decision to exploit the geothermal resources at the Geysers in the midfifties, there has been a steady increase in company involvement in the exploitation of this resource. The rate of increase of this participation would have probably been much greater had it not been hampered by the withdrawal of Federal lands from exploration in 1967. Nevertheless, the momentum of the programs started previously carried the industry in a steady expansion, culminating in major programs begun at the Salton Sea sites.

One of the significant events that helped to maintain this momentum was passage of the Geothermal Steam Act of 1970. However, by the end of the sixties and the beginning of the seventies, the difficulty of dealing with the super-saturated brine at Salton Sea resulted in widespread disenchantment with this resource by most of the participating segments of industry. As a result, some of the companies curtailed or abandoned their programs in the early seventies. It was not until 1973 that the 1970 Steam Act was implemented, and the effects of the implementation were augmented by the passage of the 1974 Geothermal RD&D Act. The latter act was especially noted by most of the industrial respondents as an event whose impact, as a result of its loan guarantee provisions, was most significant in influencing corporate strategies to opt for development. This act went far in counterbalancing the concern felt by industry with regard to the acreage limitations contained in the original 1970 Act.

But it was the Arab Oil Embargo of 1973 that catalyzed industry planning and resulted in the formulation of aggressive strategies for geothermal energy development. By 1977, however, most of the companies that had begun geothermal programs had had sufficient experience with the institutional constraints being enacted (discussed in Chapter IV); and, in view of the delays experienced in attempts to secure Federal loan guarantees, corporate strategies began to change. As previously noted, many of the most aggressive companies with the greatest expertise in this resource formulated new

EXHIBIT VI-1 Industry Entrance/Exit Events

strategies, shifting their programs to overseas opportunities and/or curtailing current programs. In contrast, as seen in the exhibit, the direct heat application programs have increased at a steadily steepening acceleration—as a result of the Federally sponsored demonstration programs.

Thus, it is evident that the frustrations and perceived constraints of industry were translated into corporate strategies that downgraded their geothermal development programs. In Exhibit VI-1, the activities incidental to geothermal development programs are also depicted within the same time frame. It is seen in the exhibit that the chilling effect of the 1967 withdrawal of Federal land is identified by a decrease in the number of geothermal wells drilled, and the large spike of activity reflecting the passage of the 1970 Geothermal Steam Act is seen in 1972. The remarkable response of industry to legislative initiatives is seen in that they were able to react to the legislation with lag time in the neighborhood of a year. Considering the fact that corporate budgets and corporate strategies are subject to both long- and short-term planning, industrial response to this legislation is seen to be remarkably swift. Similarly, industry required but a year to decide that the implementation of the 1970 Act was more a restraint than an accommodation to their programs, and the number of wells drilled decreased sharply in the 1972 period.

Most of the corporate strategies were revised by industry as a result of the 1974 RD&D Act and the Arab Oil Embargo; and this revision is seen in the subsequent increase in wells drilled. Similarly, the implementation of the 1970 Steam Act in 1973 resulted in a large number of applications for Federal leases (over 2000) in 1974, and this activity is reflected in the exhibit.

From 1970 on, it is seen that the drilling program continued at a rather steady rate—reflecting the comments of most of the respondents with respect to their corporate strategies at that time. The companies responded well to the 1970 legislation, but later withdrew as a result of the technological problems encountered at Salton Sea and the institutional difficulties experienced in their attempts to conform to the restraining factors of the 1970 Geothermal Steam Act. Again, the legislation and extrinsic events of 1973 were reflected in the increase in the number of companies initiating geothermal programs in 1974, and a sharp increase in wells drilled that year. In addition, as has been mentioned, 1974 marked the peak year for applications for Federal leases. This again confirmed the views expressed in the interviews

in which the respondents particularly identified 1973 as the year their companies entered the geothermal field with drilling programs and applications for Federal leases.

By 1977, a general disenchantment with geothermal energy as a program to be pursued, had set in among most of the companies interviewed. The perceptions of these companies have been reported in detail in previous chapters, and their corporate actions reflecting these attitudes are well illustrated in the exhibit. As is seen, the number of companies leaving the field or curtailing their programs is on the increase; by 1977 a drop in participating companies is apparent. Moreover, the steady rise in the number of wells drilled has begun to slacken. The fact that the drilling programs continue, albeit at a reduced pace, reflects the attitudes of industry reported with respect to this resource. Most of the companies, even those reporting frustration with their programs, have decided to continue exploration, and beyond that, to generally adopt a "wait and see" strategy. These corporate decisions are most clearly evidenced by the rapid drop-off in the number of applications for Federal leases. Part of this drop-off is an indirect and ironic result of the enthusiasm with which the 1974 Act was received by industry—especially within the perspective of the Arab Oil Embargo of 1973. A surge of over 2,000 applications was seen in 1974. The extremely long delay experienced in the processing of the applications by a government staff unprepared for such a task accounts for much of the frustration of industry and the consequent drop-off in the reported leasing of acreage—since some of the original applications have still not been acted upon. The delay in acting on the lease applications accounts for only part of the lessening of the rate of acreage leased (as seen in the exhibit); more important, fewer companies applied for leases after 1975 as a result of their experience with the delay and institutional restraints associated with the Federal leasing program. Even more significant is the steep rise in the acreage released by the applicants after 1975—as a result of the curtailment or complete abandonment of their geothermal programs with respect to Federal land. As seen in the exhibit, the slope of the rate of acreage released follows the leasing rate and accounts for much of the drop-off in the leasing programs.

The significance of Exhibit VI-1 is hard to exaggerate:

- First, it gives a clear indication that the frustrations and perceived constraints of industry with respect to geothermal energy, in general, and the government programs in particular, were accurately described by the respondents.

- Second, and more important, these attitudes were reflected in changes to corporate strategies whose implementation resulted in various companies curtailing their programs or leaving the field altogether.
- Third, it is seen that corporate management is acutely aware of the implications of external events and responds very quickly to government initiatives—either positively or negatively in accordance with its perspective of the initiatives' objectives and their experience with their implementation.
- Fourth, it is interesting to note that most corporate executives could point to specific events that influenced the formulation of corporate strategies with respect to geothermal energy and determined whether or not their companies entered or exited the field.
- Fifth, the response time by American industry to world events and to government programs is extraordinarily rapid—showing expansion or contraction in their program efforts within a year.
- Sixth, it is clear that the attitudes portrayed by the respondents fully reflected the attitudes of their corporation—in that they identified corporate entrances and exits to and from the geothermal field, which coincided with the events portrayed by the respondents as either incentives or inhibitors to their companies.
- Seventh, the correlation between external events and corporate strategies suggested by the respondents is objectively confirmed by corporate actions with regard to the levels of their drilling and leasing activities.

2. STRATEGIES IN GEOTHERMAL ENERGY DIFFER IN ACCORDANCE WITH CORPORATE EVALUATION OF GEOTHERMAL ENERGY AS A BUSINESS OPPORTUNITY

The two major blocs of the current geothermal industry, the developers and the utilities, have based their overall strategies on the development of this energy source for electricity production. Some of the less dominant segments of the current geothermal industry structure have developed

strategies with more limited scope. Several of the smaller companies have developed fully integrated approaches to geothermal development—extending from leasehold to power production.

Each segment of the industry, whether part of the power-oriented structure or part of that evolving industry concerned with direct heat application, has developed particular strategies—often complex and subtle—for each of the four phases of resource development:

- . Resource ownership and leasing
- . Exploration
- . Resource development
- . End-use for electrical and thermal energy.

(1) The Strategies Adopted in the First Phase of Geothermal Development—Ownership and Leasehold—Vary With the Industry Segment, But Are Dominated by the Major Objective of the Dominant Components of the Industry—the Use of Geothermal Energy for Power Generation

Although this phase of the resource development is concerned with both power generation and direct heat applications, it is more generally associated with the current structure of the industry and the landholdings of large developers in the past. For this reason, most of the corporate strategies with respect to the purchase or leasehold of geothermal resource areas had, as their overall objective, the development of a feasible alternative source of energy for the production of electricity. The strategies of each of the segments of the industry with respect to their acquisition of resource holdings vary, as seen in Exhibit VI-2. These strategies are discussed below:

. Large Energy Companies

The strategies of the large energy companies can be divided into four categories. About a third of these companies have decided on a strategy aimed at maximizing their control over available geothermal resources for immediate or future development. One of these companies has acquired large holdings of private land; however, it has no immediate plans for development, but is maintaining control of this land in order to retain the

EXHIBIT VI-2
Strategy for Resource Ownership/Leasing

option for future development if the resource proves a feasible energy alternative in the future. One of the companies currently has no holdings of its own; but all of the companies in the large energy company club are aware of its financial and industrial strengths, and they accept the fact that this company, with its ready capital, would be able to force a position for itself in future developments— if it proved desirable. The company itself reported that it has an immediate interest in acquiring some good resource sites, but more to develop the technology for future years than for the prospect of immediate return. Another of the large companies has an active program, which up to now has been confined to research and development. This company has supported the program because it feels that, as an energy company, it should be pursuing all energy alternatives to determine their worth for possible future development. The rest of the companies have adopted a general "wait and see" strategy.

Small Energy Companies

Most of the active geothermal development in the past couple of decades has been carried out by smaller energy companies in concert with interested and involved utilities. The objective of their programs was the exploitation of the more suitable geothermal sources to provide low-cost energy to nearby utilities. Since most of the geothermal resources are located in the West, there is a natural affiliation between the western energy companies and geothermal energy. Moreover, geothermal energy represented a resource that was not yet dominated by the larger energy companies and constituted a development opportunity that could be implemented incrementally. This latter aspect of geothermal energy interested the smaller companies, since, to some extent, it vitiated the capital advantage of the larger energy companies. In the latter context, some of the energy companies indicated that they had been reluctant to buy or lease lands containing geothermal resource potential because the economic opportunity presented

by even a very large geothermal field was the equivalent of a small oil and gas field. Energy companies, both large and small, because of their experience with the institutional requirements and procedures associated with leasing on Federal lands, as a matter of corporate policy generally sought private lands for development. As a result, the major geothermal developments by energy companies have been carried out on private landholdings. The rest of the energy companies have adopted rather passive strategies for the time being. Some of the companies have decided to follow the success of the programs of the other energy companies; some of the companies are just monitoring the resource because it represents another alternative with some potential; and a very few energy companies have made land investments on the basis of future appreciation. The strategy of this latter group does not envision the development of the resource—rather, it intends the sale of the resource at the new appreciated price, planning for a return on the investment without having to undertake a risk of development.

Geothermal Companies

Many of the available leases and a substantial portion of private lands containing geothermal resources were acquired by companies specially organized to develop geothermal resources. At the outset the initial strategies of these companies had, as their objective, gaining maximum resource ownership or leaseholds in order to undertake complete programs of resource development. However, because of the economic pressures felt by these companies—partly as a result of complying with institutional requirements in the development stage, and partly because of the lack of responsiveness in some of the government incentive programs on which their programs depended—some of these companies used their leaseholdings as bargaining chips in mergers with larger, better capitalized companies. As a result, many of those companies entering the field as a result of the incentives promised in the Geothermal Legislation of 1970 and 1974

were absorbed by larger companies, joined new consortia, or passed out of existence altogether. However, those companies that survived, either affiliated with various consortia or in their original form, maintained their strategical objective: the development of geothermal energy.

- Engineering Companies

A small number of engineering companies actually acquired a basis for ownership of geothermal resources in order to meet particular needs. Sometimes these acquisitions were needed merely to provide test beds for company research and development plans; sometimes the company became involved in the resource ownership because of the lack of capital of their customers; and some of the smaller companies joined development consortia whose programs included the acquisition of land or leaseholds.

- Electric Users

Since the geothermal industry, as currently structured, is oriented around the generation of electricity, the market pull of the industry's development is provided by the utilities located in the vicinity of the major geothermal resources. These companies, the major market for the industry, comprise a small number of utilities located in the western states. A small portion of that number acquired, over the years, landholdings with geothermal resources. These acquisitions reflected early strategies of some of the utility companies that aimed at developing the resources and building the power plants themselves. Through the years, most of these strategies have changed, and only a very few utility companies still consider the development of the resource a feasible role for their companies.

- Nonelectric Users

The outright purchase or acquisition of development rights and/or leases of lands containing

geothermal resources by nonelectric users was carried out in accordance with one of the three major strategies of the direct-heat users.

First: Some of these companies acquired the resource to meet a particular energy need as an ingredient of their development of a site-specific industry. The availability of geothermal energy (providing the possibility for an inexpensive energy source for its industrial application) was, in some cases, the determinant for a company's decision to develop the new industry. Consequently, the user, in an effort to maintain control of the low-cost energy source, formulated a strategy aimed at the acquisition and/or control of the geothermal resource.

Second: Another small group of nonelectric users found themselves in positions to acquire geothermal leaseholds or, in some cases, to purchase the areas in which the resources were located. These companies had little interest in developing the resource, but maintained ownership and/or control as investments. The strategy of these owners was one designed to use the resources as tax shelters—with a view toward possible large returns in the future as a result of new and enhanced appreciation.

Third: The majority of landholdings and/or leases of nonelectric users has been acquired as part of a general "wait and see" strategy. These landholders, sometimes companies, sometimes individuals, track the success of various nonelectric users of geothermal energy. If the monitored programs achieve success, without government subsidy, these companies would probably develop strategies centered on the development of the resources under their control.

General Promoters

These groups of companies—sometimes engineering companies, sometimes companies specially formed in joint ventures to develop geothermal

resources for special purposes—acquired resource sites to meet the requirements of special applications. These acquisitions were sometimes made as part of an overall defense strategy to preclude the preempting of the sites by competitors—even though these companies had no immediate plans to develop the resources themselves. In most cases, these promoters developed acquisition strategies for securing sites for either immediate or future development for their clients or as part of their participation in various development consortia. In many cases, after the development, the promoters withdrew as members of the landholding consortia and remained only as program managers. In other cases, they retained equity positions in both the resource and the development operations.

Others

In addition to the segments of the geothermal industry described above, various other entities, from time to time, have acquired ownership or control of geothermal resources. Some of these resource owners are industries with large landholdings that contain geothermal resources. In some cases the development of these resources represents potential for the future; in other cases, their development would actually interfere with the primary industrial function of the land—e.g., some mining applications and some oil and gas extractions in which the presence of geothermal water becomes a complication to their production processes. Some of these industrial owners of geothermal resources have little knowledge of the existence of the resources and no interest in their development. Their only interest in their resource is as a current tax shelter—accompanied by the hope of a major windfall, if and when, geothermal energy becomes a competitor to conventional fuels.

(2) The Formulation of Strategies for the Exploratory Phase of the Development Requires a Basic Corporate Decision With Regard to Investment—To Prove Out The Resource for Either Sale or Development

Of all of the companies and/or individuals holding leases or owning tracts of land on which geothermal resources are located, only a small portion have undertaken exploration of these resources. Decisions by the various industrial segments to go on to the next phase of the resource's development—its exploration—stems from the nature, circumstances, and overall strategies of these resource holders. The strategies of each of the segments of the industry with respect to the exploration of the geothermal areas outlined in Exhibit VI-3 and will be discussed in turn:

• Energy Companies

The same energy companies whose acquisition strategy called for maximizing their geothermal holdings as part of their overall development strategy planned to explore these holdings to assess their value for development. This segment of the energy industry is composed, for the most part, of the smaller energy companies that are engaged in the exploration, development, and operation of the major producing sites. However, although few of the larger companies have initiated any significant effort in geothermal development, they have formulated extensive programs for exploring and evaluating their resource holdings. In fact, not only was extensive exploration part of the companies' geothermal strategies, but it was funded as part of corporate strategic exploration programs—without any expectation of return on this investment in the near future. One of the large companies interested in geothermal resource exploration has decided that it will not invest in any area under Federal control unless and until the institutional requirements with respect to geothermal development in general, and exploration in particular, are modified. The environmental impact analyses required for this phase of development were cited by one company as the reason

EXHIBIT VI-3
Strategy for Resource Exploration

for this corporate decision. Although most of the exploration conducted by the energy companies is being carried out to evaluate the resources for development, some of the exploration is being engaged in, the companies admitted, to develop exploratory techniques for use in the future—in other unspecified areas.

Geothermal Companies

Since most of the geothermal companies were organized specifically to develop geothermal energy, a large proportion of these companies developed a strategy for detailed exploration of their holdings to prove them out for development. A small number of these companies, because of economic pressures stemming from the stretch-out of Federal Loan Guarantees, new requirements for environmental assessment, and general lack of success in attracting venture capital for the resource's development, modified their strategies to that of limited exploration to prove out the resources for future sale to companies with greater capital strength. Alternatively, these companies utilized the proven resource to bargain for places in various development consortia. Most of the surviving companies, however, have been successful in maintaining their own developmental strategies.

Engineering Companies

Only a very small portion of the engineering companies in the current geothermal industry structure have developed strategies for active exploration of geothermal resources. These companies have done so as outgrowths of their strategies of land acquisition for particular purposes discussed previously. These companies, on occasion, have been tasked with the exploratory phase of development by members of the consortium that have acquired the resources and are formulating overall development programs. In general, the engineering companies that have developed aggressive strategies for geothermal exploration have generally been engineering companies

with a long-established history of geophysical exploration and program management—in addition to their overall general engineering competence. In addition, there remains a larger group of engineering companies involved in geothermal development whose interest is more limited to the conventional engineering role of design and construction in association with resource development.

. Electric Users

With rare exceptions, the electric users—generally utilities—have not formulated corporate resource exploration strategies, since some of their very early plans were curtailed. On occasion, they have been part of joint efforts, a phase of which encompassed exploration.

. Nonelectric Users

Unlike the utilities, the nonelectric users have had a substantial role in geothermal resource exploration. The strategies adopted by these companies with respect to exploration for energy sources have generally fallen into two categories. A slight majority of the users reported that they undertook such programs in accordance with an overall strategical requirement of their corporations to meet their industrial energy needs. Some of these users own the resources and undertook their exploration as part of specific development programs. Others were municipalities who, in order to provide low-cost energy sources for either their own needs or to attract new industry into their areas, arranged, with either state funds or Federal support (e.g., the exploration of the Susanville area by the Bureau of Reclamation), for exploration of potential geothermal energy sites. Other users in this category comprise industries with substantial holdings of known geothermal resources that undertook exploratory programs to determine the extent these resources could, if developed, meet their corporate energy requirements. Some wood and

paper products companies conducted such exploratory programs—as a result of corporate strategies to reduce energy costs—in the hope of developing alternative energy sources under their control.

The other major group of nonelectric users approached geothermal energy opportunities with strategies that essentially dictated that all of their efforts would be confined to determinations of the value and the possible uses of resources available to them. Some of the exploratory work in making these determinations was carried out by the users themselves; but, more frequently, engineering companies with strong geophysical backgrounds were tasked to conduct the evaluations for this class of users.

To the extent that the exploration for either objective—determination of the resource for a special requirement, or its evaluation for subsequent use—was successful in identifying resources suitable for development, new strategies for their development and final use would then be required by this segment of industry.

General Promoters

The general promoters/developers for direct heat applications, in putting together geothermal projects, are often required to provide a capability for geothermal resource exploration themselves, or arrange for such exploration to be completed prior to their structuring project development plans. The strategies of such companies require that careful evaluations of the resources be completed before the selection of the general market area—and in anticipation of specific projects in the future.

- (3) Strategies for Resource Development Are Market-Driven but Are Changing With Shifting User Interface and as a Result of Operational Experience Are Focusing on Markets Overseas

Resource development has traditionally been carried out by large and small energy companies and

those companies specifically organized for the development of this resource. In addition, another class of developers has also emerged in the evolving direct-heat portion of the industry. This latter group of companies, the promoters/developers of that portion of the industry, currently constitutes the most potent factor in the development of direct heat uses of geothermal energy. Each of the components of the geothermal industry, whether the power production oriented industry existent today or the direct heat applications oriented industry that is evolving, has developed particular corporate strategies to guide this development. Because of the impact of the various factors discussed in previous chapters—economic, institutional, and technical considerations—these strategies have been formulated from the perspective of industry's evaluation of geothermal energy in general, and the corporations' objectives in particular. A summary of these strategies is seen in Exhibit VI-4.

As will be seen, these strategies have undergone change as a result of corporate experience with the development of this new energy source. The controlling strategies of each of the segments of the geothermal industry will be discussed in turn:

Energy Companies

With one exception, the large energy companies have, through the years, pursued a "wait and see" strategy with respect to geothermal energy. Most of these companies have acquired large tracts of land with high potential for geothermal resources, but have not formulated corporate strategies aimed at their development. Some of these companies have initiated relatively significant research and development projects and conducted extensive exploration work in geothermal energy and in fact have funded, in whole or in part, the demonstration of new and sophisticated techniques. However, these companies have not put in place corporate programs aimed at bringing geothermal energy to the marketplace as a major energy resource. In almost every case, corporate strategies dictate that corporate investment will continue in the

EXHIBIT VI-4
Strategy for Resource Development

area of oil and gas exploration and production—rather than geothermal energy. Under the umbrella of the standard "wait and see" policy, each of the large energy companies has developed a specific strategy.

One of the companies has sought leaseholds or land purchases to provide the opportunity to develop its technology, but is only interested in acquiring fields with power generation potential—such as the Geysers. This company indicated that its interest in geothermal development in the United States is minimal for a number of reasons: First, geothermal projects are not large enough—this company looks for development projects with a minimum size approaching \$200 million; in contrast, typical geothermal projects, at least incrementally, are in the \$20 to \$50 million range. It has concluded that anything that size is not worth the management trouble to the corporation other than as a test bed for technology development. Second, there is little corporate interest in exposing the company to the institutional pressures that would result in any large energy development project in this country. Third, its corporate strategy encompasses an interest in the development of geothermal energy; but any project undertaken in the United States would be done so to develop a technique that could be implemented worldwide—in a more benign institutional environment with a greater profit potential. Representatives of this company expressed their frustration in being urged by one part of the Department of Energy to undertake an aggressive development program for geothermal energy—as a corporate obligation to the public—while at the same time being subjected to pressure from other government groups to prevent its diversification into other energy fields.

Representatives of another large energy company reported that, after much effort and expenditure of funds, they had finally succeeded in acquiring a leasehold suitable for power generation; but their experience

in dealing with the institutional strictures of the government have made them regret this undertaking. Consequently, the current corporate strategy is similar to the first company—all interest in geothermal development will be concentrated on overseas sites and development within this country will be avoided until the current institutional environment changes sufficiently to encourage the investment. Neither of these companies had any interest in direct heat applications because of their lack of size. Both companies stressed that their competitive advantage lay with large projects.

Two other large companies indicated no immediate interest in geothermal development because of the general lack of interest of their companies in involvement with programs so dominated by institutional restrictions. As a result, their corporate strategies emphasize the acquisition of potential geothermal sites, with minimal investment in development programs.

One of the large companies has formulated an aggressive development strategy based on the premise that, as an energy company, it should pursue all energy alternatives of reasonable potential. Consequently, this company has maintained a significant research and development program, has acquired leaseholds and the ownership of large tracts of land with geothermal potential, has bid on government research and development procurements, has been involved in multi-industry development programs, and has proposed new and advanced development concepts under the government demonstration program. This company has maintained this aggressive strategy despite overall disenchantment with the field as a result of the impact of government restraints upon its programs.

The smaller energy companies have been, to a large extent, the architects of most of the programs in place today. Having been invited in at the outset by the original geothermal companies, these energy companies

quickly developed corporate strategies aimed at leading the industry into full-scale development for power generation. Whatever commercial success has been achieved by the geothermal industry has been largely the result of the efforts of this group. Overall, a small group of these companies has made most of the advances in the field, following a strategy whose basic objective was the development of a capability for the generation of steam for their logical customers, the electric users.

However, since 1977, a major reappraisal of their geothermal energy programs has taken place—based on their companies' experience in developing this resource. Some of the companies intend to continue their exploratory and development programs and monitor government initiatives closely—deferring the final evaluation of the resource until current programs can be evaluated. These companies are frankly sceptical of the desirability of their being involved in geothermal energy development. Some of the companies—unfortunately the leaders of the current geothermal industry—reported that their companies intend to maintain current programs; but their corporate strategies dictate that there will be no new programs undertaken in the United States, and that all future initiatives in geothermal energy will be undertaken overseas.

These companies indicated that this strategy was adopted after extensive review of their experiences in geothermal development and overall evaluations of geothermal energy as an alternative to other available fuels. These latter evaluations were arrived at after an assessment of the financial, technological, and institutional considerations described at length in the previous chapters. Overall, these companies concluded that, because of institutional constraints upon nuclear energy and the impact of the implementation of the new air quality standards, geothermal energy would be competitive to other forms of energy—given that future

government restrictions will preclude the use of gas and oil for power generation. However, against this evaluation corporate planners arrayed their experiences in attempting to bring geothermal energy into production and concluded that the new restraints placed on American industry by government, at all levels, have vitiated that advantage and made the desirability of geothermal programs questionable—in view of alternative opportunities for investment. These corporations have adopted a strategy of curtailing development activities in the United States and, taking advantage of the technology developed here as well as the inherent competitive advantages of the resource itself, of transferring their operations to overseas sites with fewer restraints and higher profits. The corporate strategies adopted by the smaller energy companies, the leaders of the industry, constitute a more immediate implementation of the internationally oriented, long-term strategies of the large energy companies.

In formulating these strategies, these corporations chose the possible instability of foreign governments over the uncertainty of domestic government policy. Their overall evaluation rested on the time element. They decided that a geothermal project could be implemented overseas—from beginning to end—in a period of time varying from 2 to 3 years versus an anticipated 7-year stretch-out in the United States. They decided that most of the governments for whom they would undertake the development overseas would provide a stable condition for this minimum time, whereas the capital outlay and administrative uncertainty in the 7-year interval was judged the less acceptable alternative.

Geothermal Companies

From the outset, the strategies of these companies have been very aggressive. They intended that their companies would become the leaders of the industry. To a large

extent their strategic objectives have been achieved—particularly in those cases in which the geothermal companies joined energy companies in joint development of resources. Some of these companies have been successful even without that affiliation.

The basic strategies of these companies are aimed at becoming steam producers for utilities. To meet this objective, these companies have been engaged in all phases of the development process. As indicated in previous discussions, they have attempted to maximize their landholdings; they have conducted either singly or jointly their own exploration of their holdings; and either singly or jointly with other developers (e.g., energy companies), they have developed the resource to the point of actually building operational plants for the production of steam. A small number of these companies have taken the development program to its ultimate—producing electricity for later distribution by affiliated utilities.

Because of present restrictions with regard to power generation and because of the concern of all such companies with the possibility of being regulated as public utilities, most corporations avoid the actual production of electricity. Instead, their corporate objectives are limited to resource development and the operation of the production plants for the sale of steam to the electric users. Some companies have undertaken power production because of the reluctance or inability of utilities to invest in the geothermal power plants; however, they plan to sell their plants, when proved successful, to the utilities. Thus, those companies whose corporate strategies encompass the generation of power see this production as an interim measure and feel it can be pursued but temporarily—and only when the level of production remains small.

Because of their willingness to produce power, because of their more effective internalization of government incentives, and because these companies do not have the resources to

follow the energy companies overseas, their overall strategies aim at replacing or fitting between the energy companies currently developing the field.

Engineering Companies

Most of the engineering companies involved in geothermal energy follow corporate strategies aimed at establishing these companies as leaders in the design and construction of geothermal production plants as well as all of the related engineering activities associated with the development of the resource and the transmission of power from the production plant. However, because of the current financial difficulties of the utilities, their natural market in geothermal energy, a small number of these companies have found themselves in the role of developer as well as the engineering company. Most of the corporate strategies of the engineering companies specifically exclude resource development, but such strategies have been modified in an effort to establish a lead position in the industry. In fact, a small number of these engineering companies have actually provided venture capital for the development in return for an equity position in the enterprise. However, this latter development is a nontraditional role for engineering companies; one in which they feel uncomfortable; one in which they are concerned that they may be seen as competitors to their natural customers—the developers; and one that is almost never included in the overall corporate strategy governing their company's programs.

Electric Users

As is seen in Exhibit VI-4, most of the electric users are utilities whose interest in geothermal energy is based on developing a possible low-cost energy source for electricity production to meet the requirements of their subscribers. The development strategy of these companies is to effect an appropriate interface with developers or plant operators to buy steam for power generation.

The role of the utilities in the development phase of geothermal energy has varied over the years and reflects changes in corporate strategy with regard to the development of this resource. Early strategies of some of the larger utilities envisioned that the development of the resource, its production, and the use of the steam produced would be implemented under the control of the utilities. Some utilities, even today, include in their corporate strategies vestiges of this concept. Most of the companies, however, with programs close to the actual development phase, have brought in developers/operators for development of the resource and the production of steam—which the utilities will buy for power generation. As previously noted, some of the geothermal companies, and in one instance a small energy company, have actually produced electricity for sale and distribution to some of the utilities. To a large extent, the interface between the developer and the electric user is determined by the financial strength of the user. The stronger the company is—e.g., the utility—the farther it strives for the interface to be pushed toward the development and control of the resource; on the other hand, the weaker the financial position of the user, the more it is willing and indeed anxious to have the interface moved toward power generation. In the next section an analysis of a group of western utilities will be presented and their individual strategies will be considered in the perspective of their current financial position.

Nonutility Electric Users

A small number of electric users, other than utilities, have evolved different strategies with respect to this resource's development. These companies are generally large energy users in industries that are located near geothermal resources or control large areas in the region of potential geothermal resources. They have now begun to consider the development of these resources to meet their own power needs. Among those companies that have evaluated geothermal

energy in this regard are companies in the forestry industry, the pulp and paper industry, some mining companies, and a small number of process industries. Despite this evaluation, few of these companies have developed cogent strategies for geothermal development; more frequently, their corporate strategy dictates a modest research and development program, efforts to acquire Federal funding in demonstration projects, and long-term monitoring of the developments in both the geothermal industry and the uses of this resource by their competitors in their own industry segment.

Nonelectric Users

In contrast to the current structured industry based on a limited market comprised generally of electric users, the nonelectric users, it has been pointed out, represent a variety of industries which with a variety of energy requirements—many of which can, to some extent, be addressed by geothermal energy. The relationship between the developer and user varies with the variety of uses represented by this evolving portion of the geothermal industry. In contrast to the current industry dominated by developers with a one-to-one relationship to a single market entity—usually a utility—the nonelectric users represent a diverse market composed of many industrial groups generally located near a geothermal resource of varying quality, with interfaces and producer-market relationships still undefined.

However, the strategies of these users in the development phase vary widely. Most of the users have little interest in developing the geothermal resources; and their corporate strategies center on evaluating the program package put together by the promoters/developers—to determine if the adoption of this resource in programs suggested by the promoters will appreciably approve their financial operation. The developer/promoter and the user will ordinarily formulate a joint venture for the development and utilization of the resource

to meet the user's needs. The developer/promoter ordinarily functions as the Program Manager, and even earlier as the originator of the concept. In these situations, the user becomes the Purchasing Agent of the energy source and his participation in the development most frequently is limited to the role of buyer, or sometimes as investor supplying venture capital.

When a user's energy situation is more critical, and its industrial application more energy-intensive, the user may take the initiative in forming an organization to explore and develop the geothermal energy sources available to him or which he already controls. Most frequently, the application is on a small scale with specific energy needs—the sophistication of which is at a low-enough level that the development can be undertaken successfully by the user itself. Sometimes, in large, energy-intensive industrial applications (e.g., the pulp and paper industry or certain metal processing applications), the user of necessity seeks out consultants, developers, engineering firms with geothermal expertise, drilling companies, and financial institutions. In short, the user puts together a team to undertake development of an alternative energy source much in the manner that such projects are generally put together by the promoters/developers.

At the present time, this industrial strategy (in other than small applications) is rare throughout the geothermal industry. In fact, most of the major applications of this sort have evolved only as a result of government programs. Most of the corporate strategies of large companies located near geothermal resources, and with energy-related problems, are still oriented around the use of government funds rather than major corporate commitments by management.

Although this strategical bias may change in the future, the tendency for user groups to seek out professional promoters/developers to develop programs for user review and

evaluation seems to be on the increase. As a result, a whole new industry segment is evolving within the broad framework of the geothermal industry. The emergence of engineering companies and other companies specifically organized to manage geothermal development projects for users, is one of the more significant developments reported by industry. The significance of this finding increases when viewed in the perspective of the current potential for direct heat use on the one hand, and the migration of the large energy companies—the traditional geothermal developers—from the geothermal energy field on the other. This new and evolving segment of the geothermal industry will be discussed in the next section.

General Promoters

As indicated in the last section, the traditional developers of the geothermal industry—the energy companies and the geothermal companies—have concentrated on the generation of electric power; and their corporate strategies are oriented toward this market. In interviews with these companies, they all agreed that, by far, the larger market for geothermal energy lies in direct heat applications. However, they also pointed out that currently the greatest profitability for developers lies in power generation; and the corporate strategies of these companies reflect the acceptance of this fact. Moreover, these companies maintain a traditional corporate bias against site-specific applications of energy; they are conditioned to think in terms of energy as a commodity that may be transported either in a barrel or by transmission lines. These developers have not yet formulated the hydroelectric psychology of developing the energy source near the market and making a capital investment based on a certain symmetry of industrial growth near the energy source. Consequently, very few of the geothermal companies, and almost none of the energy companies, have seriously considered direct heat applications as part of their near-term corporate strategies for geothermal development.

Given this situation and the growing need for energy, especially in areas with major biases against nuclear and fossil fuel alternatives, the vacuum left by the lack of interest in direct applications of geothermal energy by the traditional developers was soon filled by companies brought in by potential users—frequently as part of government demonstration programs to provide engineering or geophysical support and/or act as Program Managers for the projects. As the larger development programs progressed, the need for a capability to meet government administrative and management requirements, as well as to prepare the financial strategy for projects, soon developed. Some of the engineering companies, earlier engaged in program management, found they were obliged to seek sources of venture capital in order to ensure the success of the project for which they had been given technical responsibility. As a result, some of these companies developed new corporate strategies for penetration into the geothermal market, which included not only developing the capability to provide technical support, program management, and development of the financial and business plans, but also extended to the marketing of the resource to potential user industries. This latter role was the result of various local governments and municipalities seeking professional support in attracting new industry into economically depressed areas with the promise of available low-cost geothermal energy.

From the original cadre of engineering companies that first assumed the role of promoters, it was but a short step to companies specifically organized for the purpose of developing complete application packages (e.g., industrial park development, municipal program management, and formulation of corporate strategies for users). From the beginning, these new promoters have developed strategies intended to gain for them equity positions with minimum investment of their own capital. Most frequently, they trade the tax benefits provided by Federal programs

and a limited equity position to companies with sufficient cash flow—for venture capital. The promoters, with little cash flow and hence an inability to take advantage of the tax benefits, provide, in addition, extensive technical and management services, including resource evaluation, technical support program management, environmental assessment, and administration of government permit/license applications—in return for an equity position in the project. Thus, the promoter receives an equity position for his trouble; the investor receives tax benefits and a diminished equity position for his venture capital; the owner of the rights to the resource receives a completed business project with capital, management, the necessary government approvals, and a diminished equity position for rights to the resource; and the ultimate user receives access to a new low-cost energy resource in the area of its industrial operations or in an area to which such a package may attract it.

Others

In addition to the major components of the industry, there are industries playing a necessary, if ancillary, role in the overall geothermal energy development. Since drilling represents a significant proportion of the overall development cost of geothermal energy, the strategies adopted by these companies would have a substantial effect, in light of the technical considerations discussed in Chapter II but not a controlling one. Most of the drilling companies interviewed stated that the long-range business strategies of their companies were oriented around oil and gas exploration and production—rather than geothermal energy. Generally, these companies viewed the development of geothermal energy as a sideline to their basic corporate objectives—of providing drilling support to the oil and gas industry. For this reason, investment in geothermal-related research and development did not figure in the corporate strategies of these companies.

More directly impacting the geothermal program were the strategies of the financial community. A small group of financial institutions have identified geothermal energy as a potential area for investment. The larger, traditional financial houses have, in general, viewed the geothermal program as they would any other investment in any other energy development field. To a large extent, these companies have not adopted particularly aggressive strategies with respect to geothermal energy, nor have they been particularly innovative in their financial arrangements with respect to this resource. Most of the corporate strategies of the financial community have been extremely conservative, in part because of the perceived uncertainty with respect to resource reliability and institutional restraints associated with this energy source. Consequently, most of the company strategies relating to financial planning for this resource's development have been based on the requirement of Federal loan guarantees for the capital investment of these institutions.

However, a very small minority of these companies have decided that geothermal energy presents a unique opportunity for investors and have been most innovative in developing mechanisms to insulate corporations undertaking the development of geothermal energy (under the Federal Loan Guarantee Program) from the consequences of possible default by the development of third-party corporations. Moreover, the most successful of these companies possesses a strong technical capability for the actual development of the resource as well. One of these companies has developed a modular approach to the resource development that keeps pace with the investment commitments of the program. This company, in contrast to the rest of the community, feels that the current incentives provided by the Federal Government—particularly the Loan Guarantee Program—are adequate to constitute a reasonable investment environment to industry. In short, this type of company has itself become a

promoter—fashioning strategies aimed at promoting major projects in an integrative fashion—from exploration to incremental resource development to actual application for power generation and/or direct heat use—with their equity position guaranteed by their ability to attract, raise, and contribute venture capital. Although companies of this sort represent a minority within even the evolving geothermal industrial structure, their success represents a possible industrial potential that could be developed to fill the void being left by the traditional developers—the geothermal companies and the capital-laden energy companies. A new development in the industry was also noted by the promoters. Other than the innovative financing schemes advanced through their own efforts and some government support, the only ready sources of capital to the industry are of foreign origin—a counterpart to the flight of United States developers to foreign markets. However, their equity requirements for capital investment appear to be severe—raising a concern with regard to program control.

- (4) Although the Potential for the Utilization of Geothermal Energy Has Diminished Because of the Currently Discouraging Institutional Environment, New Direct Heat Applications Are Emerging— but Will Be Sustained Only if Favorable Conditions for Investment Can Be Maintained After Government Support Recedes

As has been indicated throughout this study, the two major uses for geothermal energy are power generation and direct heat applications. The industry, as currently structured, is chiefly oriented toward the generation of electricity; and, hence, the strategies of electric users essentially define and focus the pattern of development of the resource. On the other hand, some of the new breed of promoters/developers have formulated development concepts that, along with attracting new users to this energy source, will be having an increasingly significant effect on the industry in the future. Most of the other segments of the industry have been involved in the use of the resource, for the most part, as part of development consortia. Exhibit VI-5 depicts the strategies

EXHIBIT VI-5
Strategy for Resource Use

adopted by the various components of the geothermal industry with respect to that resource's use. They will be discussed in turn:

. Energy Companies

As indicated previously, a small number of energy companies—small companies at that—have developed strategies for complete programs of geothermal energy development from the resource, through operation of the steam plant, to the actual generation of electricity. Corporate management of the companies involved in power generation, view this role of their companies as an interim measure to spur the development of the power generation capability of utilities in the absence of sufficient capital or willingness on their part. The primary objective of the strategies of the energy companies so involved is the creation of a market among utilities. A secondary objective is the sale of the power generation facility to the utility—after the resource has been successfully developed and the feasibility of continued operation has been assured. In general, most of the energy companies will not only avoid all appearances of power generation but will even maintain a distance from Federal Loan Guarantees—out of fear of being subjected to Federal regulation as public utilities. Even those companies that have, as part of their corporate strategies, planned for a capability of power generation, have stressed in their plans that such generation will be at an extremely low level and will represent only a temporary activity of the company.

This view is to be contrasted with the integrated approach of the foreign developers—that is not only difficult to compete with overseas but is the basis in which foreign companies are exploring all possible exceptions to the traditional developer/user interface for their investments in the United States.

Geothermal Companies

Some of the companies that have been specifically organized to develop geothermal energy to meet the needs of electric users have developed a completely integrated geothermal capability within their corporate structure. This capability extends from land acquisition or leasing, to exploration and drilling, to resource development and operation, to power production. The motives for this corporate development strategy are similar to those of the energy companies previously described. However, since these companies are generally smaller and the level of power generation is lower, a longer interval of power generation is generally assumed in corporate strategies. However, even the geothermal companies accept the fact that they must, eventually, offer their power generation plants for sale to the utilities that purchase their power. A small number of geothermal companies have included in their corporate strategies a future development program to meet the needs of municipalities—both for power generation and for district heating. Moreover, some of these companies have developed, as part of their future strategies, approaches to dual use of resources—utilizing the effluents from power generation plants in a series of cascading direct heat applications. However, most of these companies do not see this further use of the resource in the near future; and the strategies adopted by the companies generally categorize these latter applications as a future business area to be developed—rather than a current business opportunity.

Engineering Companies

None of the engineering companies associated with power generation indicated any interest in being an end user of geothermal energy. Most of these companies felt that they would go only as far as becoming involved in the actual resource development—in addition to their traditional role of providing

engineering services and program management support. At least one of the large companies reported that it would even provide venture capital for such development, but indicated that it required an equity position in the project in exchange.

In overseas operation, these companies are meeting stiff competition from foreign engineering companies that provide completely integrated programs from design to power production. United States engineering companies, without such a base in domestic operations, are handicapped; but they are still considering strategies based on an integrated approach. This change in strategy is the result of the foreign combines using that approach to gain virtual control of the generation equipment market, and now being able to use the availability of equipment as a competitive lever to acquire development projects.

One such company was aware that its equity position would involve it in indirect participation in the resource use, but felt that such limited participation would not make it vulnerable to government regulation.

Electric Users

Because the geothermal industry is market driven, and because utilities represent the natural market for the industry as it is currently structured, the perspective and expectations of that segment of the geothermal industry are particularly significant. Since 1973, the utilities view of geothermal energy's potential for meeting their energy requirements has been diminishing.

In Exhibit VI-6 eleven independent assessments of geothermal energy utilization, projected over the next two decades, are portrayed. It is seen that independent evaluations of the potential of the resource for meeting the energy demands of affected utilities have indicated, with each new assessment, a lower projected capability.

EXHIBIT VI-6 Comparison of Recent Geothermal Electric Energy Utilization Projections for the Year 2000

SOURCE OF FORECAST/PROJECTION

1. Bechtel Corp., "Geothermal Technology Assessment Study," Dec. 7, 1973, in A Technology Assessment of Geothermal Energy Resource Development, National Science Foundation, Government Printing Office, Apr. 15, 1975, pp. 278-284 (Normal).
2. Project Independence, Geothermal Energy, National Science Foundation/FEA, Government Printing Office, Nov. 1974, pp. 3-4 (Crash).
3. Program Definition for Geothermal Energy, Background and Program Definition Summary, Jet Propulsion Laboratory, California Institute of Technology, Vol. 1, Aug. 29, 1975, pp. 1-11.
4. ERDA-86: Definition Report, Geothermal Energy Research, Development, and Demonstration Program, Oct. 1975, pp. 1-2.
5. U.S. Energy Through the Year 2000 (Revised), Bureau of Mines, Department of the Interior, Dec. 1975, p. 36.
6. The Mitre Corp., Analysis of Benefits Associated with the Introduction of Advanced Generating Technologies, Mar. 1977, pp. xxxv-ii.
7. Geothermal Prospects for the Next 50 Years, EPRI, ER-611SR, Feb., 1978, pp. 3-16.
8. EPRI Utility Survey 1978 in "EPRI Geothermal Program - Overview," Vasek W. Roberts, in Proceedings of the Second Geothermal Conference and Workshop, EPRI WS-78-97, Oct. 1978.
9. DOE Commercialization Task Force, June 15, 1978.
10. EPRI Utility Survey 1979, in "Perspective on EPRI's Geothermal Program," Vasek W. Roberts, at the Third Annual Geothermal Conference, June 25-29, 1979, Monterey, California.
11. Booz, Allen interviews with Electric Utilities.

As a result, by June of 1979, the utilities were reporting an installed capacity of 663 megawatts, with another 1043 megawatts under construction and only another 1308 megawatts planned altogether between now and 1990—as is shown in Exhibit VI-7. These projections directly reflect, not only the estimates by the utilities of the potential of this energy source, but also the corporate strategies that will dictate capacity in large programs for the future. This profile of projected geothermal capacity was developed by the utilities for the various states and estimated in terms of potential capacity for those locations and in the aggregate. An assessment of an overall national potential was conducted as well. The state-by-state aggregation and estimates of overall national geothermal potential were not only consistent but, more importantly, remained below the early predictions of potential energy capacity available from the development and utilization of the national geothermal energy resources. A synopsis of these views of the utilities is illustrated in Exhibit VI-8.

It was mentioned earlier in the study that the development strategy of utilities, and the interfaces established between users and developers, are functions of the financial health of the users, in this case utilities. In Exhibit VI-9, a basic categorization of the utilities interviewed in the course of the study is presented. Displayed in this tabulation are the current bond ratings, the major field services, recent budgets for capital expenditures and research and development, and, in particular, the companies' past geothermal energy budgets. Finally, the exhibit presents the companies' current net electric generation capabilities, their sales, and, most important, their projected expenditures for geothermal energy.

All of these companies are located in western states, are nearly contiguous to sizeable geothermal resources, and constitute a natural market for sale of geothermal energy.

EXHIBIT VI-7
Geothermal Capacity Installed,
Under Construction, or Planned
(as of June 1979)

EXHIBIT VI-8
Electric Utility Outlook on
Geothermal Energy Development
by the Year 2000

STATE GEOTHERMAL CAPACITY

- COULD POSSIBLY CONTRIBUTE 100 MW
- POTENTIAL FOR 1500 MW, BUT MORE LIKELY 500 MW
- UNCERTAIN, BUT AT LEAST 70 MW
- UNCERTAIN, BUT POTENTIALLY 400 MW
- 1600 MW
- 1100 MW EXPECTED
- NONE
- REALISTICALLY, 100-300 MW
- 40-50 MW, LIMITED BY DEMAND
- POTENTIAL FOR 2000 MW (INCLUDES EXPORTS TO THE OTHER STATES)

TOTAL: 6120 MW

NATIONAL GEOTHERMAL CAPACITY

- MINOR IMPACT UNTIL THE NEXT CENTURY
- COULD SUPPLY 2000-3000 MW
- AT BEST, 5000 MW
- LIKELY CAPACITY OF 2000-3000 MW
- 12-13 GW IS EXTREMELY OPTIMISTIC, BUT POSSIBLE
- UNCERTAIN
- 3-4 GW
- 12-13 GW
- UNCERTAIN
- UNKNOWN

CONCLUSIONS

ELECTRIC UTILITIES CONSISTENTLY ESTIMATE THE NATIONAL POTENTIAL FOR GEOTHERMAL UTILIZATION TO RANGE FROM 2-6 GW

- UNCERTAINTIES ARE ASSOCIATED WITH THE DIFFICULTIES IN DEVELOPING HYDROTHERMAL RESOURCE
- THE TOTAL OF THE ESTIMATES ON A STATE LEVEL IS CONSISTENT WITH NATIONAL POTENTIAL
- A 12-13 GW INSTALLED GEOTHERMAL CAPACITY IS OPTIMISTIC, BUT POSSIBLE WITH A DEDICATED EFFORT

EXHIBIT VI-9
 Characteristics of Electric Utilities
 in the Geothermal Industry*

	<u>Net Electric Capability (GWe)</u>	<u>Electric Sales (Millions \$)</u>	<u>S&P Bond Rating</u>	<u>Major Fuel Source (Percent)</u>	<u>Capital Expenditures (Millions \$)</u>	<u>R&D Expenditures (Millions \$)</u>	<u>Geothermal Budget (Thousands \$)</u>	<u>Estimated Geothermal Expenditures (78-83) (Millions \$)</u>
Utility A	14.7	2,300	AA	Oil (74%)	568	18	5,000	90
Utility B	13.4	2,100	AA-	Oil/Gas (50%)	800			
Utility C	2.6	480	BBB	Oil/Gas (76%)	220	6	3,000	5
Utility D	3.1	450	A-	Coal (68%)	400		0	0
Utility E	2.7	420	A	Coal (92%)	260	1.6	0	17
Utility F	2.8	420	AA	Coal (85%)	210	2.1	0	0
Utility G	0.8		AA	Coal (64%)			250	20
Utility H			BAA	Oil/Gas (96%)		.4	150	1
Utility I			BAA	Coal (65%)			0	0
Utility J	2.1	195	AA	Hydro (65%)	117	.8	250	11
Utility K			A				15	0
Utility L	3.0	300	BAA	Hydro (30%)/NUC (30%)	280	2.2	250	12

These companies have studied the economics of geothermal energy and weighed their conclusions against projected costs for alternative energy sources. The results of their analyses are shown in Exhibit VI-8. The results of these assessments can be compared with the financial analysis detailed in Chapter III. However, the extent of correlation is less important than the fact that the utilities, the major customers for geothermal energy, have evaluated and reported on the resource in their terms—depicted in the exhibit. Clearly, such analyses provide a direct input and have a major impact on the formulation of corporate strategies dictating the use of geothermal energy.

Relative price is not the only factor determining the selection of energy sources. As previously noted, corporate strategies with respect to the use of geothermal energy result from an amalgamation of considerations that span the spectrum of impact from basic technology to the economics governing the energy selection, to the incentives provided by government, to the institutional requirements. Exhibit VI-10 lists various motivating and inhibiting forces affecting the corporate decisionmaking of the utilities with regard to the choice of energy sources. Further, the constraints upon their selection of geothermal energy as the source for power generation—as reported by utilities in the interviews conducted in the course of this study—are listed in Exhibit VI-11. From such decisions, strategies evolve. These strategies, as reported by members of the Corporate Management and reported to the study team, are generalized and summarized in Exhibit VI-12. As seen in the exhibit, there are some utilities that are actually pursuing geothermal as a possible energy source—in part because of the increasingly difficult position these companies find themselves in with respect to new and reasonably priced sources of energy and their own deteriorating financial

EXHIBIT VI-10
Summary of Major Barriers or
Concerns for Electric Utilities

COMPANY		TECHNICAL				ECONOMIC			ENVIRONMENTAL/INSTITUTIONAL							
		LACK OF INNOVATIVE F/S TECHNOLOGY	LACK OF TECHNOLOGY FOR LOW T. HYDROTHERMAL	RESERVOIR IDENT. & RISK	SYSTEM INTEGRATION	LOSS OF ECONOMIC ADVANTAGE	ECONOMIC RISK	INABILITY TO OBTAIN FINANCING	BRING PRODUCTION & REINJECTION	CONTROL OF AIR & WATER EFFLUENTS	CHANGING REGULATIONS	LICENSING & SITING DELAYS	CONTRACTS AMONG DEV. & USERS	LOSS OF POLITICAL APPEAL	EXCLUSION OF DEV. COST IN RATE STRUCTURE	LACK OF KNOWLEDGE
UTILITY A	↓	○				○			●		●	●				
B		○							○		○					
C			●			●				○	●	●				
D				●							○		●			
E				○		●		●			●					
F			○	○		●					●					
G			○	○		●		●			●					
H			○	○		●		●			●					
I			○	○		●		●			●					
J			○	○		●		●			●					
K			○	○		●		●			●					
L			○	○		●		●			●					

EXHIBIT VI-11
Driving Forces in Electric Utilities'
Geothermal Decisionmaking

	UTILITY											
	A	B	C	D	E	F	G	H	I	J	K	L
MOTIVATING FORCES												
• DIVERSIFY CAPABILITY	•				•			•	•			•
• ALTERNATIVE TO OIL	•	•	•				•				•	•
• CLOSE TO LOAD CENTERS			•	•								
• FLEXIBILITY (ADD INCREMENTAL CAPACITY)	•						•			•		•
• FAVORABLE ECONOMICS		•		•	•		•					•
• POLITICALLY ATTRACTIVE		•	•									
RETARDING FORCES (REFER TO CONSTRAINT EXHIBIT)												
• RESERVOIR RISK					•			•	•			
• TECHNICAL RISK				•	•			•	•	•	•	
• ECONOMIC RISK									•		•	
• LEGAL/REGULATORY ISSUES		•			•	•			•	•		•

EXHIBIT VI-12
Electric Utility Strategies
for Geothermal Energy Utilization

position. Other companies, with less stringent requirements, have formulated corporate strategies that specify cautious and modest investments in this energy source—looking at its long-term potential as a means for providing future capacity. And lastly, a group of utilities are monitoring the success of the development programs of the other companies with a view toward meeting their own needs in the last decade of this century.

The shifting strategies of the utilities with respect to this resource have resulted, in part, from the impact of extrinsic events—as can be seen in Exhibit VI-13. Management representatives of the utilities pointed out they were aware of at least three events that caused conscious decisions within their companies to reevaluate geothermal energy as an alternative energy source and to formulate plans for its utilization. The impacting events were the passage of the 1970 Geothermal Steam Act, its implementation in the 1973-1974 period—coincident with the enactment of the 1974 Geothermal RD&D Act—and the overall impact of the 1973 Arab Oil embargo. Admittedly, there is a long lead time in electricity generation programs, and a substantial amount of program inertia that delays both the initiation and the termination of projects. Nevertheless, the step increase in geothermal energy capacity coinciding with their conscious decisions in response to major external events is interesting to observe. Some of the respondents indicated that the significance of the step increase lies in the fact that programs underway were accelerated—or at least not restrained—by the events impacting corporate decisionmaking in the 1973-1976 time period. This point will be discussed in a more general sense later on in this chapter.

In reviewing the overall corporate decisions of the utilities with respect to geothermal energy, portrayed in Exhibit VI-14, it is seen that the strategies adopted do not specify that all of the power from geothermal

EXHIBIT VI-13
Historical Perspective of Electric Utility
in Geothermal Energy Development

EXHIBIT VI-14
Integrated Strategies by
Industry Segment

energy distributed over their networks are to be generated by the utilities. In fact, the strategies of some of the companies accept the fact that they will be purchasing electricity, rather than steam, from some developers—whether energy companies or geothermal companies. Whether or not this comes to pass will obviously be the result of the effects of new legislation and decisions by the FERC with respect to the generation of electricity by nonutilities. Nevertheless, consideration of such an alternative has been included in the formulation of utilities' strategies for future operations.

Nonelectric Users

As was described previously, most of the potential direct heat users of geothermal energy have not formulated strategies for this resource use. Most frequently, under the aegis of government-funded programs, the developers/promoters market this energy source to logical segments of industry and solicit their participation in joint programs. As an outgrowth of the government programs, the developers/promoters have been surveying existing geothermal resources to discover a conjunctive relationship between those sources and proximate industries requiring low-cost energy sources. This point will be discussed in more detail in the next section.

Exceptions to this approach to strategic planning for industrial uses of geothermal energy are seen in the strategic plans of a quasi-industry—the municipality. Some of these local governments have formulated, or have had formulated for them, strategies for the development, utilization, and/or offering for sale the generated power and/or direct heat uses of the geothermal energy resources under their control or to which they have been able to acquire rights of development. The municipalities have an interest in the implementation of such strategies to meet their own requirements for energy, such as district heating, and more

frequently of late, the development of geothermal energy resources to provide a low-cost energy source for industries in the area. These aggressive strategies have been derived from community pressures such as unemployment, migrating industry, and need for new sources of revenue and low-cost energy sources for government-sponsored activities.

General Promoters

Strategies formulated by the new breed of developers in the industry—the promoters of direct heat uses of geothermal energy—are complements to the strategies of the direct heat users. The immediate objective of these companies is to establish a direct heat market by enhancing the natural relationship between the existing or potential industries located in the area and the availability of geothermal resources. The overall strategies of these companies, with variations unique to the individual corporations, is to organize the market in associations large enough to warrant the development of a resource. Since geothermal energy can be developed incrementally, it makes an ideal vehicle for implementing such a strategy. These companies envision developing industrial parks in which industries will be invited into jointly funded projects to take advantage of the low-cost energy represented by the proximate geothermal resources. The financial arrangements for such ventures have already been discussed. One of the more interesting conclusions from this study is the recognition by the industry of the need for such companies—both by the traditional geothermal companies comprising the current structure of the industry and by the new potential user group that professes a lack of confidence to undertake substantial development of the resources themselves.

Others

Beyond the rather significant evolution of direct heat applications envisaged by the

promoters/developers, various industrial groups with specific energy requirements have also considered geothermal energy as a solution to their needs. From time to time, these companies have developed strategies utilizing geothermal energy to meet their energy requirements—as part of their overall corporate business plans. In most of these cases, the corporations, in their long-term programs, have made the decision to give careful consideration to geothermal energy as an alternative to other energy sources. Occasionally, small energy users, located near geothermal resources, have considered the use of geothermal energy in their company plans. DOE has actually provided technical assistance to these small users as part of its outreach program. It would be expected that as the direct heat segment of the industry evolved, individual applications of the resource by small users would increase as well.

3. THE STRATEGIES OF THE VARIOUS SEGMENTS OF THE GEOTHERMAL INDUSTRY, FORMULATED FOR EACH PHASE OF THE DEVELOPMENT, WHEN VIEWED TOGETHER, COMPRISE THE INDUSTRY'S OVERALL CORPORATE STRATEGY AND IDENTIFY THE LEADERS OF THE INDUSTRY

Although the strategies of the individual segments of the industry varied from phase to phase, it is clear from discussions with industry that certain companies have maintained leading roles in the exploitation of the resource. These companies pursued the most aggressive strategies in each phase and, as a group, were instrumental in moving the industry forward.

In Exhibit VI-14, the various strategies for the industry segments are arrayed for each phase. It can be seen that from the first phase—the acquisition of leaseholds—to the development of the resources, the industry was pushed by a small number of energy companies and geothermal companies. Similarly, the market for this resource is seen in the aggressive power generation and distribution strategies of the electrical users.

The major roles of the promoters/developers of direct heat use are apparent—in contrast to the generally passive strategies of the engineering companies in the current

industry structure. In addition, various defensive strategies of some of the large energy companies and some direct heat users are readily apparent.

Thus, the probable exit of some of the energy companies from the field is seen to be unfortunate, for they have pushed the industry; however, the opportunities resulting from their departure may prove a counterpoise for the development of this industry. Moreover, the rapid rise of the promoters/developers of direct heat applications provides an index to the future structure of the industry.

* * * *

Thus, the perception of geothermal energy as a feasible alternative for the United States by industry's managers—its potential, their experience with its development, their view of government programs associated with it, and their evaluation of world events impacting its use—has been portrayed. As a result of their consideration of the technology, the economics, the institutional environment, and the basic structure of the geothermal industry, corporations in every segment of the industry, have arrived at conclusions, based on their own viewpoints of the geothermal world—whether valid or invalid—have made decisions, and formulated strategies for the future that impact the geothermal world.

APPENDIX A

Rogers

GEOHERMAL INDUSTRY ASSESSMENT

For

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S-79014

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Rogers

1.0

INTRODUCTION AND SCOPE OF WORK

Booz-Allen & Hamilton Inc., under contract with the Department of Energy (DOE), has undertaken the task of assisting the government in understanding the structure of the geothermal industry and the industry perspective of the DOE geothermal program. Towards this end, Booz-Allen & Hamilton's strategy has been aimed at:

- Defining the current and expected geothermal energy market
- Characterizing the industry and its structure
- Determining industry perspective of the geothermal energy field, its strategies and motivation for market development
- Determining industry's view of federal government programs

In order to complete these tasks, Booz-Allen & Hamilton Inc. (Booz-Allen) requested technical support from Rogers Engineering Co., Inc. (Rogers) to complete an analysis that would satisfy the following requirements:

1. Determine the technical problems associated with the development and utilization of geothermal energy as identified by Booz-Allen as a result of a survey of the geothermal industry.

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2. Identify and evaluate the technical problems arising in the same area and considered to be significant.
3. Determine those problems most likely to hinder the development of geothermal energy.
4. Describe general solutions or technical approaches to the identified problems, their probability of success, a prospective timetable for implementation and general funding requirements.

As a first step in the technical assessment of the geothermal industry, Booz-Allen submitted to Rogers the results of an industry-wide survey identifying and ranking the technical problems impeding the commercialization of geothermal energy for power generation and/or direct heat utilization. Rogers provided input and prepared the data in matrix form which is included as Attachment A to this report.

As shown, technical constraints to geothermal development are subdivided into Production and Utilization sections and further delineated into unique technical constraints. Constraints were evaluated against the specific type of resource and ranked from zero to ten according to the evaluation criteria shown in Attachment B. The severity of the constraint in terms of its hinderance to geothermal development increases from zero to ten.

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The results of the survey and matrix development establish a trend that is comprehensible and does not offer many new surprises. There are a few major problems that create substantial technical difficulties and severely impede economic investment; there are less severe problems that will tend to keep costs up on a short term basis.

2.0

GEOHERMAL TECHNICAL OVERVIEW

Once a geothermal plant is constructed, it is unfortunately tied to a specific site for its fuel supply with no back-up supply or resource alternative to count on. If there were, this degree of flexibility would reduce the uncertainty associated with production problems and well life.

Despite extensive tests and some operational experience with hydrothermal (liquid dominated) types of geothermal reservoirs, commercial-size well production and reinjection practice over a period of time commensurate with the life of a power plant has yet to be demonstrated. Hence, reservoir depletion and chemistry related problems appear to be the primary unknowns as related to resource dependability.

In a similar manner, the utilization of this resource for both power generation and direct heat application is confronted with the same problems: chemistry and reliability. For the power generation

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cycles, the utilization of geothermal energy appears to have low technical uncertainty for the flash cycle and moderate uncertainty for the binary cycle due to its development status at the present time. The flash cycle has an advantage at this time over the binary cycle because of the basic steam plant design and the relatively extensive demonstration at several non-U. S. hydrothermal sites in the world. Binary cycles employing hydrocarbon working fluid have been used in the chemical and gas processing industry for years but introduce some uncertainty when used in power generation. Because of this industrial experience, the technology associated with the working fluid loop and systems is considered available, but demonstration at the commercial scale size is required.

Both of these conversion systems are relatively simple to design, operate in low temperature and pressure regimes and employ no unusual components, materials or systems. Poor performance may well occur in the early plants, but performance (cycle efficiency and plant availability, etc.) is expected to improve with experience. Component and system reliability is clearly an important technical consideration because of its dependence on the capacity factor.

While development difficulties may initially be expected, they are not likely to be of the type to preclude plant technical possibility. For these reasons, there appears to be a need for a commercial size binary demonstration plant to substantiate these expectations

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and prove that an investment of this source is worthwhile. Equally important, however, is the need to locate and develop resources providing long well life and minimum technical impediments (e.g., scaling, corrosion, brine modifications and waste disposal). Developing power plant prototypes and testing equipment on this type of reservoir will greatly accelerate the growth of geothermal resource utilization.

3.0 PROBLEMS, GROWTH CONSTRAINTS AND SOLUTIONS

3.1 Impediments to Production

The conventional drilling technology used in oil, gas and most geothermal exploration and development efforts is based on the use of rotary drill string and roller bit. The pipe sections and bit are rotated by a motor while the drill cuttings are carried from the hole by the circulation of a drilling fluid (mud).

Well casing is normally installed in the well bore for the purpose of stabilizing the wall of the well and containing drilling fluids during drilling operations, and for conducting well fluid discharge when the well is produced. The casing is fixed in place using a suitable cement injected between the casing and the well wall.

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There are a number of other elements involved in the drilling process, however, the methods and tools required and used are known and available. Economics of drilling operations and well development can be expected to improve as the problems posed by the characteristics of the formation are solved through normal development of tools, materials and techniques to meet the specific situation.

3.1.1 Drilling Fluids

The role of drilling fluids in the geothermal environment is to provide cooling for the bit and other downhole components, carry cuttings out of the hole, support the hole walls hydrostatically, prevent formation fluids from entering the hole during drilling, and assist in monitoring formation temperature while drilling.

The major limitations imposed on such fluids in geothermal drilling is associated with the elevated temperatures of the formation. In addition, the loss of drilling fluid into the geological formation can be very high and complicate the selection of materials used in the drilling fluid.

Drilling muds typically begin to develop performance problems at temperatures exceeding 150° to 170°C. As the temperature rises, the mud viscosity increases resulting in altered flow rates and mud

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solidification. In addition, mud may accumulate within the well bore, forming a barrier lining that could severely limit the potential flow rate of the productive formation. Besides the complications of elevated temperature, the formation may be fractured to the extent that drilling mud is lost through the wall of the hole during the circulation process.

Careful selection of drilling fluid is also required to avoid damage to the formation resulting from the flow of the mud into the fissures that provide the path from the formation to the well bore. Future advances in foam drilling fluids might offer an alternative drilling fluid that will have some advantages.

Improved methods of lost circulation control will tend to increase safety, lower drilling costs and increase productivity in geothermal drilling. Control methods must be capable of surviving in the geothermal environment, be easily removed for production and leave no residue to plug the formation. Additives to or constituents of drilling fluids must be amenable to removal or degradation after use so that no permanent damage to the environment will result.

3.1.2 Drilling Materials and Equipment

Elastomers form a small but very important component of the materials needed for successful drilling. These products are used

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wherever flexible seals are needed, whether it is in drill bits and drilling motors (to control loss of lubricating fluid) or in packers (to seal off a section of the well). Unfortunately, virtually all of the currently available elastomers are degraded by exposure to temperatures exceeding approximately 150°C. Other problems associated with the use of elastomers include difficulties in bonding it to steel, poor lifetime in an abrasive environment and embrittlement on exposure to H₂S. Elastomer decomposition in seals and packers places severe limitations on the performance of present drilling equipment and equipment which use these materials becomes subject to failure.

Limits on the durability of steels can be related to the site-specific incidence of H₂S which causes embrittlement and corrosion. The temperature encountered in many geothermal wells approaches the annealing temperature of common steel so that high-temperature hardness and fracture toughness are poor. Use of appropriate steels will improve the lifetime and performance of a number of important drilling tools, thereby reducing cost.

Many tools that utilize sealed, lubricated bearings are incapable of operation under the high temperatures in the geothermal environment. Lubricant failure exposes the bearings to abrasive materials. The

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lubricants themselves tend to decompose after extended exposure to high temperatures. Many of the lifetime and failure problems encountered in geothermal drilling are related to bearing and/or lubricant failure.

Improvement in steels, elastomers and lubricants which protect the bearings would significantly contribute to the life and performance of many drilling tools. These improvements are expected to occur but will be dependent upon research and practical application experience.

3.1.3 Drill Bits

The bits used in geothermal drilling fall into two main types: roller bits, including those with sealed bearings and those with unsealed bearings, and diamond bits.

Sealed roller bearing bits normally use elastomer seals and appropriate lubricants for friction surfaces. Open bearing roller bits rely on the drilling fluid for cooling and lubrication of friction surfaces.

The importance of drill bit performance is reflected by its considerable impact on drilling economy. The bits cost may comprise 5

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to 15 percent of the cost of the well and are a major portion of the actual drilling costs because of downtime incurred in changing them.

Bits used in geothermal drilling exhibit accelerated wear in bearings, frequent breakage of roller cones, cutter teeth and bearings, loss of tungsten carbide inserts and gauge wear. These limits are dominated by temperature effects on materials. Improving bits to the point where they perform as well as in oil and gas application would significantly reduce drilling and maintenance requirements. Significant returns could result from improvements in seals and bearings, particularly in terms of increases in bit lifetimes.

3.1.4 Well Instrumentation

Instrumentation used in monitoring pressure, temperature, and flow in the two phase flow characteristic of saline hydrothermal well production is subject to severe performance limitations. Thermowells have accumulated layers of insulating scale so thick that temperature readings have become invalid. Pressure taps have been sealed over and pressure gauge diaphragms covered over with scale. Readings obtained from conventional flow measuring instruments including orifice plates have also been found invalid because of scale. By virtue of its being a closed loop on the brine side, a

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binary cycle should experience minimum precipitation of dissolved solids and use of the normal instrumentation available should provide acceptable results.

The key to the instrumentation problem is, first to select those types which do not depend on in-stream sensors wherever available. Where in-stream sensors cannot be avoided they should be placed in the most benign stream location possible. Pressure and temperature sensing in the brine stream provided with devices which enable operators to clean a tap insert a sensor and then take a reading have a good chance of success. Improvements in instrumentation devices for determination of well flow characteristics in the difficult geothermal brine environment will permit more accurate information for assessment of well and reservoir potential.

3.1.5 Drilling Technology Limitations

Several incentives exist for the improvement in drilling technology. Among these are reduction of costs, resultant reduction of on-line power costs, encouragement of more extensive exploration for resources, safety, availability of major equipment, and improved capability to drill in difficult formations. Generally, drilling can be expected to represent the most expensive aspect of resource exploration and assessment.

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Current experience suggests that the use of conventional drilling technology for geothermal resources is two to four times as expensive as drilling to the same depth for oil or gas. In the case of a hot well, decreased bit life, reduced pipe life and/or the need for high quality specialized equipment and materials (pipe, cement, casings, muds) at increased expense can be expected.

Drilling experience in areas such as the Imperial Valley suggests that the high cost of geothermal drilling compared to that of oil and gas drilling is to a great extent associated with the higher temperatures encountered, the high saline content of the reservoir fluids, and the highly abrasive formations encountered.

Of all of the drilling involved in obtaining data to evaluate the resource, exploratory drilling can be expected to be the most expensive. To a great extent this results from the large number of holes which must be drilled, the variety of formations encountered, and the requirement for removal of the bits (trips) for regular inspection of the drill bit and stem and extraction of core samples for analysis and logging.

3.2 Impediments to Utilization

Technical impediments to utilization as outlined in the matrix of Attachment A will be developed in this section. The first section

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investigated the status, problems and solutions associated with geothermal well production. Technical impediments associated with utilization of geothermal resources, for both power generation and direct use, will be evaluated here.

Technical impediments to geothermal utilization are associated with equipment, design, operation and research development. Some impediments such as scaling and corrosion affect both the production and utilization areas of the geothermal resource development and are evaluated as they occur and are characterized in the Imperial Valley of California in both a moderate-temperature, low-salinity brine (Heber) and in a high-temperature, high-salinity brine (Salton Sea area) and with reference to both the direct flash and binary cycles. An attempt has been made to concentrate on impediments having a major impact on geothermal utilization development. Other impediments while of significance, are expected to be reflected only in normal generating plant improvement or optimization programs and are not critical to overall geothermal development.

3.2.1 Scaling

Scale deposition in equipment which handle geothermal brines is a universal occurrence. In general, brine is in equilibrium with the host rock and lowering of the temperature or changing the concentra-

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tion of the brine by flashing affects the solubility of the constituents. Experience to date indicates that a moderate reduction in temperature and pressure and accompanying increase in flashing results in the deposition of a scale containing predominantly heavy metal sulfides. As the temperature is lowered further the predominant constituent of the scale is usually found to be silica. At Heber the predominate scale forming constituents are metallic sulfides and silica. Some reservoirs contain substantial quantities of carbonates which can form scale and carbonate plugging of well bores can occur.

Scale formation in piping and equipment other than heat exchangers is not expected to be a significant problem for a binary cycle plant when brine is pumped and not flashed.

The scaling characteristics of the Salton Sea area hypersaline brines are different from Heber brines. Salton Sea brines are unique and by no means characteristic of liquid-dominated reservoirs. On the other hand, the Heber reservoir is more representative of the KGRA's in the Western United States. The management and control of scale deposition and removal at the Salton Sea area is the major remaining problem for which economic solutions are being sought. One solution is to lower the pH of the brine to about 4,

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thereby inhibiting the rate of scale formation. Research is presently underway to verify the practicality of this pH adjustment method of scale control. Other methods are under consideration but have not reached a conclusive stage.

3.2.2 Brine Modification

As mentioned above, one way to control scale is to modify the brine. Salton Sea-type high salinity brines modified by the addition of acid have shown a decrease in scaling rate by as much as a factor of 10. However, there is a disadvantage because of the risk of increased corrosion from the acid. For flashed steam cycles from lower salinity brines there is less incentive to use brine modification. In a binary loop with a closed brine circuit, there is probably even less incentive to modify the brine to reduce scaling.

Brine modification by the use of an organic inhibitor is sometimes effective in the prevention of some scales. Also, the use of colloids may be effective in preventing the formation of silica.

If unmodified, the spent brine may be processed through a clarifier and filter at the plant exit, prior to injection, to prevent scaling of injection lines and plugging of the wells and formation. This

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process has been quite successful and can be expected to be considered for future power plant design.

Brine modification provides an opportunity to effect scale control and improve overall performance. The costs involved must be assessed relative to the total plant costs to determine the effect on the cost of energy.

3.2.3 Corrosion

This is an obvious problem area for metals exposed to geothermal brines. The severity of the corrosion problem is affected by the characteristics of the brine, brine modification and the power plant design. In a flashed steam cycle power plant, corrosion in the vapor areas of the installation will be related to the efficiency of the steam scrubbers in preventing carry-over and, also, to characteristics of the brine because of impurities introduced by carry-over.

In some conceptual designs of 30-year life power plants using carbon steel materials, corrosion allowances up to 5/8" in thickness have been assumed. Obviously, this allowance will need further review with availability of longer term data. Besides the obvious approaches of corrosion allowance and materials selection to solve the

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corrosion problem, redundant flash vessel trains should also be considered which could provide some relief from the corrosion problem, as well as the scale problem. In the long term the impact of corrosion on plant performance can be mitigated to some extent by selection of suitable materials and development of operating procedures aimed at the minimization of corrosion.

3.2.4 Water Availability

The availability of cooling water makeup could become a problem because of the competing demands of agriculture and other needs. It would be conservative to assume that a supply of good water is not readily available. Steam condensate from a flashed steam plant can be used for makeup unless it is required to be reinjected. In a binary plant the condensate option is not available and a cooling water source must be provided.

If it is necessary to utilize water which requires extensive treatment, the cost of energy will rise. However there should be no question as regards to technology required to accomplish the treatment.

3.2.5 Noncondensable Gas

The presence of noncondensable gases in the brine will strongly affect the choice of the power plant cycle. For a flashed steam

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cycle excess gas will decrease turbine efficiency, will require a larger more expensive condenser and will increase auxiliary power requirements associated with gas removal. At a noncondensable gas level of about 0.5% by weight of the brine, a flashed steam plant is preferred. At a higher gas content level it may be more economical to use the binary power plant.

If hydrogen sulfide is present in sufficient quantities to create a pollution problem, a cost impact for removal equipment will result. Assuming that something like the Stretford process is available and could be used, an increase in energy cost of about 5 percent could be expected. Ordinarily the technology associated with the treatment of ordinary noncondensable gases does not impact heavily on the choice of plant type or other related designs.

3.2.6 Two-Phase Flow

In cases where the production wells are self-flowing, a mixture of steam and brine will be present at the wellhead. Usually, the flow in the well is steady-state because of the relatively high velocities. However, unstable and pulsating flow can occur between the production well, and the plant with this unstable flow condition causing a corresponding instability within the power plant.

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It is known that surging may be minimized by high velocities with accompanying high pressure drops. This may not be an acceptable solution because of the loss in temperature between the well and the plant. One way to handle the problem is to provide a wellhead separator and then transport the steam and the brine to the plant through separate lines. While this method is considered practical, it is also expensive. If the plant is located immediately adjacent to a production island, the problem would appear to be minimal.

In cases where the wells are pumped, the two-phase flow does not exist between the well and plant. In cases where the geothermal brine is used directly in a tubular heat exchanger (binary cycles), no vapor is formed and two-phase flow is avoided.

3.2.7 Waste Disposal

The disposal of cooling tower blowdown is a general problem common to other types of power plants and many types of industrial installations. In the Imperial Valley it is probable that cooling tower blowdown can be disposed of in initial plants by discharge to the Salton Sea. If not environmentally acceptable, reinjection may be required. A major geothermal development in the Imperial Valley may require the application of other methods of treatment or disposal of cooling tower blowdown.

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Obviously, in a great majority of cases, spent geothermal brine must be injected into the reservoir for safe disposal. A special problem in the Salton Sea area is the disposal of solids containing silica resulting from the removal of suspended solids prior to injection. Disposal poses a problem in securing a suitable site. The problem does not exist at some places but could exist in varying degrees at other sites where silica removal prior to injection is either required or desirable.

3.2.8 Steam Quality

It is important that geothermal steam, whether used directly in a steam turbine in a tubular heat exchanger, be of sufficient quality not to form deposits on the steam turbine or on the heat exchanger surfaces. For geothermal power plant design it is important the particulates in the steam be reduced to a level where fouling of either the turbine or heat exchanger surface will not take place. This involves reducing the moisture content to .1% and the TDS content of the steam to 7.5 ppm or less.

The seriousness of the problem varies with the reservoir being produced. At The Geysers, for instance, commercial steam separators appear to be satisfactory. Centrifugal type separators have been in use successfully in hydrothermal plants operating on moderate salinity brines in New Zealand, El Salvador and Mexico. The type of

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separation or treatment equipment required for steam clean-up for turbine use from a high salinity reservoir has not been successfully established at this time, but the technology to implement the requirement is available.

3.2.9 Control Systems

Control systems for steam flash plants are essentially straightforward. Steam flash plants have been operating successfully in several foreign countries for a number of years.

Control systems for binary cycle plants do not appear to require new technology, but close attention needs to be paid to the different response characteristics embodied in large hydrocarbon turbines and in the relatively slow response characteristics of large brine hydrocarbon heat exchangers.

Because of scaling, much difficulty has been experienced to date in the measurement of control variables such as temperature, pressure and flow and in the operation of control valves and other valves in this scaling environment associated with steam from hydrothermal brine.

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3.2.10 Equipment

Steam Turbine. Single entry steam turbines have long been used successfully in geothermal steam service. Two pressure entry steam turbines are in use on some of the newer plants. There are no problems evident in specifying and operating the dual pressure steam turbines in geothermal service where the steam quality is controlled at a suitable level.

Hydrocarbon Turbines. For binary cycle applications, large 50 to 70 MW_e expanders are proposed, utilizing light hydrocarbons as working fluids. These can be either axial flow or radial in-flow designs. The axial flow designs are basically steam turbine designs modified to accommodate a different working fluid. The radial in-flow designs have been used for many years successfully in cryogenic service and hydrocarbon processing. While there are many of these latter industrial installations, none of them so far approach the size of a 50 MW_e plant. Because no large units of either type have been built and operated, large hydrocarbon turbines have been considered to be a major risk item from a technological operating view point. However, there has been much experience in the operation of high-pressure, high-temperature compressors of this size, and this experience should translate easily to the design of large turbines.

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Pumps. The pumping requirements in steam flash plants are no different than in any other power plant. Pumping requirements for binary cycle plants are characterized by the need to pump relatively large quantities of light hydrocarbons at fairly high pressures. The conditions are not extreme. Pumps have been developed and operated over a long period of years for hydrocarbon services more severe than the ones proposed here.

Heat Exchangers and Condensers. It is probable that most steam flash plants will incorporate surface condensers rather than barometric condensers in order to control H_2S emissions effectively. From a technical standpoint, there is little risk involved in providing surface condensers for the service since suitable materials of construction are available for this service, probably stainless steel, which will resist the corrosive effects of H_2S and CO_2 .

The large brine hydrocarbon exchangers required in binary cycle designs are presently available since this type of exchanger has long been used successfully in the hydrocarbon processing industry.

3.2.11 Total Flow Concepts

In the total flow concept, the entire output of a geothermal well is expanded through a prime mover which is used to drive a generator.

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Although hydraulic impulse turbines for the total flow concept are within the present state-of-the-art with respect to size, a substantial development effort will be required to adapt these units to the erosive-corrosive scaling environment of high velocity, two-phase hot brine solutions. Multi-staging of turbines introduces unique hydrodynamic design problems which are compounded in two-phase flow systems. Lack of complete operating and test data for the one available analytical model for two-phase brine flow in the turbine buckets and nozzles compounds the ability to project the required development time and development costs associated with this type of equipment.

Nevertheless, because of the potential for achieving high performance at low cost, the total flow energy recovery device deserves continued consideration and developmental effort.

3.2.12 The Downhole Heat Exchange Approach

The downhole heat exchanger has been proposed as an answer to the problems inherent in utilizing the high temperature/high salinity brines such as occur in the Imperial Valley. The concept of the downhole heat exchanger is to install a simple, double pipe heat exchanger into the geothermal reservoir such that only the thermal energy in the reservoir will be brought to the surface by heat

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exchange using a clean fluid which is pumped through the heat exchanger as the heat transfer medium.

The primary technical factors controlling the performance of the downhole heat exchanger are the rate of natural heat convection within the reservoir formation and the rate of heat transfer from the formation to the working fluid. The driving force for heat transfer to the working fluid is the temperature difference between the hot brine and the cooler working fluid flowing through the annulus between the casing and the internal pipe of the downhole heat exchange pipe.

The advantages of such a system are numerous and have a major impact on the cost of geothermal energy conversion. Major advantages are as follows:

(a) Brine and Noncondensable Gas Handling

Since the high-salinity brines will not be produced, there will be no brine and noncondensable gas handling and disposal problems.

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(b) Land Subsidence

The downhole heat exchanger avoids the problem of land subsidence because only thermal energy is extracted from the reservoir.

(c) Steam Clean-up Facilities

In the high-salinity geothermal brine resource areas, clean-up facilities are required to minimize the carryover of corrosive/erosive constituents of the brine in the steam supply to preclude equipment damage and performance deterioration. Again this will not be a problem with a downhole heat exchanger design.

(d) Power Generating Plant

A power plant using geothermal steam produced from the reservoir requires high cost stainless steel alloys or claddings in the manufacturing of the turbine, condenser, condensate pumps, and the piping systems. Since the downhole heat exchanger uses a clean demineralized water for production of steam, less expensive carbon steel can be substituted for the high cost materials.

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The downhole heat exchanger must be designed to meet the conditions of the reservoir available to be exploited. The amount of casing surfaces area per well (which determines the rate of energy extraction per well) is limited by the maximum depth to which it is economically and technically feasible to drill with current drilling methods. Directional drilling technique is employed to provide maximum surface exposure of the downhole heat exchanger in the hot zone of the resource which will maximize preheating and vaporization of the working fluid and enhance generation of steam in the exchanger.

The successful performance of the DHE depends on the magnitude of the overall heat transfer coefficient governing energy transfer from the reservoir to the heat exchanger which in turn is dependent upon reservoir permeability. These parameters have not been measured in geothermal reservoirs.

Concern has been expressed over the potential fouling of the heat exchanger surface exposed to the brine. Fouling, however, is not considered to be a serious problem for the following reasons. In the reservoir the heat exchanger extracts heat without causing brine concentration due to flashing. In addition, there is no change in pH due to the evolution of dissolved CO_2 in the brine. The degree to which the brine will be cooled by the heat exchanger is less than that to which the brine is subjected when it is produced from the

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well and flashed at the surface. The pressure to which the brine may be flashed without experiencing fouling problems is known, even when there is simultaneous concentration of the brine, increase in pH and lowering of temperature due to flashing.

The simplicity of the DHE design inherently reduces the financial risk involved in the field test of the concept. Should the DHE fail to meet acceptable performance criteria, the inner pipe of the DHE would be pulled and the casing perforated in the production zone to yield a well completed in the conventional manner.

3.2.13 Direct Heat Utilization

The search for geothermal resources for nonelectrical applications is essentially the same as the search for geothermal resources for production of electricity. However, the temperatures which are acceptable are much lower, that is about 50 to 160°C; accordingly the chances of finding such resources should be better.

There appears to be no technical impediment to drilling into geothermal reservoirs in this temperature range. At higher downhole temperatures as indicated earlier drilling muds and special bits are required. Techniques for extracting geothermal liquid vary according to the temperature of the liquid and any requirements to keep the brine completely in the liquid phase. For waters at less than

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100°C and a hydrostatic pressure, the water must be pumped to the surface.

Electric generation has been the main target of all of the geothermal research and technical development efforts. All the technical experience necessary to design and construct facilities for nonelectric application is available because of its transferability from other application including electric generation. Obviously the main reason for the development of electric generation facilities from geothermal resources is that electricity can be generated at the resource site and sent relatively long distances to the load.

There are other factors that make nonelectric application have significant potential in properly utilizing the bulk of the geothermal resource. These factors include the fact that the number of resources in the low to medium temperature range are estimated to be greater than at those higher temperatures, and that energy requirements for heating are compatible with these temperature ranges. In addition these heating needs are difficult to meet efficiently from either electricity or fossil fuels.

Applications of these resources include space heating, water heating, air conditioning, refrigeration and industrial use by direct heat or process steam. All of the technical difficulties associated

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with geothermal electric generation are applicable to nonelectric application.

It is important that suitable materials be selected since corrosion can be a problem due to water, atmospheric and soil conditions. Hydrogen sulfide, carbon dioxide, steam wetness and the presence of air in pipes are the most significant factor influencing corrosion. Mild steel and cast iron have sufficient corrosion resistance to give economic service life in this application.

Ideally for this service, heat exchangers should be made of a material which is highly conductive to heat, strong enough to allow the use of thin wall, sufficiently corrosion resistant and with characteristics that minimize the formation of stagnant fluid layers.

Disposal of geothermal fluids used in nonelectrical applications is not likely to be a trivial matter owing to the sheer quantity of fluids involved in these applications. The options available for fluid disposal depend mainly on the water quality and the temperature of the spent brine. Spent geothermal water with temperatures near ambient and with qualities that qualify it as irrigation water would pose no disposal problem at all. More caustic brines would have to be disposed of by deep well injection, direct discharge to

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surface waters or evaporation pond disposal as environmental constraints permit.

A next step in analyzing the potential for nonelectrical applications is to combine the available concepts and data with geothermal resource data and to evaluate that portion of the potential geothermal applications which can be located near acceptable geothermal resources.

4.0

ECONOMIC CONSIDERATIONS

The current supply curves for geothermal energy will change with time as new resources are discovered and evaluated, and as costs change with technical advances. Generally as the geothermal fluid brine temperature decreases, the cost of the energy supply increases significantly.

Geothermal well drilling technology is an adaption from the oil and gas drilling industry with drilling costs for geothermal wells averaging 1-1/2 times the cost of oil and gas wells in similar geologic regimes. Technology improvements resulting in decreased well costs will be important in low temperature geothermal systems and not as important for high fluid temperatures. Actual cost reductions from decreased fluid costs may be difficult to define because of the price of other power plant fuels. Improvements in

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heat exchanger and expander (turbine) design in binary systems will be important in reducing power costs. Technology improvements which result in decreased operating and maintenance costs and increased plant availability factor (e.g., downhole heat exchangers, scale control, H_2S removal upstream of the turbine, corrosion control) appear to be the most important in reducing costs for the higher temperature systems. Use of dry cooling or wet/dry cooling at competitive costs may be of critical importance in geothermal utilization for power production as well as for water conservation.

It is possible that current research will lead to major innovations (such as total flow conversion system) that will have major effects on costs before the year 2000. These possibilities should be viewed as appreciable but unpredictable, similar to the probability of discovering very large geothermal reservoirs.

Technical improvements will probably not reduce average plant costs. Current estimates for new plants on specific sites are the most realistic for the next few plants that will actually be built, and it is the ongoing efforts in engineering research which will tend to bring the costs of later plants down.

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On this basis, it is to be expected that future changes in the supply of energy from these resources will be shaped more by new resource discoveries than by cost changes.

A main conclusion which shows through all the uncertainties is that the potential supply of geothermal energy is neither very large nor very small compared to the expected need for new generating capacity in the western states.

Future plans and projections will foreseeably meet with serious problems on their way to realization, some economic and technical and some institutional. The geothermal supply is not large enough to obviate the overall problems of expanding capacity with coal and nuclear plants even if the competitive resources could be developed in the next twenty years. It is large enough, though, to reduce the size of the overall energy problems and to solve many particular problems faced by individual utilities.

Two special characteristics of power production from hydrothermal resources may be very important in determining when and where geothermal energy is the best alternative. One is that geothermal systems, unlike nuclear plants and modern coal plants, show no great economies of scale above 100 MW or so and are in fact limited in size by the cost of insulated gathering lines to feed a central plant from distant wells. Developing a geothermal field in steps of

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50 to 100 MW, as the reservoir is tested, is a safe and economic course which may well suit a utility's needs better than a single commitment to an 800 MW coal or nuclear plant. Another special characteristic is that flashed-steam geothermal plants can provide their own makeup water for evaporative cooling, unlike all other thermal power sources.

5.0 SUMMARY OF MAJOR CONCERNS

5.1 Production

Knowledge about the distribution, extent and quality of geothermal resources in the United States is the number one impediment to the rapid development of an energy industry based on the use of geothermal resources.

This lack of knowledge manifests itself in many areas of resource exploration and development. While the interpretation of data obtained using current instrumentation and exploration techniques has improved markedly in recent years there is a need for developing more sophisticated sampling and exploration techniques while improving and understanding the correlation between geophysical data and geochemical profiles and expected levels of productibility. There is also a need for a coherent dynamic reservoir model which

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will be useful in defining optimum rates of heat extraction and reservoir lifetime. This latter requirement becomes apparent with the realization that performance history is the only current indicator available to assess resource reliability.

In addition there are problems associated with developing effective methods of inhibiting and correcting solids deposition in the formation. Further, there is a lack of confirmed understanding of the cause and effect relationship between fluid injection into the formation and the occurrence of earthquakes.

These are problems that when understood and resolved will represent a major breakthrough towards the rapid development of the geothermal resource. While resource problems appear to be individually solvable, when looked at as a group of a period of 10-20 years will be required to assess most of the uncertainties associated with this resource.

In order that geothermal resource development be as rapid as possible, all information and data available from government and private exploration programs must be stored, processed and disseminated to industry as it becomes available.

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5.2 Utilization

A problem inherent in the slow development of geothermal resource utilization is the testing of energy conversion equipment and systems that depend on reliable and representative well responses.

In terms of the energy conversion cycle, there is, at present, no large-scale demonstration for liquid-dominated resources of low to medium thermal quality. Since there are many large quantities of geothermal resources of this type are available there is a great incentive for increasing the thermodynamic efficiency and controlling brine corrosion, scaling and deposition. One such incentive relates to developing a heat exchanger which has a good efficiency and incorporating a process which can preclude scale-up. A second incentive would be the development of an efficient large size turbine developed for a hydrocarbon working fluid. A third incentive involves development of methods to control the severe scaling and corrosion activity in heat exchangers, pumps, pipes and other equipment. It is expected that most of these concerns will be alleviated five years after demonstration plants which are presently being constructed are operational.

In the areas of research and development, a massive effort should begin now to test and evaluate the downhole heat exchanger and a

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prime mover capable of continuous operation on a predominately liquid two-phase fluid. In addition the development of a reliable down-hole pump should be a high priority. This research has begun but must be accelerated to ensure successful operation within 10-15 years.

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RANKING OF
TECHNICAL AND ECONOMIC CONSTRAINTS
TO
COMMERCIALIZATION OF GEOTHERMAL ENERGY
FOR
POWER GENERATION AND DIRECT HEAT UTILIZATION

<u>Constraints</u>	<u>Steam</u>	<u>Water > 450°F</u>		<u>450°F > Water > 300°F</u>		<u>Water < 300°F</u>	
		H. S.	L. S.	H. S.	L. S.	H. S.	L. S.
<u>Production</u>							
Reservoir Capacity	8	8	8	8	8	8	8
Well Stimulation	8	8	8	8	8	8	8
Scale & Corrosion Control	2	6	1	4	1	7	2
High Temp. Drill Muds & Cement	2	4	4	4	4	2	2
High Temp. Drill Bits	7	7	7	7	7	4	4
Downhole Inst. & Equip.	7	7	7	7	7	4	4
Disposal	5	7	4	7	4	7	4
Seismicity	3	3	3	3	3	3	3
<u>Utilization</u>							
A) <u>Power Generation</u>							
Binery	1	4	1	9	9	1	1
Flash	1	7	7	7	7	1	1
DH Pumps/HXCH	1	4	4	7	7	7	7
DC HXCH	1	4	1	7	7	7	7
NC Gas Abatement	8	8	8	8	8	6	6
Water Management	6	8	8	8	8	4	4
Scale & Corrosion Control	6	8	8	8	8	4	4
Total Flow Turbine	1	5	5	5	5	8	8
B) <u>Direct Utilization</u>							
DH Pumps	1	2	2	2	2	9	9
NC Gas Abatement	1	6	6	6	6	8	8
Scale & Corrosion Control	1	5	2	5	2	7	3
Water Management	1	4	4	4	4	4	4
Materials of Construction	1	5	5	5	5	5	5

H. S. = High Salinity
L. S. = Low Salinity

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ATTACHMENT B

CRITERIA FOR EVALUATING TECHNICAL
AND
ECONOMIC CONSTRAINTS TO COMMERCIALIZATION

1. Technology and/or economics is not a constraint to the commercialization of this resource for power generation and/or direct heat utilization.
- 2.
- 3.
4. Development of technology and/or associated economics will have minor impact on commercialization.
- 5.
- 6.
7. Development of technology and/or associated economics will have a major impact on commercialization
- 8.
- 9.
10. Commercialization of this resource will not proceed without resolution of identified technical and/or economic constraints.