RESEARCH AND DEVELOPMENT OF INFORMATION ON GEOTHERMAL DIRECT HEAT APPLICATION PROJECTS

FIRST ANNUAL REPORT
OCTOBER 1980 TO SEPTEMBER 1981

William F. Hederman, Jr.
Laura A. Cohen

October 1981

Work Performed Under Contract/Number DE-AC07-80ID12099 for the Idaho Operations Office

ICF Incorporated
Washington, D.C.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th></th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td></td>
<td>I-1</td>
</tr>
<tr>
<td>General Approach</td>
<td></td>
<td>I-1</td>
</tr>
<tr>
<td>Major Accomplishments</td>
<td></td>
<td>I-2</td>
</tr>
<tr>
<td>Overview of the Report</td>
<td></td>
<td>I-4</td>
</tr>
<tr>
<td>II. CHRONOLOGICAL REVIEW</td>
<td></td>
<td>II-1</td>
</tr>
<tr>
<td>Project Startup</td>
<td></td>
<td>II-1</td>
</tr>
<tr>
<td>Economic Data Gathering/Initial Analysis</td>
<td></td>
<td>II-3</td>
</tr>
<tr>
<td>Analysis of Project Economics</td>
<td></td>
<td>II-4</td>
</tr>
<tr>
<td>Dissemination of Preliminary Results</td>
<td></td>
<td>II-5</td>
</tr>
<tr>
<td>III. RESULTS TO DATE</td>
<td></td>
<td>III-1</td>
</tr>
<tr>
<td>Resource Assessment</td>
<td></td>
<td>III-1</td>
</tr>
<tr>
<td>Well Drilling and Resource Development</td>
<td></td>
<td>III-6</td>
</tr>
<tr>
<td>System Design, Construction, and Operation</td>
<td></td>
<td>III-7</td>
</tr>
<tr>
<td>Space and District Heating Systems</td>
<td></td>
<td>III-10</td>
</tr>
<tr>
<td>Industrial Processing Systems</td>
<td></td>
<td>III-13</td>
</tr>
<tr>
<td>Agricultural Systems</td>
<td></td>
<td>III-15</td>
</tr>
<tr>
<td>Economics</td>
<td></td>
<td>III-18</td>
</tr>
<tr>
<td>Environmental and Institutional Considerations</td>
<td></td>
<td>III-20</td>
</tr>
<tr>
<td>Potential for Future Development</td>
<td></td>
<td>III-24</td>
</tr>
<tr>
<td>IV. NEXT STEPS</td>
<td></td>
<td>IV-1</td>
</tr>
</tbody>
</table>

APPENDIX A
I. INTRODUCTION

This is the first annual report of ICF's geothermal R&D project for the Department of Energy's Idaho Operations Office. The overall objective of this project is to compile, analyze, and report on data from geothermal direct heat application projects. Ultimately, this research should convey the information developed through DOE's and Program Opportunity Notice (PON) activities as well as through other pioneering geothermal direct heat application projects to audiences which can use the early results in new, independent initiatives. A key audience is potential geothermal investors.

GENERAL APPROACH

The general approach employed in this project emphasizes gearing the data collection and analysis efforts to specific purposes for which the data and analytic results would be used. This analytical focus was selected to avoid the situation where the needed data would not be available and the available data would not be needed.

The original plan included four project tasks:

- compilation of a data base
- data evaluation and analysis
- identification of barriers
- reporting.

Project accomplishments in each of these four task areas are summarized next. This brief summary is followed by an outline of the remainder of this annual report.
MAJOR ACCOMPLISHMENTS

The original project plan called for major emphasis in the project's first year on data collection and data base development, but this plan was modified very shortly after the project began. In the Fall of 1980, DOE's geothermal energy division learned that major budgetary reductions for demonstration activity such as the PON projects appeared quite likely. This suggested that the research and development of information efforts should become more narrowly focused rather than be geared towards developing a very large data base that would have little chance of being maintained in the longer run.

This first year's efforts, then, led to the following accomplishments:

Compilation of a data base: The ICF data gathering efforts emphasized two major goals, the development of a comprehensive data collection device, and the collection of detailed cost and performance data from advanced geothermal direct heat projects.

A comprehensive, 33-page data collection form for all geothermal direct heat application projects has been drafted, reviewed by selected project personnel, EG&G staff, and DOE, and revised. The revised form is included as Appendix A to this report. This data collection form has provided the basis for the development by EG&G of a standardized final report format for all PON projects. The final report format will allow the collection of application project data in a complete, comparable manner that should permit quick review by parties interested in any aspect of geothermal direct heat applications across PON projects.

Secondly, we collected from five advanced PON projects the data necessary to perform a comparative economic analysis (described below). This effort included the identification of proper tax treatment for twenty investment cost categories.
Data evaluation and analysis: The evaluation and analysis efforts have emphasized the comparative economic analysis. The approach involved: 1) using collected project cost and performance data to estimate energy supply costs for geothermal direct heat, and 2) developing a standardized economic framework for comparison with alternative energy supplies. Projections of conventional fossil fuel prices have also been used to compare geothermal and conventional energy supply costs. Results of the analysis show that at each of the projects reviewed, geothermal direct heat energy is estimated to cost less than conventional energy supplies.

Identification of barriers: This particular analytic issue has been examined within the context of the comparative economic analysis. The potentially critical barrier of a major cost disadvantage does not appear to exist for the projects reviewed. Moreover, the groundwork has been laid through the preliminary economic analysis to assess the potential effects of changes in tax regulations (such as minimum temperature requirements, energy tax credit changes, or treatment of hybrid systems) and environmental quality control measures (such as reinjection of geothermal fluids).

Reporting: The findings of the preliminary economic analysis have been reported in several ways. The analysis and its results are presented in an interim topical report, Economic Assessment of Geothermal Direct Heat Technology: A Review of Five DOE Demonstration Projects, DOE/ID/12099-1, June 1981. The results have also been reported in an April briefing to DOE Geothermal Energy Program staff, to the DOE Geothermal Direct Heat Applications Program Semi-Annual Meeting (September 1981) and in a meeting of the Rocky Mountain Basin and Range State Geothermal Commercialization Teams (September
1981). Similar presentations are planned for the Geothermal Resources Council annual meeting (October 1981) and the International Association of Energy Economists annual meeting (November 1981).

OVERVIEW OF THE REPORT

The next section of this report presents a brief chronological summary of the project's first year, followed by a summary of results to date. The results are outlined by the reporting requirements of this project, under each of the nine report topics:

- resource assessment
- well drilling and resource development
- system design, construction, and operation
- space and district heating systems
- industrial processing systems
- agricultural systems
- economics
- environmental and institutional considerations
- potential for future development

The final chapter addresses potentially useful steps for future work.
II. CHRONOLOGICAL REVIEW

One of the most useful means of establishing the progress of a research effort is to review the results and how they were obtained. The results, or accomplishments, of the project's first year were highlighted in the Introduction and are discussed in greater detail in the third chapter of this report. This chapter describes the context in which these results were developed by providing a brief chronological narrative of the project's progress. These first year activities are summarized by quarter.

PROJECT START-UP (FIRST QUARTER)

The first quarter of the project (October to December 1980) dealt with commencing the project. This included action in all four project tasks.

Early efforts in the area of data base compilation sought to determine what the important data elements were and to design a vehicle for gathering that data. A major literature review of material discussing geothermal energy development, commercialization, and related issues formed an important part of these early activities. In addition, data were reviewed from several projects for which reports were readily available from the project officer (F.W. Childs of EG&G Idaho). The project materials reviewed included:

- Contract Documents
- Interim Progress Reports
- Environmental Reports
- Drilling Specifications
- Corrosion Test Reports, and
- System Design Plans

Using insights developed from the literature and report reviews, ICF drafted a geothermal direct heat application data collection form. The draft form was distributed at the November 1980 Geothermal Direct Heat Program
semi-annual meeting in Las Vegas to DOE and EG&G personnel and to several PON project directors whose projects were nearing completion. From discussions stimulated by review of this draft form arose the possibility of using this form as a major part of project final reports. Additional first quarter efforts included amassing specific cost and performance data for advanced PON projects as one part of the preliminary economic analysis issue (discussed below).

Evaluation and analysis efforts included a review of the project work plan with the technical monitor, and the identification of major analytic items for the preliminary economic analysis. The preliminary economic analysis was identified at the Las Vegas program meeting as a major aspect of the first year's effort. This shift away from a data collection emphasis arose from the anticipated federal budget reductions in the area of geothermal direct heat applications. The consensus that developed among DOE, EG&G, and ICF staff was that if a large, computerized data base were unlikely to be maintained in the long run, then there was little sense in developing it. Instead, it was felt that the successful performance of several advanced PON projects would allow important overview analyses to proceed. Therefore, data base development efforts were postponed pending a better sense of likely future outcomes.

Barrier identification efforts during the first quarter began with parts of the geothermal literature review. Other aspects included the specification of data concerning potential technological, economic, institutional, or legal barriers which would be included in the data collection effort. Special attention was devoted to major tax policy issues relevant to investments in geothermal energy.
Reporting activity was fairly limited in this initial stage of the project. However, ICF prepared and distributed the draft data collection form, presented a report and briefing to the November semi-annual meeting, and reported to DOE and EG&G on energy supply cost standardization issues.

**ECONOMIC DATA GATHERING/EARLY ANALYSIS (SECOND QUARTER)**

During the second quarter of the year, the preliminary economic analysis of geothermal direct heat applications was the primary focus of the project. Activity during this period covered all four task areas.

A "pilot" effort was made to collect all cost data for one application project in order to determine the detail required for an accurate financial analysis and to assess the feasibility of gathering all required data from existing project documentation. Existing documentation, especially monthly voucher summaries from EG&G, proved helpful as an initial source, but required supplementary conversations with project staff to determine the allocation of costs in greater detail. Efforts were also made to collect data from other projects and to overcome the problems encountered in these collection efforts. The process involved collection of data for three additional advanced PON projects.

At the same time, steps were taken to collect data on applicable federal and state tax provisions and on alternative fuel prices. In addition, when it became clear that DOE computer facilities would not be available for any data base development, ICF gathered data on the costs of implementing such a data base management system on private computer facilities.

Significant evaluation and analysis efforts began during this period. The projections of alternative fuel costs were developed. Financial parameter inputs (e.g., return on equity, inflation, tax rates) were established, and
tax treatment issues were analyzed. The first comparative analyses of geothermal direct heat energy and alternative energy supplies were completed, and the results indicated that geothermal could be quite economical.

With respect to potential barriers to geothermal direct heat technology, ICF began to probe the cost of environmental regulations to the extent feasible with available projected cost data. In addition, we examined the implications of federal tax policy on project economics. At the suggestion of the technical monitor, ICF staff also participated in a National Bureau of Standards district heating round table exercise.

During this period, reporting activity centered on two efforts: an initial draft report on the economic comparison and a briefing to DOE staff on this analysis.

ANALYSIS OF PROJECT ECONOMICS (THIRD QUARTER)

During the third quarter, the complete preliminary economic analysis was presented, critiqued, revised, and published.

Data compilation continued during this period. ICF finalized cost and production data for the five advanced PON projects included in the preliminary economic analysis. Raw data from additional application projects were also gathered and reviewed during this time. Efforts were made to obtain complete sets of data from more projects for inclusion in the preliminary economic analysis, but these efforts proved unsuccessful.

The evaluation and analysis task formed the major part of this period's activity. The final analysis was completed for the cost and performance data from the five PON projects reviewed. The final projections of the relevant alternative fuel costs were also completed. These two efforts were then combined to prepare the comparative economic assessment of geothermal versus conventional energy supplies.
The identification of barriers proceeded and ICF found that one potentially critical barrier, a major cost disadvantage for geothermal supplies, did not exist for the projects reviewed, given current cost and production estimates. Other specific barrier issues that received special attention included the explicit analysis of the effects of selected tax treatments, and an exploration of the cost effects for geothermal supplies of stringent environmental controls such as re-injection requirements.

Reporting during this period consisted of a briefing to DOE staff, the transmittal of the draft interim topical report, the discussion of the draft with DOE and EG&G staff, and the transmittal of the revised interim topical report. The full interim topical report reference follows:


DISSEMINATION OF PRELIMINARY RESULTS (FOURTH QUARTER)

The activity during the final quarter of the first year emphasized communicating the results of the preliminary economic analysis. These dissemination activities included:


- Preparation and presentation of a paper to a meeting of the DOE sponsored Rocky Mountain Basin and Range State Geothermal Commercialization Teams at Custer, South Dakota (September 1981).

- Preparation and presentation of a paper to the semi-annual meeting of the DOE Geothermal Direct Heat Program Opportunity Notice Project Teams at Boise, Idaho (September 1981).

- Preparation and submission of a paper for the annual North American meeting of the International Association of Energy Economists in Houston, Texas, November 1981. (Paper accepted for New Energy Technologies session.)
III. RESULTS TO DATE

This chapter reviews the results of the project's first year. Because of the re-direction of the project shortly after its commencement, the greatest progress by far has been achieved in understanding the economics of geothermal direct heat applications. The project contract stipulates, however, that the annual report specifically address each of the topical report issues, and the project monitor has requested that the discussion be organized accordingly.

These nine topics can be grouped into three broad classes. The first three topics address technical issues associated with resource exploitation: resource assessment, well drilling and resource development; and system design, construction, and operation. The second three topics address specific types of geothermal direct heat applications: space and district heating systems, industrial processing systems, and agricultural systems. The final three topics provide focused overviews of the geothermal direct heat application project experiences. They address economics, environmental and institutional considerations, and potential for future development.

Findings associated with each of these topics are discussed below.

RESOURCE ASSESSMENT

Geothermal resources which serve as energy sources for geothermal direct heat applications can be of much lower quality than the resources required for geothermal electricity generation, the major form of geothermal energy use at present. Such low to moderate temperature resources appear to have potential occurrence throughout most of the western continental United States, as well as some parts of the South, Great Lakes region, and Middle-Atlantic states.
Because these resources are more widespread than the higher temperature resources, they have not been as carefully reviewed at this time. Figure III-1, however, provides an overview of the latest assessment of the extent of geothermal resources underlying the United States.

As mentioned earlier, ICF has undertaken detailed examinations of five advanced projects, emphasizing in particular economic factors. This review provided some insights about the resources with which successful projects are likely to proceed. The resource conditions for these projects were not, in general, unusually favorable, and they varied significantly in temperature, depth, and level of impurities. This range of resources is presented in Table III-1.

There was little perceived uncertainty about the resources used at any of the five advanced projects. The three South Dakota projects all tapped the large, geothermally heated and well-defined Madison Aquifer. The only important surprise concerning this resource was that the temperature at the St. Mary's Hospital project proved to be 11°F (106°F versus 117°F) lower than had been estimated.

Of course, the resources were perceived to be relatively well-understood at all the projects for which any information has been reviewed so far. The major problem of differences between anticipated and actual resource characteristics related to the flow rate of the geothermal fluids. For instance, geothermal fluid flow rates have proven inadequate at Warm Springs State Hospital in Deer Lodge County, Montana (a space and domestic water heating application).
KNOWN AND POTENTIAL HYDROTHERMAL RESOURCES

### TABLE III-1

RESOURCES OF THE FIVE ADVANCED PON PROJECTS REVIEWED

<table>
<thead>
<tr>
<th>Project</th>
<th>Well Depth (feet)</th>
<th>Temperature (.F)</th>
<th>Flow Rate (gallons per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamond Ring Ranch</td>
<td>4,100</td>
<td>152</td>
<td>170</td>
</tr>
<tr>
<td>St. Mary's Hospital</td>
<td>2,200</td>
<td>106</td>
<td>375</td>
</tr>
<tr>
<td>Klamath YMCA</td>
<td>1,400</td>
<td>147</td>
<td>310</td>
</tr>
<tr>
<td>Pagosa Springs, CO</td>
<td>275, 300</td>
<td>148, 131</td>
<td>1,200, 600</td>
</tr>
<tr>
<td>Philip, S.D.</td>
<td>4,300</td>
<td>157</td>
<td>300</td>
</tr>
</tbody>
</table>
Another type of potential problem uncovered in ICF's research is that a resource assessment may not adequately identify the quality of geothermal fluids. The Philip, South Dakota project provides a good example of these risks. This project provides space and domestic water heating for a school and a limited district heating system. The U.S. Environmental Protection Agency tested Philip geothermal fluids and discovered Radium 226 at levels in excess of federal standards for drinking water (99 pico curies per liter versus a 5 pico curies per liter maximum acceptable level). The Philip project was therefore forced to incur the unanticipated expense of adding a Barium Chloride Treatment facility to remove 99 percent of the Radium 226. Only then could the fluids be discharged into the Bad River.

Data concerning the accuracy of a resource's estimated useful lifespan remain to be developed. Since the projects had operated for a maximum of less than two years when reviewed, significant information could not be gathered on reservoir lifespans.

Other potential resource-related problems are more closely associated with well drilling and resource development, both of which are discussed in the next section.

This project's data collection plans include reporting of the following data elements for each resource assessment exercise identified:

- Assessment type (estimate or actual measurement)
- Assessment date
- Type of geothermal resource (water dominated, vapor dominated, geo-pressured, hot dry rock)
- Temperature range
- Temperature (best estimate or actual)
- Temperature gradient
- Flow rate
- Drilling depth
WELL DRILLING AND RESOURCE DEVELOPMENT

The well drilling and resource development phases comprise key steps in the success of a geothermal direct heat application project. All five projects reviewed in the economic analysis were successful in completing production wells and, where necessary, re-injection wells.

Only four of the five projects, however, drilled wells; the Diamond Ring Ranch used an existing well. There have been some problems with the wells at these projects. For instance, the Pagosa Springs, Colorado district heating project had also planned on using existing wells, but problems concerning the integrity of the existing wells arose and the project team decided to drill new wells. Three wells were drilled to obtain two production wells; the other hole was cemented closed. Another problem arose when the production well at the Klamath YMCA required proper cleaning through air surge and extended, continuous pump testing.

Other specific issues have also been identified as potentially significant for geothermal projects. These include the contract letting processing for the driller (e.g., the importance of a competitive bid process), and the use
of water-well drillers (as opposed to oil-well drillers) and the communication to such drillers that they could perform the tasks necessary for geothermal well development.

The current data collection plan calls for gathering the following data elements for each well at a project:

- Date of estimate or measurement
- Well depth
- Bottomhole temperature
- Wellhead temperature
- Temperature gradient
- Flow rates
  - Daily peak
  - Annual average
  - Summer average
  - Winter average
  - Production peak season average
- Bottomhole static pressure
- Drilling technique
- Casing material
- Percent of well depth hard rock
- Downhole/re-injection pumps
  - Number
  - Size
- Expected useful life of well
- Drilling start date
- Drilling costs
- Other costs
- Well O&M expenses
- Well completion method
- Drilling firm type and experience
- Special features
- Problems encountered and how they were overcome.

The plan calls for these data to be collected for every well (successful or not) and for each estimate or actual measurement at each well.

SYSTEM DESIGN, CONSTRUCTION, AND OPERATION

The geothermal direct heat system design, construction, and operation activities vary to a greater degree with a project's particular application than do the previous elements. The key elements of the direct heat utilization
system include the transmission pipelines from the wells to the application site, the heat extraction equipment, the distribution system, the heating equipment, and the disposal system. The construction information relates directly to the parts of the heat utilization system just mentioned, while the operations data relate both to the components mentioned above and to more general aspects of project operations.

The data elements planned for collection concerning transmission pipelines include the following:

- Transmission line length
- Pipe diameter
- Kind and thickness of insulation
- Inlet temperature and pressure
- Outlet temperature and pressure
- Heat loss in pipeline
- Flow rate
- Number and size of pumps
- Piping material
- Special features of transmission system
- Map of system

Transmission system construction data will include:

- Start and completion dates
- Expected useful life
- Capital costs
  - Total
  - Per unit, if applicable
- Firm involved (and types)
- Contractual arrangements
- Problems encountered and how overcome.

These data should be presented for each transmission loop and information about original estimates and designs as well as actual costs, schedules, etc. should be reported.
For heat extraction and distribution data reporting would include the following:

- Number of heat exchangers
- Heat exchanger type
- Location of heat exchanger(s) (well site or application site)
- Inlet/outlet temperatures of geothermal fluid
- Inlet/outlet temperatures of secondary fluid
- Metering equipment
- Any cascading from one use to another
- Heat transfer performance of exchangers
- Expected useful life of equipment.

Construction data would include:

- Start-up and completion dates
- Capital costs
- Installation costs
- Identity and types of firms
- Contractual arrangements.

Again, these data would be collected for estimated and actual figures.

The distribution system data would be analogous to those for the transmission subsystem. The data for heating equipment at point of use would be similar in nature to the heat exchanger data, but would include retrofit data when appropriate.

The extent of disposal data would vary according to the environmental restraints imposed. Included would be:

- Disposal system type (e.g., deep-well reinjection or direct discharge into surface waters)
- Treatment required
- Capital costs
- Environmental restrictions encountered
  - Type
  - Source
  - Resolution of problem
- Other problems encountered and how overcome.

Again, estimated and actual figures would be reported.
The operations data for projects would also vary considerably by application. In general, however, the data would include the following items:

- Organization structure and responsibility for operations
- Federal involvement in operations
- Load-factor (estimated/actual)
- Description of down-time
- Other operational data
  - Flow rate
  - Temperatures
  - Loads
- O&M costs by system components (estimated/actual)
- Problems encountered and how overcome
- Billing system description

SPACE AND DISTRICT HEATING SYSTEMS

Space, water, and district heating systems represent some of the most common applications of geothermal direct heat energy. Geothermal district heating systems have existed in Boise since 1890; new systems are being operated and built in a number of cities, including Pagosa Springs, Philip, Klamath Falls, Susanville, and El Centro. The technology of geothermal space and water heating is well understood. Existing radiators and heating coils can easily be adapted for use with geothermal energy. In some cases geothermal fluid can be used directly in heating systems, replacing or supplementing boiler fluid. Alternatively, if the danger of corrosion is high, heat exchangers can be employed to transfer heat from the geothermal fluid to clean water which is then circulated through the heating system. Geothermal direct heat energy can be economically employed in smaller space heating projects for single structures (as, for example, at the St. Mary's hospital or the Klamath Falls YMCA) or for larger district heating systems which distribute geothermally heated fluid through a number of buildings. Space and water heating systems can utilize a wide range of geothermal
temperatures; if geothermal fluid temperatures are not high enough to completely supply energy needs, they can still be used for preheating, thus reducing boiler fuel expenses.

Our initial economic study focused on determining the costs of supplying geothermal and conventional energy to five PON projects, all of which involved space heating applications. The Diamond Ring Ranch project, which uses geothermal energy for both space heating and grain drying, is discussed in the agricultural applications section of this report; the other four projects are briefly described below.

**St. Mary's Hospital**

The geothermal heating system at St. Mary's hospital in Pierre, South Dakota has been operational since October 1980. 106°F water from the Madison Aquifer is used for space heating and preheating of domestic hot water in an existing, retrofitted hospital building and in a new hospital wing. The 2200 foot well flows at 375 gpm. After flowing through plate-type heat exchangers, the geothermal fluid is discharged into the Missouri River. The geothermal system will deliver up to 11,440 million Btu per year (supplying 55 percent of hospital heating needs), allowing a yearly savings of approximately 115,000 gallons of fuel oil. Capital costs for the St. Mary's system total $769,000; project staff estimate that yearly O&M costs over the life of the project will be approximately $10,800.

**Klamath YMCA**

Operation of the geothermal system at the YMCA in Klamath Falls, Oregon began in April 1980. A plate-type stainless steel heat exchanger transfers heat from the 147°F geothermal fluid to a supply of boiler fluid, which is then circulated to heat a swimming pool and provide space and domestic hot
water heating to the YMCA building. Geothermal fluid flows at 60 to 250 gpm (depending on heating needs) from a 1400 foot production well and is re-injected into a 2000-foot injection well. The system provides approximately 7,000 million Btu per year. Total capital costs for the project were $285,000; yearly operating costs are $2,100.

**Pagosa Springs**

In the town of Pagosa Springs, Colorado, a geothermal district heating system will supply heating to at least 127 businesses, residences, and public buildings. Two shallow wells (300 feet and 275 feet) will provide 131°F and 148°F fluid, respectively, from a Dakota sandstone aquifer at a combined total flow rate of up to 1800 gpm. Clean city water will be heated using two plate heat exchangers; afterward, the geothermal fluid will be discharged into the San Juan River. The heated city water will be circulated to users through two independent closed loops. Construction for the distribution system and building retrofit have begun. At capacity, the system is expected to deliver 56,700 million Btu annually, replacing approximately 82,500 million Btu of natural gas. In the first year of operations, now scheduled for the 1981-1982 heating season, the geothermal system will operate at approximately 38 percent capacity. Total project capital costs are estimated at $1,462,000; yearly O&M costs will be approximately $50,400 at full capacity.

**Philip**

The Philip, South Dakota geothermal project comprises a small-scale district heating system. 157°F fluid flowing at 300 gpm from a 4300 foot well in the Madison Aquifer is supplied to five school buildings and then cascaded to eight business district buildings. After treatment in a barium chloride plant
to remove Radium 226, the fluid is discharged into the Bad River. The geothermal system displaces 17,800 million Btu currently supplied by fuel oil, propane, and electricity. Operation of the system began in November 1980. The total project capital costs were $1,188,000; yearly O&M costs will total approximately $4,000.

Our analysis of these projects indicates that for these applications, geothermal systems can supply energy needs at costs lower than those of any standard gas, liquid, or solid fossil fuels. Details of this economic analysis are provided later in this report.

In addition, we have received some preliminary cost and/or design data from the PON geothermal district heating system projects in the cities of Boise, Idaho; Susanville, California; Klamath, Oregon; and El Centro, California; from space heating systems planned for a state prison near Salt Lake City, Utah; a condominium complex in Reno, Nevada, three commercial buildings in Elko, Nevada, and a private hospital in Marlin, Texas. These projects range from preliminary design to system construction phases.

Data gathering efforts for space and district heating systems should cover all project phases, including resource assessment, initial design, permitting, financing, well-drilling, system construction, and system operation. In addition, data collection for municipal district heating systems should incorporate creative financing mechanisms, rate-setting designs, metering, and customer billing systems.

INDUSTRIAL PROCESSING SYSTEMS

While much of the geothermal activity to date has focused on space heating applications, industrial process heat represents another important potential use of geothermal energy. Geothermal process heat applications projects
initiated thus far have been largely limited to agricultural applications, discussed in the next section, and production of fuel alcohol. As of June 1981, four geothermal ethanol plants were in service, with 53 more under consideration for operation by 1984. If all of these plants are constructed, total geothermal energy consumption for ethanol production by 1984 will be over 16,000 billion Btu annually.

The largest direct heat user of geothermal energy accounting for 10,000 billion Btu per year, or 75 percent of total current geothermal direct heat energy use, is a waterflood oil recovery project in Wyoming. The sheer size of this application suggests it as a target for future investigation. Analyses should focus on the costs and benefits of using geothermal energy in oil recovery applications compared to other potential uses of the geothermal resources, as well as comparison of flooding using geothermally heated rather than unheated water.

Our investigations to date have turned up relatively little data on geothermal industrial applications, since only a few of the PON projects involved industrial process heat. Plans for food processing plants in California and Idaho have been abandoned. The Elko, Nevada PON project includes plans for a geothermal retrofit of a laundry facility to heat water for washing machines. This project was still at a relatively early stage of development at the time of our first year analyses, which focused only on the most advanced projects from which more actual (rather than estimated) data were available.

While geothermal industrial process heat activity to date has been minimal, the potential for utilizing moderate temperature geothermal fluids in process heating applications is quite extensive. Industry accounts for about 40
percent of U.S. energy consumption, and process heat consumes almost 70 percent of industrial energy. 1/ While many of these industrial applications require temperatures substantially greater than those typically available from geothermal energy, 35 percent of all process heat is used in applications that require temperatures below 350 degrees Fahrenheit. 2/ Table II-2 lists some of the industrial and agricultural process heating applications most suitable for geothermal energy, noting the required temperatures for each process. Our future work may include a more extensive investigation of potential industrial users of geothermal energy and an identification of the match between industry locations and heat requirements and available geothermal resources.

AGRICULTURAL SYSTEMS

Geothermal direct heat energy is ideally suited to many agricultural applications. These include greenhouse heating, crop drying, animal husbandry, food processing, and fish farming. Two agricultural PON projects are already operational: Aquafarms International and the Diamond Ring Ranch. The Diamond Ring Ranch geothermal project was one of five advanced projects included in our initial economic assessment of geothermal direct heat energy. In addition to space heating, the Diamond Ring Ranch used geothermal


### TABLE III-2

**TEMPERATURES REQUIRED FOR SPECIFIC END-USE APPLICATIONS**

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Application Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>In-the-can cooking of vegetables, Soybean oil distillation, Most multiple effect evaporation</td>
</tr>
<tr>
<td>225</td>
<td>Rendering of animal fats and oils, Protein denaturation in soybeans, Distillation of pure water, Blanching clams, Soybean drying</td>
</tr>
<tr>
<td>200</td>
<td>Fruit juice pasteurization, Corn drying, Tobacco redrying, Preheat boiler feed water for steam production, Hydronic space heating, Lumber drying (soft woods), Soap manufacturing</td>
</tr>
<tr>
<td>175</td>
<td>Vegetable blanching, Lower limit of absorption air-conditioning, Milk pasteurization, Clean-up water for food processing plants, Hardwood lumber drying, Bottle washing for soft drinks</td>
</tr>
<tr>
<td>150</td>
<td>Wet capsule formation in pharmaceuticals, Hot water for oyster gapping, Domestic hot water</td>
</tr>
<tr>
<td>125</td>
<td>Poultry plant scalding water, Metal plating solutions, Caustic peeling of tomatoes</td>
</tr>
<tr>
<td>100</td>
<td>Forced air space heating, Aluminum and magnesium hydroxide production, Egg incubation, Bottle warming for soft drinks</td>
</tr>
<tr>
<td>75</td>
<td>Poultry house space heating for chicks, Soil warming and greenhouses, Rinse water for soft drink bottling and canning</td>
</tr>
<tr>
<td>50</td>
<td>Poultry house space heating for mature chickens, Aquaculture</td>
</tr>
</tbody>
</table>

fluid to supply process heat for a 700 bushel per hour grain dryer. The system, which began operations in the fall of 1979, delivers 7,800 million Btu per year, displacing 185,000 kwh of electricity and 49,400 gallons of propane. 152°F fluid from a 4100 foot well drilled into the Madison Aquifer in 1959 flows at approximately 170 gallons per minute. After circulating through the grain dryer or through a plate-type isolation heat exchanger, the geothermal fluid is discharged to surface reservoirs. Project capital costs, including the costs which would have been incurred in drilling a new well, total $489,000; yearly operating and maintenance expenses are expected to be $5,000.

Additional agricultural PON projects for which we have received some preliminary cost and design data include Aquafarms International and Utah Roses. Both of these projects are briefly described below.

- The Utah Roses project will utilize geothermal energy to provide space heating for a greenhouse in Sandy, Utah. 124°F geothermal fluid is expected to supply 25 percent of heating requirements, with an anticipated fuel savings of 14 MMcf of natural gas and 40,000 gallons of fuel oil.

- At Aquafarms International, 79°F. water from several geothermal wells is pumped directly to ponds which are used for year-round prawn farming. Total yearly energy use is expected to be 170 billion Btu.

During the first year of this information research and development project, we performed a thorough economic analysis of one agricultural geothermal project: the Diamond Ring Ranch. Our analysis indicated that the cost of geothermal energy to a private developer under circumstances similar to those at the Diamond Ring Ranch would be approximately $4.65 per MMBtu of conventional energy displaced. This compares to levelized prices for
comparable amounts of conventional fuels ranging from $5.65 per MMBtu for natural gas to $8.65 per MMBtu for distillate oil. Details of our economic analysis are provided below.

ECONOMICS

The major portion of our efforts during the first year of this project focused on an economic comparison of direct heating applications with conventional heating fuels. All the projects analyzed involved replacing conventional fluids (e.g., natural gas and fuel oils) with geothermal energy in existing heating systems. The cost of using geothermal energy in existing systems was also compared with the cost of new coal-fired equipment.

The costs for the geothermal retrofit projects were estimated from the results to date in five projects which were partially funded by the U.S. Department of Energy (DOE). These cost estimates are highly realistic since four of the five projects are operational and the other project is currently under construction. The five projects examined are the Diamond Ring Ranch space heating and grain-drying operation, the Kamath YMCA and St. Mary's Hospital space and water heating systems, and the Pagosa Springs and Philip district heating systems.

The approach used to compare the projects was a discounted cash flow analysis. The costs of the different projects were adjusted to account for the particular financial situation faced by each of three types of investors:

- private, for-profit firms
- non-profit organizations without tax exempt bond authority, and
- local governments (or non-profit organizations with tax-exempt bond authority).
The costs of all fuel alternatives for each investor type were then converted to a levelized unit cost (in constant dollars) of conventional energy displaced over the projected life of the geothermal project. Conventional fuel prices were estimated based on a recent DOE world oil price forecast in which oil prices increase about three percent annually.

Subsequently, a sensitivity analysis was performed to assess the effect of changes in the original assumptions. The assumptions which were altered in the sensitivity analysis included project costs, geothermal fluid flow over time, financing, federal tax policy, and world oil prices.

Table III-3 summarizes the results of the Base Case economic comparison. The table shows that for each of the potential investor categories examined, the full range of geothermal energy costs lies below the range of the conventional fuel costs. The sensitivity analysis indicated that geothermal energy maintains its economic advantage under most circumstances.

<table>
<thead>
<tr>
<th>Investor Type</th>
<th>Range of Cost Estimates</th>
<th></th>
<th>Conventional Fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range of Cost Estimates</td>
<td>Geothermal</td>
<td></td>
</tr>
<tr>
<td>Profit, for-profit</td>
<td>$2.37 - $5.73</td>
<td>$5.82 - $9.33</td>
<td></td>
</tr>
<tr>
<td>Non-profit(^1)</td>
<td>$1.77 - $4.17</td>
<td>$6.10 - $10.34</td>
<td></td>
</tr>
<tr>
<td>Local government(^2)</td>
<td>$1.33 - $2.65</td>
<td>$6.28 - $10.79</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Without tax-exempt bond authority.
\(^2\) Or non-profit with tax-exempt bond authority.
The difference between the geothermal costs and conventional fuel costs (except for new coal projects) are least for the private, for-profit investor and greatest for the local government investor. The major cause of the differences between investor groups is that the private, for-profit firm must pay taxes and faces a higher cost of capital and relevant discount rate than government and non-profit institutions.

Within each investor category, the costs for different geothermal projects vary significantly. Five projects are not sufficient to assess conclusively the relative importance of different application or resource characteristics in the determination of unit costs, but it appears that well depth is a particularly important determinant of geothermal energy supply costs. Other factors that may prove important include geothermal fluid temperature, flow rate, and well capacity utilization.

Our economic assessment indicates that geothermal energy can provide an economical alternative to conventional fossil fuels in low temperature heating applications. The cost estimates developed should be applicable to similar projects where the geothermal resource resembles the resources used in the projects examined. Consequently, potential investors in geothermal direct heat applications can use the results of this study to evaluate the economic attractiveness of proposed projects in some specific locations.

ENVIRONMENTAL AND INSTITUTIONAL CONSIDERATIONS

Although geothermal direct heat applications have proven their economic viability through decades of successful operation at scores of sites, development has remained at a rather low level. There are many reasons for such low levels of development. These reasons include uncertainty about resources and
uncertainty concerning relatively large-scale applications of geothermal direct heat, of which there have been few. Potential environmental constraints and other institutional factors, however, also appear to play a major role in the hesitancy of potential geothermal direct heat investors.

Certainly, the length of time required for planning a project, obtaining all the necessary permits, completing exploration (at unexplored sites), and constructing a system constitute important considerations for potential investors. Environmental regulations can play a key role in determining the time requirements for initiating a geothermal direct heat project, and the data collection plan that will be implemented with the standardized final report format is designed to develop insights into how these factors might delay projects.

Data related to environmental considerations that will be gathered include:

- **Environmental Report**
  - Preparer
  - Start/completion dates
  - Cost
  - Reviewers
  - Review completion date
  - Changes required (in project, in report)

- **Permits required**
  - Regulator (federal, state, local)
  - Title
  - Date request submitted
  - Data approved
  - Unusual problems

- **Effects of legislation on project approval process, including**
  - National Environmental Policy Act
  - Clear Air Act
  - Clean Water Act
  - Federal Water Pollution Control Act
  - Solid Waste Disposal Act
  - Safe Drinking Water Act
  - Noise Control Act
  - Marine Protection and Sanctuaries Act
In the work to date, the importance of environmental and other institutional factors has arisen periodically in both the general data efforts and the economic analysis. With respect to environmental factors, we have explored the effects of major pollution control techniques on project economics, in particular the barium chloride treatment plant at the Philip project and the addition of re-injection wells at all projects. In the instances examined, we discovered that re-injection well requirements could offset the economic advantage of geothermal energy over natural gas at the Philip site, but that the other projects examined could remain less costly than natural gas even if subject to a re-injection requirement.

Although environmental regulations pose a major set of potential obstacles for geothermal direct heat projects, there are other potentially significant institutional considerations that could impinge upon geothermal development. Two major classes of such factors deal with tax treatment of geothermal investments and financial criteria for investments.
The tax code provisions for geothermal energy projects can provide private for-profit developers with significant tax benefits. There are restrictions on eligibility for these benefits, however, and these restrictions are non-trivial. These tax issues received special attention in Appendix C (Federal Income Tax Treatment of Geothermal Costs) of ICF's interim topical report Economic Assessment of Geothermal Direct Heat Technology. Here we briefly summarize the major points.

Four kinds of tax benefits have special importance for geothermal projects: the expensing of intangible drilling costs, percentage depletion allowances, alternative energy tax credits, and new accelerated depreciation provisions. The tax code allows intangible drilling costs such as labor, fuel, repairs and hauling costs for drilling, completing, and testing geothermal production wells, to be deducted from taxable income in the years incurred rather than depreciated over the tax life of the investment. The costs of acquiring geothermal properties and determining their production potential are recovered through geothermal resource depletion allowances, which may exceed the full acquisition costs through percentage depletion allowances in cases where the energy is sold.¹ The fifteen percent energy investment tax credit, currently authorized through 1985, is available for equipment used to produce, distribute, or use geothermal energy. To qualify for the credit, an energy system must utilize geothermal fluids hotter than 50°C (122°F) and must exclude fossil fuel peaking and topping systems. Finally, the Economic Recovery Tax

¹ See ICF, Economic Assessment, Appendix C for a discussion of the restrictions on percentage depletion allowances.
Act permits accelerated depreciation schedules that should allow geothermal equipment to be depreciated with a five year tax life on a double declining balance schedule. All of these tax provisions provide major reductions in the effective costs of geothermal energy exploitation.

**POTENTIAL FOR FUTURE DEVELOPMENT**

Low and moderate temperature geothermal resources, capable of being harnessed for direct heat energy applications, underlie vast portions of the North American continent. (Refer to Figure III-1.) Although impractical in many regions and for many applications, exploitation of geothermal energy could potentially allow significant reductions in future consumption of fossil fuels. Extensive development of this alternative energy source will depend on the reduction of perceived geological risks and uncertainties surrounding geothermal resources, on the elimination of institutional barriers, and most importantly, on the comparative costs of constructing geothermal energy systems. Our economic analysis has shown that, at least for some specific applications and resources, retrofit of existing energy systems for use with geothermal energy is considerably less costly than continuing to purchase conventional gas and liquid fossil fuels. Commercial prospects for geothermal development would thus appear to be quite favorable. Indeed, interest in geothermal direct heat energy continues to grow. The U.S. Department of Energy reports in its Fifth Geothermal Progress Monitor that 197 new geothermal direct heat projects have been proposed, and feasibility studies are known to be underway for an additional 47 projects. Together, these applications could provide as much as 24 trillion Btu per year.¹

In developing the geothermal direct heat data collection instruments discussed above, we emphasized the gathering of information from projects already operational or under construction, rather than proposed development efforts. Interest in further geothermal development can be gauged, however, by determining the existence and extent of expansion plans for current projects. Data collection from existing projects should therefore include the following items:

- Potential market for the type of energy provided
- Status of expansion plans
- Likely constraints on expansion, and
- Extent of interest expressed by others in similar systems elsewhere.
IV. NEXT STEPS

Efforts on the Research and Development of Information on Geothermal Direct Heat Application Projects have already experienced an important shift in emphasis in response to changes in DOE's Geothermal Energy Program. As described above, these changes involved de-emphasizing planning for an analytical, investor-oriented data base for geothermal direct heat application projects because the likelihood of permanently maintaining such a data base appeared remote. This de-emphasis was offset by the acceleration of an analytic overview of project economics, which became possible through the successful progress of several PON projects. This section details suggestions for potential efforts during the second year of this project.

The generally favorable preliminary findings in this report indicate the need for additional analysis along several avenues of inquiry. For example, the preliminary findings based on projects using known geothermal resources should be verified further. To the extent feasible, we will also expand the scope of the economic assessment to include the costs associated with identifying and confirming the presence of a useful geothermal resource. In addition, some of the innovative financing approaches successfully introduced at several geothermal direct heat projects deserve attention in the next year of this effort.

The major form of supplemental verification will be the inclusion of economic data for additional PON retrofit projects which have advanced to a stage where their cost and production data could be useful in the analysis. Candidate projects are Susanville (California), T-H-S Hospital (Texas),
Klamath Falls (Oregon), Elko (Nevada), Utah Roses (Utah), and Aquafarms (California). When possible we will also try to include direct heat application projects implemented independent of the Department of Energy.

The act of identifying and confirming the quality of a geothermal reserve may or may not lead to an exploitable resource base. Future work on the economics of geothermal direct heat applications needs to estimate the costs of exploratory activities and the risks at each stage of a resource proving unacceptable or of institutional factors disrupting a project.

Drilling partnerships and other innovative financial vehicles have long played important roles in oil and gas development. The young geothermal direct heat industry is just learning how to take advantage of the special government incentives offered to encourage domestic resource development. An analysis of the effect of such incentives on project economics could help focus attention on the options available. The analysis could prove especially helpful in light of the major tax changes Congress and state governments are currently implementing.

Other subjects that will be considered by DOE and its contractors, EG&G and ICF, for analysis in the coming year include (i) further analysis of alternative fuel prices, (ii) exploration of industrial heat requirements in relation to areas of geothermal resource availability, (iii) planning guidelines for geothermal projects, (iv) examination of a potentially major special use of geothermal energy, enhanced oil recovery, and (v) development of the topical report series as a set of basic introductions to the major issues associated with geothermal direct heat applications.
The preliminary evidence gathered thus far indicates that geothermal direct heat can be commercially successful. Our future work will seek to provide more information to potential investors about the range of opportunities for economic exploitation of geothermal direct heat energy.
APPENDIX A

DRAFT DATA COLLECTION FORM
### BASIC PROJECT INFORMATION

<table>
<thead>
<tr>
<th>Field</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Name</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>Application</td>
<td></td>
</tr>
<tr>
<td>Size of Application</td>
<td></td>
</tr>
<tr>
<td>Percent of energy needs to be satisfied by geothermal energy</td>
<td></td>
</tr>
<tr>
<td>New heating/process system or retrofit existing system</td>
<td></td>
</tr>
<tr>
<td>Planned Energy Utilization</td>
<td></td>
</tr>
<tr>
<td>Btu (annual)</td>
<td></td>
</tr>
<tr>
<td>Btu (peak)</td>
<td></td>
</tr>
<tr>
<td>Amount and kind of conventional fuel displaced</td>
<td></td>
</tr>
<tr>
<td>Expected Load Factor</td>
<td></td>
</tr>
<tr>
<td>Number of Production Wells</td>
<td></td>
</tr>
<tr>
<td>Number of Injection Wells</td>
<td></td>
</tr>
<tr>
<td>Distance from wells to application site</td>
<td></td>
</tr>
<tr>
<td>Unusual characteristics</td>
<td></td>
</tr>
</tbody>
</table>
**Project Operator (organization):**

---

**Operator Status (public, private, or nonprofit organization):**

---

**Project Manager (name and phone no.):**

---

**Other Participants (name and role):**

---

**Resource Ownership:**

---

**Total Project Cost:**

- **Latest Estimate:**
  - Date: 
  - Actual: 

**Project Chronology**

<table>
<thead>
<tr>
<th>Event</th>
<th>Original Estimate</th>
<th>Latest Estimate</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application to DOE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(response to PON)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE Decision Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DOE Contract Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resource &amp; Environmental Assessment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Design/Planning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well Drilling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Well Testing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution &amp; Utilization</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systems Construction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start-Up of Operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of Federal Support</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Project Status:**

- **Date:**
- **Stage:**

**Next Step:**

- **On Schedule?:**
- **Main reason for delays:**
Reasons for selection of project: 

PRE-PROJECT ACTIVITIES

Origin of idea for project: 

Extent of knowledge of resource prior to project initiation: 

Is this a Known Geothermal Resource Area (KGRA)? 

Was there a feasibility study?: 

If yes, study dates: Start ____________________ Completion ____________________ 

Performer: 

Areas examined and findings: 

Geology: 

Technology: 

Market: 

Cost: 

Other:

What sorts of other expert advice were sought prior to project initiation?:

If pre-project analyses identified problems, elaborate and describe the steps taken to address the problems identified: 
LEASING AND PERMITTING

Is the resource Federally owned?: ________________________________

If yes, competitive or non-competitive lease?: ______________________

Federal Leasing Chronology

"Notice of Intent" to Obtain Lease
First Approval Received
   ____ Unconditional
   ____ Conditions: _______________________________________

____________________________________________________________
____________________________________________________________
____________________________________________________________

Lease Signed
Plan of Operations Submitted
Plan of Operations Approved
Changes required in Plan of Operations: __________

____________________________________________________________
____________________________________________________________
____________________________________________________________

Drilling Plan Submitted
Drilling Plan Approved
Changes required in Drilling Plan: ____________________________

____________________________________________________________
____________________________________________________________
____________________________________________________________

Explain delays in project schedule caused by slow-down in leasing process:

____________________________________________________________
____________________________________________________________
____________________________________________________________

Total acres leased: ________________________________________
## Environmental Report

When was environmental report prepared?  
Start:  
Completion:  

Environmental report prepared by whom?:  
Reviewed by whom?:  
When was review completed?:  
Changes required in project:  

## Other Local, State, and Federal Permits Required

<table>
<thead>
<tr>
<th>Permit</th>
<th>Agency</th>
<th>Date Request Submitted</th>
<th>Date Approved</th>
<th>Unusual Problems or Good Points</th>
</tr>
</thead>
</table>
Effects, if any, of the following legislation on project approval process:

- The National Environmental Policy Act: __________________________
- The Clean Air Act of 1970: __________________________
- The Clean Air Act Amendments of 1977: __________________________
- The Federal Water Pollution Control Act: __________________________
- Solid Waste Disposal Act: __________________________
- Safe Drinking Water Act: __________________________
- Noise Control Act: __________________________
- Marine Protection and Sanctuaries Act: __________________________
- Resource Conservation & Recovery Act: __________________________
- Endangered Species Act (1973): __________________________
o Arts and Artifacts Indemnity Act: ____________________________
__________________________________________________________

o Toxic Substances Control Act: ____________________________
__________________________________________________________

o Endangered American Wilderness Act of 1978: ______________
__________________________________________________________

o The Non-Game Fish and Wildlife Bill: ______________________
__________________________________________________________

o The Historic Preservation Act: ____________________________
__________________________________________________________

o Occupational Safety and Health Act of 1970 (OSHA): ________
__________________________________________________________

o Forest and Rangeland Renewable Resources Act of 1974: ______
__________________________________________________________

o National Forest Management Act of 1976: ________________
__________________________________________________________

Pertinent state or local legislation (list separately):

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
To what extent did the following groups affect the permitting/leasing process?

Federal Agencies: ____________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
State Government: ____________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Local Government: ____________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Local Community: ____________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Others (list): ____________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
<table>
<thead>
<tr>
<th>Resource Assessment Summary</th>
<th>Original Estimate</th>
<th>Latest Estimate</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate Date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature: Best Estimate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement Technique</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Gradient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling Depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reservoir Life Span</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reservoir Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellhead Pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid Quality:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TDS (ppm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unique Resource Characteristics

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Assessment Performer

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Time to Complete Assessment

Assessment Technique

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Describe problems encountered in assessment

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
Lithology

Productive Zone: ____________________________

Reinjection Zone: ____________________________

Describe any surprises encountered: ____________________________
PLANNING

Site

Who made the site choice?: ________________________________

How?: ________________________________

Is it a "representative" site for this type application?: ________________

Why or why not?: ________________________________

Has the particular site generated any anticipated or unanticipated problems?: ________________________________

If there were changes in site plans, describe (with dates): ________________
Application

Who made the application choice?: ____________________________

How?: _____________________________________________________

Is it a "representative" use in the relevant industry?: ____________

Why or why not?: __________________________________________

Has the particular application caused any problems?
___________________________________________________________

If there were changes in the application, describe (with dates): ______
Scale

Who made the scale choice?:

How?:

Is it a commercial scale for this type application?:

Why or why not?:

If not, what are additional scale-up problems?:

Has the particular scale caused any anticipated or unanticipated problems?:

If there were any changes in scale, describe (with dates):
Equipment/Technology

Who made the equipment choice?:

On what basis?:

Was the equipment specially developed for this application?:

If special, could it become a routinely produced system? Has the equipment caused any anticipated or unanticipated problems? If there were equipment changes, describe (with dates):
Project Planning Process

What parties played important roles in project planning decisions?:

<table>
<thead>
<tr>
<th>Application Selection</th>
<th>Site Selection</th>
<th>Equipment Selection</th>
<th>Scale Selection</th>
<th>Operations</th>
<th>Other (specify)</th>
</tr>
</thead>
<tbody>
<tr>
<td>User(s)</td>
<td></td>
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<tr>
<td>Operator</td>
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<tr>
<td>Contractors*</td>
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<tr>
<td>Local Government</td>
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<tr>
<td>Other Local*</td>
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<tr>
<td>State Government</td>
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<tr>
<td>Federal Government</td>
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<tr>
<td>Federal Contractor*</td>
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</tbody>
</table>

* Specify.
### WELLS

(Complete one sheet for each well.)

<table>
<thead>
<tr>
<th>Well Name:</th>
<th>Original Estimate</th>
<th>Latest Estimate</th>
<th>Actual</th>
</tr>
</thead>
</table>

**Date of Estimate**

**Depth**

**Bottomhole Temperature**

**Wellhead Temperature**

**Temperature Gradient**

**Flow Rates:**

- Hourly Peak
- Annual Average
- Summer Average
- Winter Average
- Production Peak Season Average

**Bottomhole Static Pressure**

**Percent of Well Depth Hard Rock**

**Drilling Technique**

**Casing Material**
Downhole/Reinjection Pumps:

<table>
<thead>
<tr>
<th>Original Estimate</th>
<th>Latest Estimate</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size (Hp)</td>
<td></td>
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</tbody>
</table>

Expected Useful Life of Well

Start of Drilling (date)

Completion Date

Well completion method:

Special Features:

Expected Useful Life of Well:

Describe problems encountered and how handled. Include reasons for delays and cost overruns.
## TRANSMISSION PIPELINES

(Attach any maps showing pipeline layout. Complete one sheet for each main line.)

<table>
<thead>
<tr>
<th>Name of Pipeline:</th>
<th>Original Estimate</th>
<th>Latest Estimate</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Estimate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pipeline Length</td>
<td></td>
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<td></td>
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<tr>
<td>Pipe Diameter</td>
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<td></td>
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<tr>
<td>Kind of Insulation</td>
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<tr>
<td>Insulation Thickness</td>
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<tr>
<td>Trench Depth</td>
<td></td>
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<tr>
<td>Geothermal Fluid or Other Fluid</td>
<td></td>
<td></td>
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<tr>
<td>Inlet Temperature</td>
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<tr>
<td>Outlet Temperature</td>
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<tr>
<td>Inlet Pressure</td>
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<tr>
<td>Outlet Pressure</td>
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<td></td>
</tr>
<tr>
<td>Heat Loss in Piping System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Number of Pumps</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Size of Pumps</td>
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<tr>
<td>Piping Material</td>
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<tr>
<td>Casing Material</td>
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<tr>
<td>Special Features</td>
<td></td>
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<td></td>
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<tr>
<td>Construction Start-Up</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Construction Completion Date</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Expected Useful Life</td>
<td></td>
<td></td>
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</tbody>
</table>
Describe problems encountered and how handled. Include reasons for delays and cost-overruns:

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
HEAT EXTRACTION AND DISTRIBUTION (attach any diagrams)

Process description: ___________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Kind of Heat Exchangers (floating head, reboiler, plate & frame, etc.)
Number of Heat Exchangers
Location of Heat Exchangers (well site or use site)
For Each Heat Exchanger:
Inlet Temperature of Geothermal Fluid
Outlet Temperature of Geothermal Fluid
Inlet Temperature of Secondary Fluid
Outlet Temperature of Secondary Fluid
Are Geothermal Fluids Cascaded from One Use to Another?
If yes, list inlet and outlet temperatures for each process:
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________

Overall Heat Transfer Coefficient
(Btu/hr ft²°F)
Construction/Installation: Start-Up Completion
Expected Useful Life of Equipment
Describe problems encountered and how handled. Include reasons for delays and cost overruns:

________________________________________________________________________

________________________________________________________________________

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Process Modifications/Retrofitting

Describe existing heating/cooling or industrial process system:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Describe required modifications to existing system: __________________________

________________________________________________________________________

________________________________________________________________________

Estimated Equipment Life: __________________________
For Space and Water Heating/Cooling Systems:

Number of Heating Days Per Year: _______________________
Number of Cooling Days Per Year: _______________________

Building Density: _______________________________________
_________________________________________________________________

For Industrial Processes:

Temperature requirements for each process: ________________
_________________________________________________________________
_________________________________________________________________

Total heat requirement for each process: ______________________
_________________________________________________________________
_________________________________________________________________

DISPOSAL

Type of Disposal System:  ___ Deep-Well Reinjection
                         ___ Evaporation Pond
                         ___ Direct Discharge into Surface Waters
                         ___ Other

Describe disposal system: __________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
Problems encountered: __________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

Equipment Life: _____________________________________________

ENVIRONMENTAL SAFEGUARDS

Discuss environmental impact of this geothermal project. Include particular environmental problems encountered and how handled:

Extraction: ________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

Distribution/Utilization: ______________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

Disposal: __________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
Give description of each major piece of pollution control equipment:

____________________________________________________________________

____________________________________________________________________

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Describe environmental monitoring:

____________________________________________________________________

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## PROJECT COST INFORMATION
(Attach additional sheets if project costs extend beyond 1982)

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</thead>
<tbody>
<tr>
<td><strong>Resource Acquisition and Related Costs:</strong></td>
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<tr>
<td>-- Lease Bonus Bid</td>
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<tr>
<td>-- Purchase Price of Land</td>
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<td>-- Permitting</td>
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<tr>
<td>-- Geological &amp; Geophysical Exploration</td>
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<tr>
<td>-- Environmental Assessment</td>
<td></td>
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<tr>
<td>-- Other</td>
<td></td>
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<tr>
<td><strong>Well Drilling:</strong></td>
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<tr>
<td>-- Design and Planning for Well</td>
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<td>-- Tangible Well Equipment</td>
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<tr>
<td>-- Intangible Drilling Costs (includes site preparation and well testing)</td>
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<tr>
<td><strong>Distribution System and Retrofit:</strong></td>
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<tr>
<td>-- Design/Planning/Bidding</td>
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<tr>
<td>-- Pump Houses and Other Structures</td>
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<tr>
<td>-- Geothermal Space Heating System in New Buildings</td>
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<tr>
<td>-- Equipment Not Used Exclusively with Geothermal Energy</td>
<td></td>
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</tr>
<tr>
<td>-- Disposal Equipment</td>
<td></td>
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</tr>
<tr>
<td>-- All Other Construction Costs</td>
<td></td>
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<tr>
<td><strong>General and Administrative Expenses</strong></td>
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<tr>
<td><strong>Direct DOE-Related Costs</strong> (e.g., conferences, publicity)</td>
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</tr>
</tbody>
</table>
Anticipated Yearly O&M Costs
Yearly Rental/Royalty Payment
Unit Selling Price (if applicable)
Total Capital Cost
Federal Share

Federal Share Applicable to Which Project Phases?
Non-Federal Share:
Amount
% Debt
Interest Rate on Debt
Expenditures To Date: $ ____________ Date: ______________

Reasons for cost overruns:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Non-Federal Sources of Funding:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Describe problems encountered in arranging financing:
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Contractual arrangements with constructor (cost plus, fixed fee, etc.):
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
First-of-a-kind project costs (describe and list costs for extra instrumentation, frequent down-time for examining the system, etc.):
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Describe customer billing system: ____________________________

_________________________________________________________________

Depreciation methods used for financial reporting: ____________________

_________________________________________________________________

Depreciation methods used for tax purposes: __________________________

_________________________________________________________________
## PROJECT MANAGEMENT

Project organizational structure: 

Who was responsible for day-to-day operations during project planning and construction?: 

Who will be responsible for operations and maintenance once project enters operational phase?: 

Describe any significant Federal involvement in project management: 

## OPERATIONS

### Monthly Energy Production Data:

<table>
<thead>
<tr>
<th>Month</th>
<th>Btu's Delivered</th>
<th>Average Flow Rate</th>
<th>Peak Flow Rate</th>
<th>Temperature</th>
</tr>
</thead>
</table>


Describe incidents of extended down-time:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Describe testing/monitoring procedures and equipment. Was testing planned as a regular part of project's operation and/or added later?:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

PROJECT RESULTS/ACHIEVEMENTS

To what extent does the project serve its originally established goals?:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Pre-project status of and operational experience with technology employed by the project:

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

______________________________________________________________________
Status of technology after construction and operation:

What is the attitude of users (generally positive, generally negative, mixed)? Explain:

What means are being employed to disseminate information on project results?

Has there been any movement to expand the system at its site (expressed interest, decision to expand, expansion underway, expansion completed)? Explain:
Have others expressed an interest in using a similar system elsewhere? (Include how interest expressed, list of other projects underway, etc.)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Estimated potential market in the project's area for the type of energy provided:

________________________________________________________________________

________________________________________________________________________

Percent of potential market served: ________________________________________

Likely constraints on expansion: