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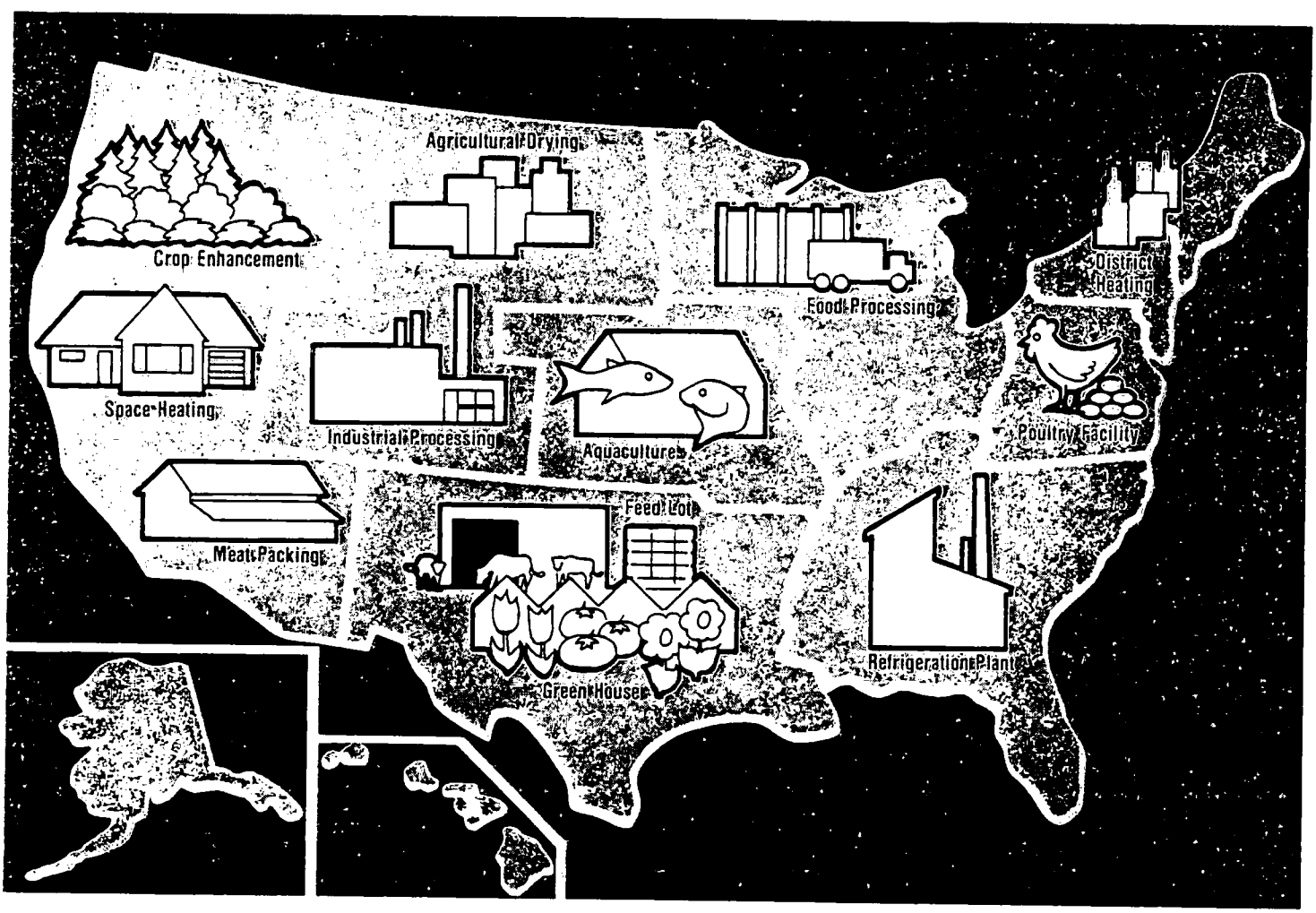
PRELIMINARY

Energy Technology Geothermal Direct Applications Program Plan



Division of Geothermal Energy

ENERGY TECHNOLOGY GEOTHERMAL DIRECT APPLICATIONS PROGRAM PLAN

PRELIMINARY

PREPARED BY

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PHILOSOPHY

- Value of geothermal energy will be determined in the marketplace.
- Direct application is often the most efficient use of geothermal energy.
- Matching of resource and use is the key to maximum utilization.
- Direct use of geothermal energy is needed to reduce fossil-fuel consumption.

NEEDS

- Stimulation of geothermal infrastructure development.
- Resource identification, exploration, and utilization.
- Economic data base.
- Technology development, i.e., environmental, resource, and utilization techniques.
- Government participation to reduce unquantified risks.

GOALS

- Foster economically viable geothermal direct applications industry.
- Power on-line goal:
  0.1 - 0.2 quad by 1985
  0.5 - 2 quads by 2000
  6 - 8 quads by 2020

(Note: 1 quad = 10^{15}Btu)

STATUS

- U.S. development currently limited by previously inexpensive energy.
- Industry presently hesitant to invest because of unquantified development risks.
- Many applications possible with available technology.
- Some applications require further technological development.
- Approximately 0.02 quad now on-line, being developed, or projected.

STRATEGY

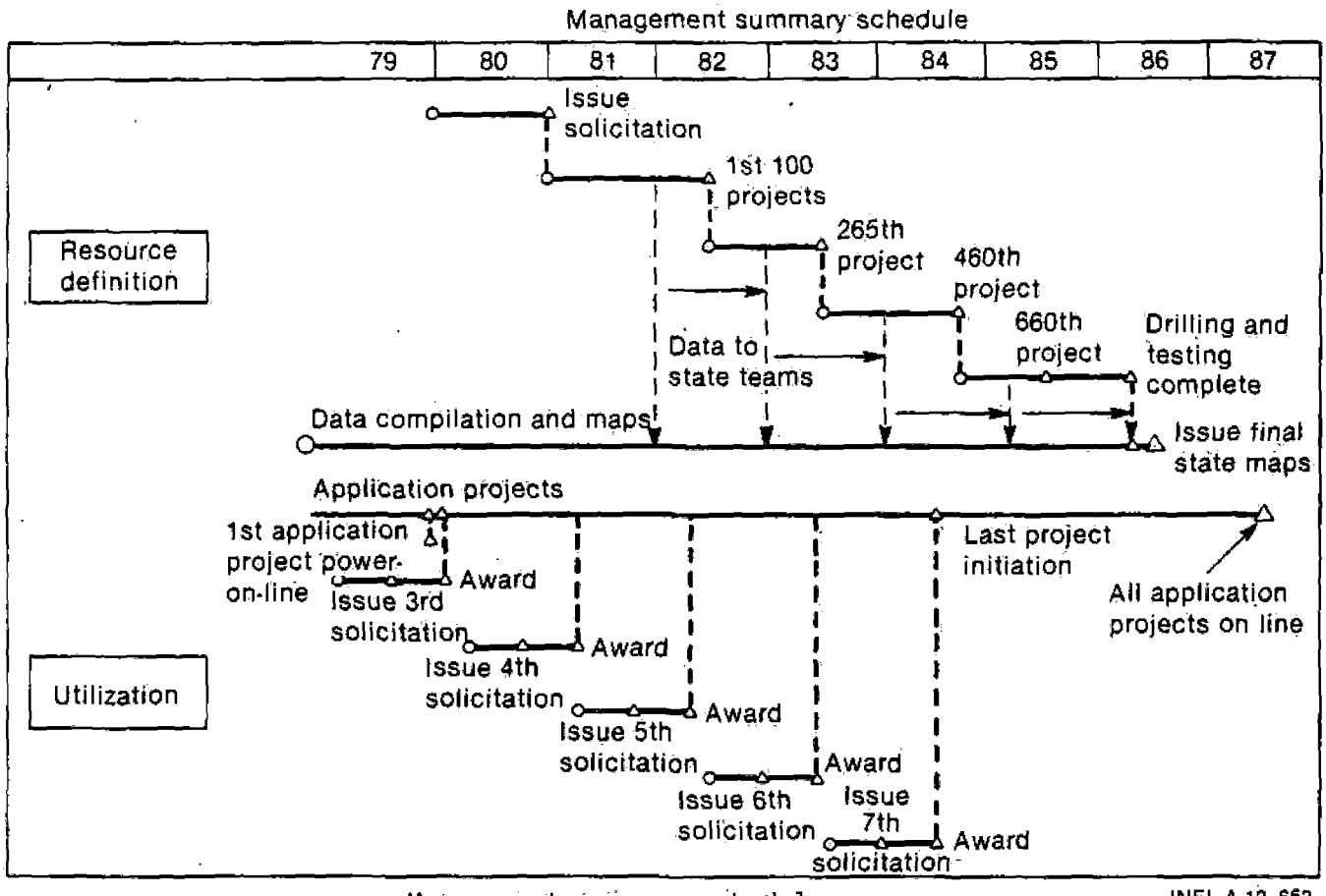
- Assume initial risks in resource development (federal role to decrease with time):
  - Cost sharing.
  - Stimulate in excess of 650 resource definition projects.
- Demonstrate direct application development of geothermal energy:
  - Utilization demonstration.
  - Data base development.
- Reduce development cost of direct heat utilization:
  - Develop infrastructure within private sector (experience leads to cost reduction)
  - Develop technology (exploration, confirmation, utilization)

PROGRAM ELEMENTS

- Resource definition -- State-Coupled Program:
  - Resource identification
    - Data compilation and assessment
    - Map and report publication

- Reservoir confirmation - competitive solicitation, user-oriented, cost sharing
  - Surface exploration
  - Drilling and testing
- Special projects

- Utilization:
  - Application projects
  - Technology development
    - Engineering
    - Environmental
  - Utilization analyses
    - Project analyses
    - Barrier identification
    - Precommercialization evaluation



Management summary schedule

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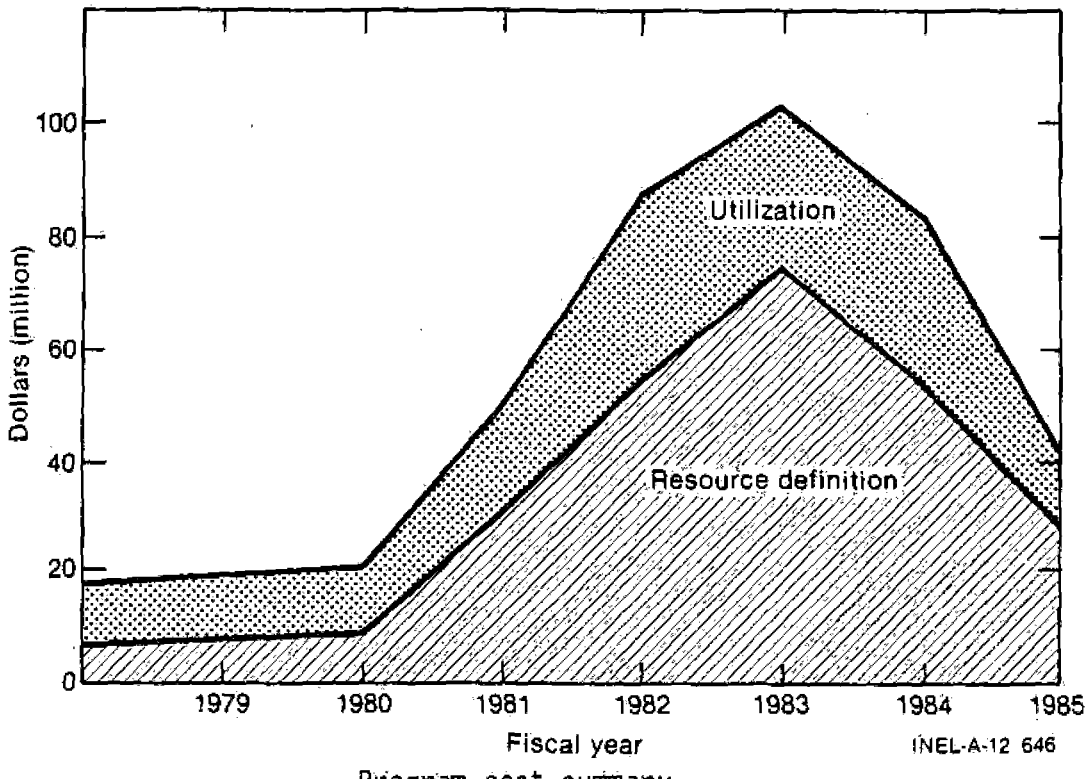

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Program cost summary

I. INTRODUCTION AND PLAN SUMMARY

The Department of Energy recognizes that the direct applications of geothermal energy from hydrothermal reservoirs, particularly the low-to-moderate temperature resource, can often be the most efficient way to use the energy and can displace significant fossil fuel consumption in many applications. A need is therefore recognized to foster economically viable geothermal direct applications along with the equally important infrastructure of consultants, contractors, equipment manufacturers, etc. needed to sustain the emerging industry.

The main impediments to commercialization of geothermal energy are the high or unquantified risks of resource exploration and confirmation and technical and economic uncertainites on how best to use the resource. An aggressive federal program is necessary to: (a) reduce the costs for direct heat utilization (develop infrastructure and technology); (b) demonstrate development of applications (resource confirmation, utilization demonstrations); and (c) assume an appropriate share of the risk. The Department of Energy's Energy Technology Program Plan for Direct Applications supports the Resource Applications Office's commercialization effort. The two main elements in the Energy Technology Plan to remove the impediments to commercialization and the development of a self-sustaining infrastructure are:

1. A significantly expanded resource definition program aimed at substantially reducing the unquantified risks associated with resource identification and confirmation,

2. Utilization development including technology development activities, application projects, and utilization analyses.

The resource definition activity incorporates a greatly expanded state-coupled program aimed at completing approximately 700 reservoir definition projects by 1985, out of which about 290 on-line projects are expected. Variable cost-share contracting will be employed to

alleviate the high risk of resource exploration and confirmation while leveraging Department of Energy funds with private capital. This leveraging mechanism requires commitment by prospective participants, which will ensure a strong link between resource development and utilization.

Utilization development in the plan is directed at the information needs of the industry for wider and more diverse applications. A technology development activity will address new and innovative applications for systems and components or research needs identified from other program elements. The application projects of the plan are directed toward new, unique, or untried direct applications of geothermal heat. Utilization analyses are focused on barrier identification and analysis, collating application project results, and precommercialization evaluations.

II. JUSTIFICATION, BENEFITS AND STATUS

Elements of information that justify an aggressive federal program plan in support of the direct applications of geothermal energy are provided below. The status of the program to date along with the expected benifits of commercialization of applications with the hydrothermal low-to-moderate temperature resource are also discussed.

1. JUSTIFICATION

U.S. Geological Survey Circular 790, Assessment of Geothermal Resources of the United States - 1978, which documents the distribution of geothermal resources as a function of temperature down to 90°C, concludes that an exponential increase in the number of known occurences can be anticipated as the temperature of the resource decreases (see Figure 1). This means that the geographic distribution of lower temperature resources is wider and that the possibility of colocation with potential users increases as temperature decreases. Favorable resource areas are shown in Figure 2. Considering this relationship, it is likely that direct heat utilization of low - to moderate-temperature geothermal resources will ultimately contribute more power on-line than will electrical generation from high-temperature geothermal resources.

Using current technology, the majority of the hydrothermal resources in this country cannot be used to generate cost-competitive electrical power. In many cases, direct heat uses are reasonably straightforward applications, providing an appropriate thermodynamic matching of energy to work to be performed. The activities of this plan are aimed at broadening the application base and developing important data on the economics of utilization to further the industry's understanding that direct application is an efficient use of this important energy resource.

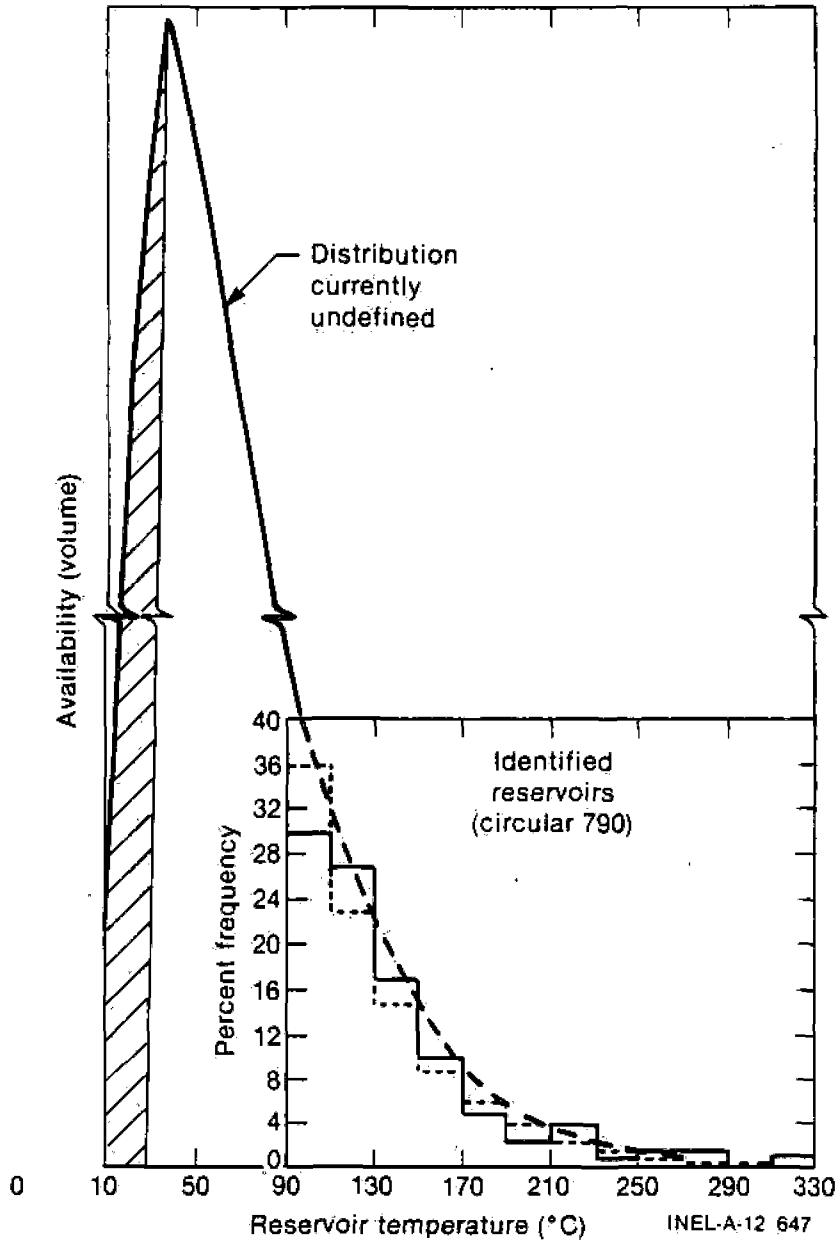

Fig. 1 Geothermmal resource temperature/occurrence profile.

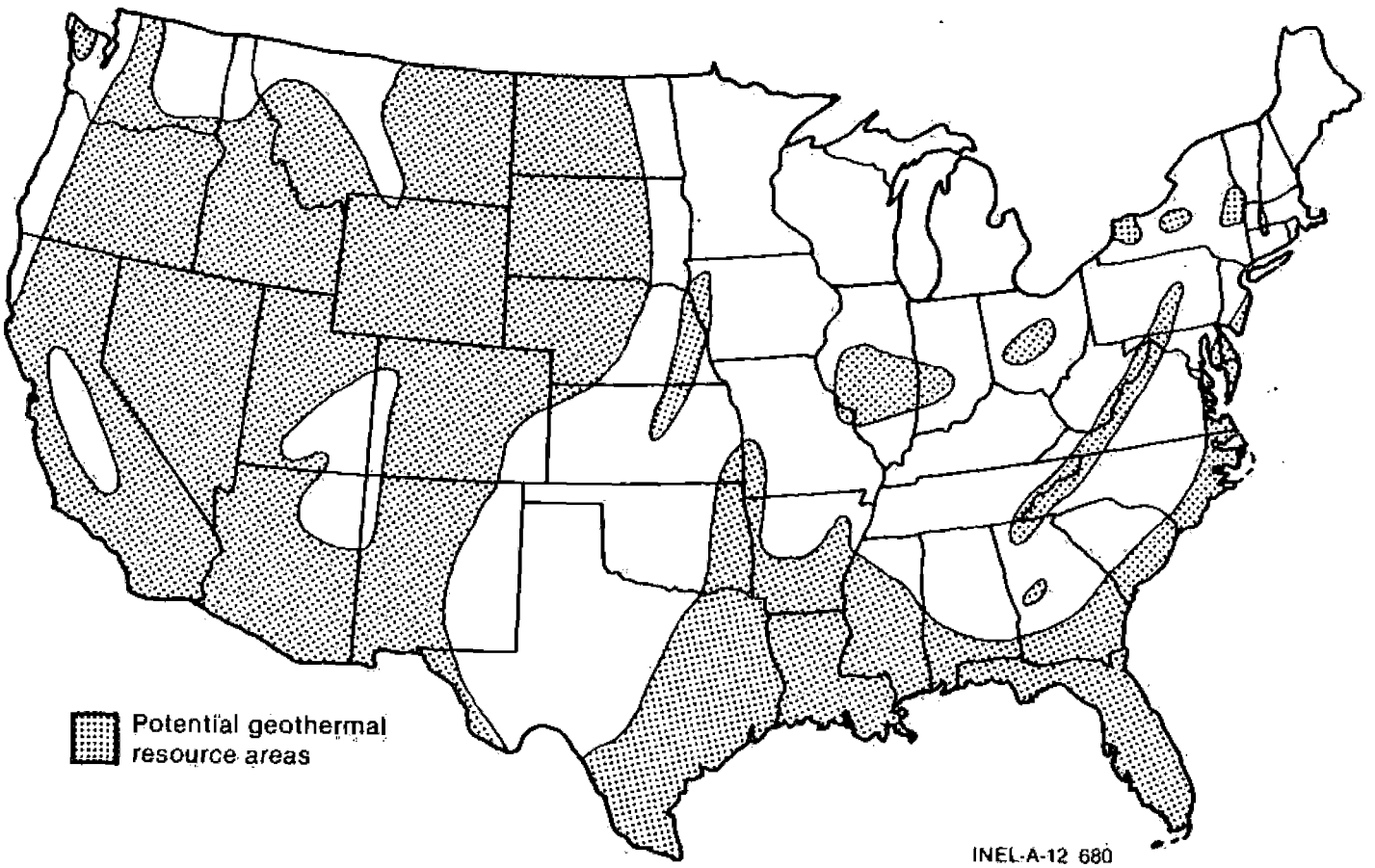

Fig. 2 Location of favorable resource areas for direct heat uses.

The approximate energy use by temperature range for the nation is shown in Figure 3, and the temperature range for energy end uses is shown in Figure 4. These figures illustrate the market potential available for direct heat applications, with particular attention centered on space conditioning, water heating, and low-to moderate-temperature industrial processing, which together represent about 50% of the total energy used in the temperature range below 150°C. A market analysis supporting the impact that direct heat applications can have on U.S. energy use is provided in Appendix A. This is a preliminary analysis since an overall national market analysis is still being formulated.

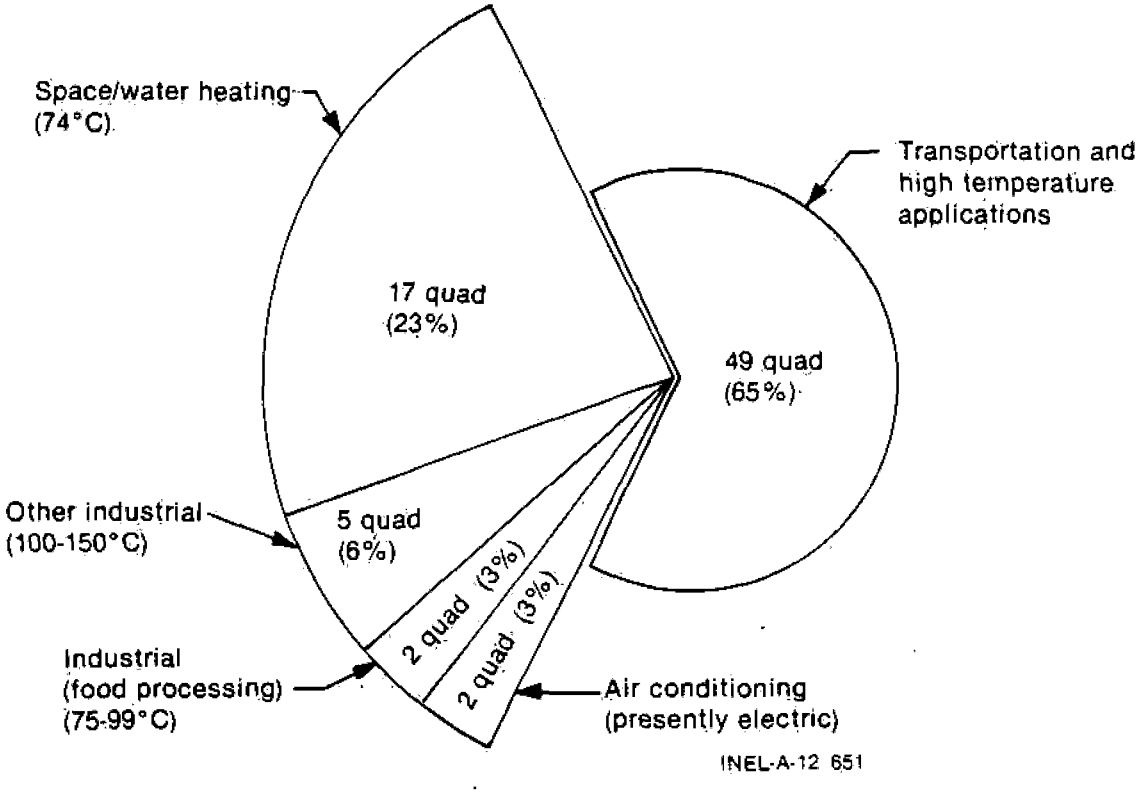

Fig. 3 National energy use versus temperature.

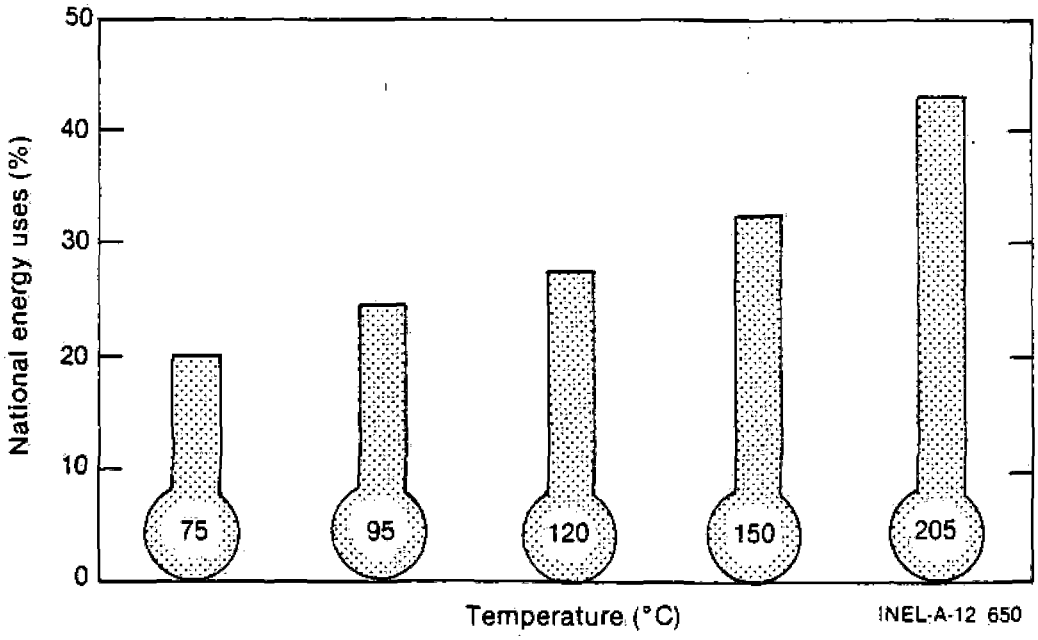

Fig. 4 Percent of national energy uses relative to temperature.

2. BENEFITS

Benefits from the development and use of the hydrothermal resource through direct applications are nationally important, but vary regionally. Development can mean new employment opportunities, contributions to energy independence, additional tax revenues, increased capital investments and industrial growth, and an improved environment. Many, but not all, of the benefits can be quantified. Unquantifiable benefits have been termed "values" in this document. Included in these values are:

Insurance Value - identifies the potential of the hydrothermal technology to be commercially viable and capable of substituting for other energy technologies that may become more expensive, unavailable, or undesirable.

Environmental Value - identifies the overall favorable environmental impacts of geothermal energy as compared with other energy technologies displaced.

Conservation Value - identifies the measure of importance that the use of geothermal heat has in conserving (replacing) natural gas and liquid fossil fuels.

Decentralizing Value - identifies the advantages to be derived from a geothermal technology that operates effectively in an on-site decentralized mode.

International Value - identifies the advantages in terms of international cooperation and trade, as well as a viable energy option for other countries that will lessen the pressures for other energy sources.

Quantifiable benefits include the fiscal benefits that will be derived by federal, state, and local governments if the resource is effectively developed. Using reasonable assumptions and the DOE direct applications goals shown in Figure 5, it is estimated that the return of revenues through income taxes and federal royalties will approach 1 billion dollars per year by the year 2000 and 4 billion dollars per year by the year 2020, if the national direct applications goals are met. A total of approximately 60 billion dollars in federal revenue is anticipated between now and the year 2020. The accompanying tax revenue to state and local governments is estimated to be 85 million dollars in 1985, 850 billion dollars in the year 2000, and 3.3 billion dollars in the year 2020.

To receive this level of financial benefit, industry must make significant capital investments. By 1985, 1.3 billion dollars will be required, 12.5 billion dollars by 2000, and 50 billion dollars by the year 2020.

Displacing oil and gas with geothermal energy will be a significant benifit; about 13 million barrels of oil can be displaced in 1985, 180 million barrels in the year 2000, and 700 million barrels in the year 2020. Using current oil prices of about $16 per barrel, a

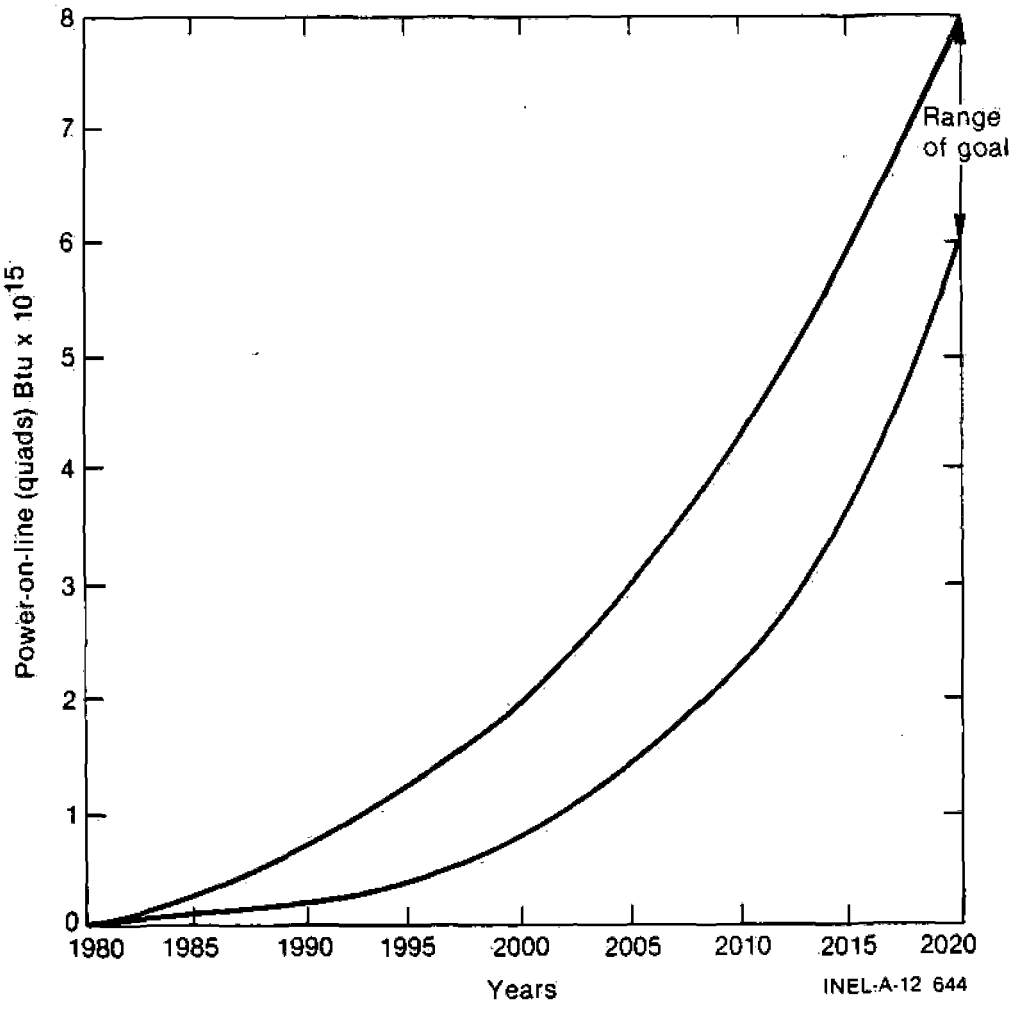

Fig. 5 Power on-line projections with DOE programs.

cumulative balance of payment advantage of 160 billion dollars would be realized through the year 2020. Figure 6 illustrates the calculated projections specified above.

For this benefit analysis, the following assumptions were made:

1. Barrel of oil costs $16.00.

2. No inflation on projections.

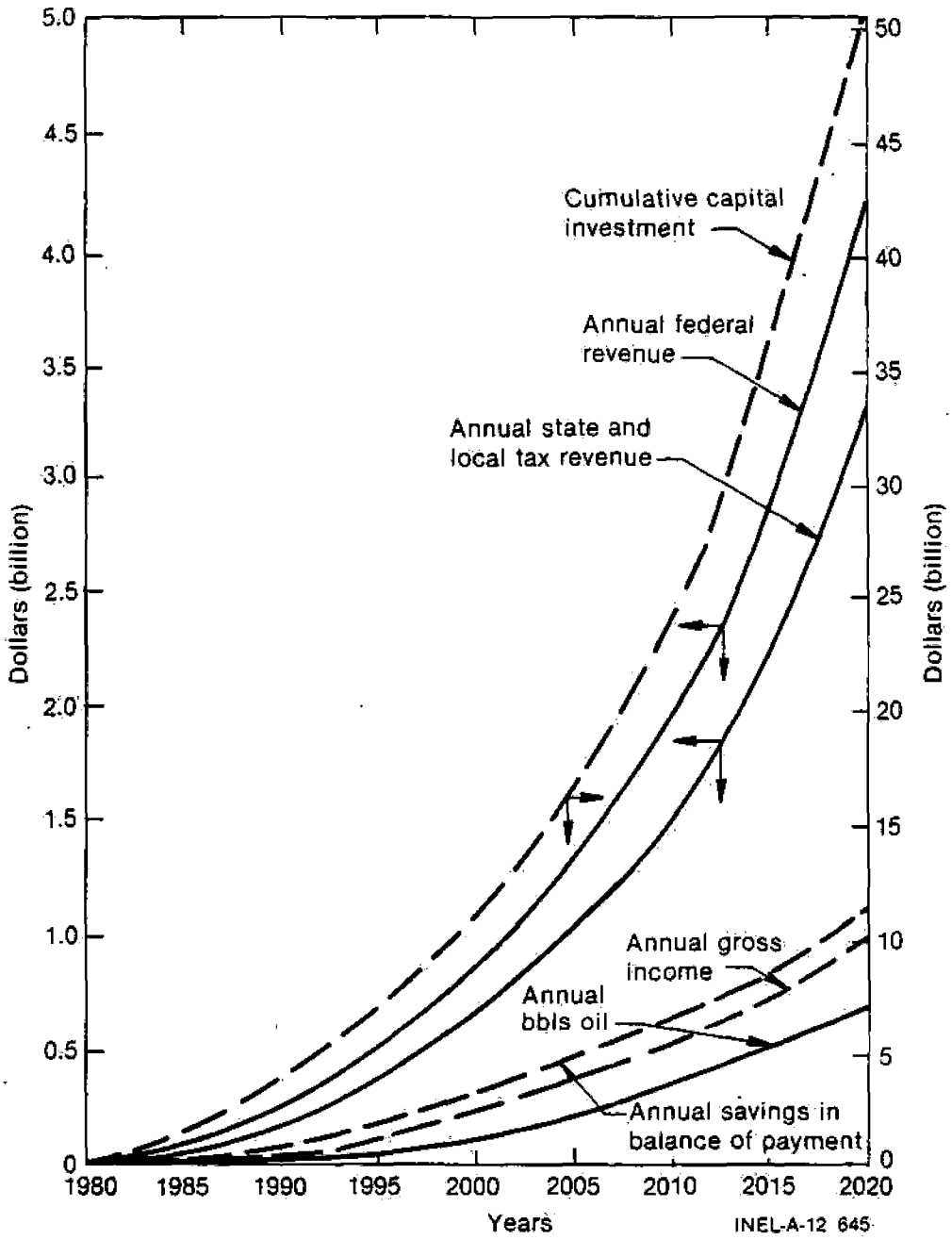

Fig. 6 Results of calculations for direct applications projections.

3. Investment capital is $500/kW installed capacity average for combination of industrial and space heating applications.

4. Geothermal fluid worth $2.50/MBtu.

5. 38% federal taxation (includes depletion allowance).

6. 10% federal royalty payment (half of development on federal lands).

7. One quad equals 180 million barrels of oil.

3. STATUS

In the U.S., direct applications of geothermal energy are minimal, a result of our former abundance of inexpensive fossil fuels. More recently, direct heat application growth has been hindered by insufficient knowledge of the resource, the high risk and costs of reservoir exploration and confirmation, and the lack of a utilization and technology data base.

DOE's goals for direct heat applictions are 0.1 to 0.2 quad for 1985 and 0.5 to 2.0 quads for the year 2000. If all the funded Application Projects from the Program Opportunity Notice (PON) Program come to fruition, the aggregate geothermal energy use will approximate 0.005 quad. Other known and projected direct heat developments contribute about 0.016 quad, for an expected 0.02 quad at this time. This is approximately 10% of the 1985 goal.

3.1 Reservoir Definition Status

Lack of resource knowledge occurs on two levels of detail:

1. On a regional scale, the locations of low to moderate-temperature resources are poorly known. Maps and compilations of such information are only now becoming

available in preliminary form through the State Coupled Program; and

2. On a site-specific scale, the lateral limits, depth, temperature, productivity, and longevity of very few low- to moderate-temperature geothermal reservoirs are known. Very little surface exploration and drilling have been done.

High risk level for reservoir confirmation stems partly from the lack of resource knowledge discussed above and partly from the fact that reservoirs are never uniform or continuous, so that dry holes can be drilled in the middle of the best of geothermal resources (e.g. the Geysers). The high cost of reservoir confirmation results mainly from the high cost of drilling. Large developers of high-temperature reservoirs are generally large companies who finance reservoir confirmation by spreading risk. The small developers most likely to be interested in low- to moderate-temperature geothermal resources are unable to spread risk in the same way, so a single dry well could mean financial disaster.

For the above reasons it is expected that, in the near future, the private sector will need federal assistance to confirm reservoirs of low- to moderate-temperature geothermal resources.

Regional resource assessment, including identifying sites and quantifying of the nature and extent of the resource base, is the responsibility of the U.S. Geological Survey (refer to Public Law 93-410). Two resource assessments[1,2] have been completed and published by the U.S.Geological Survey. That organization tentatively plans to reassess the resource base on about a three-year cycle.

Three Department of Energy programs have contributed to U.S. Geological Survey in its resource assessment activities: the State Coupled Program, the Industry Coupled Program, and the Application Projects.

3.1.1. State Coupled Program. The objectives of the State Coupled Program are: (a) to assist the U.S. Geological Survey in its resource assessment function by providing regional scale maps and reports on the occurrence of low- to moderate-temperature geothermal resources (Phase I), and (b) to investigate specific sites with a known but unquantified potential for direct heat applictions development (Phases II and III). The field programs in the western United States are carried out for the Department of Energy by resource assessment contractors located in those states. At present, this program is active in the following 14 states: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, Utah, Washington, and Wyoming. In addition, the Department of Energy plans to extend the program into Kansas, Nebraska, South Dakota, Texas, and other states.

In the eastern United States, program activities are in an earlier stage of development. Very few geothermal occurrences are known in the east, but geologic environments which could contain such resources are known or suspected. Geoscientists at the Virginia Polytechic Institute and State University have developed a geothermal target concept which is currently being tested by drilling. They have postulated that geothermal resources may occur beneath the thermally insulating eastern coastal plains sediments in the vicinity of old intrusive rock bodies which are heated by energy given off by the decay of natural radioactive elements in the intrusions. If the current drill tests are successful, the State Coupled Program will be extended to in the eastern states.

3.1.2 Industry Coupled Program. In the process of exploring for high-temperature geothermal resources in the Industry Coupled Program, much data is generated on low to moderate-temperature geothermal resources. Thus, the Industry Coupled Program contributes data on resources suitable for direct heat development at a number of the larger and more important geothermal sites.

3.1.3 Application Projects. The Application Projects described in more detail elsewhere, develops resource definition data in the course of pursuing its principal objective, which is the demonstration of uses of geothermal energy at specific sites.

3.2 Utilization Development Status

During the early planning and implementation phases of the direct heat utilization program, there was a relative shortage of information on the needs of the industry and the stimulus required for development of the resource by the private sector. Available special-purpose procurement instruments of application projects and application studies (i.e., the Program Opportunity Notice solicitations, and the Program Research and Development Announcement) were used to solicit project areas from the public and private sectors. This approach has led to a current program of demonstration of a range of direct uses of geothermal heat in the 23 Application Projects, or field experiments, which are in various stages of activity. These projects are tabulated in Appendix B-1. Currently, 35 Application Studies (PRDA solicited engineering and economic studies) have been completed or are under study. These studies are summarized in Appendix B-2.

A level of activity in direct applications research and technology development has been funded by the Department of Energy. This has included experiments for beneficial uses of geothermal fluids in aquaculture and agriculture as well as hardware research and technology. Other Department of Energy technology development programs, although not specifically direct heat oriented, have provided information in various areas such as downwell pumps, geochemistry, materials, and resource exploration techniques, and have been valuable to the direct heat applications program. Technology development activities have allowed private interests to become familiar with or participate in geothermal projects and have provided answers to many technical questions.

SECTION II. REFERENCES

1. White, D. E. and Williams, D. C., eds., (1975), Assessment of Geothermal Resources in the United States -- 1975; U.S. Geological Survey Circ. 727, 155 pp.

2. Muffler, L. J. P., ed., (1978), Assessment of Geothermal Resources in the United States -- 1978; U. S. Geological Survey Circ. 790, 163 pp.

III. PROGRAM PLAN - STRATEGY AND WORK ELEMENTS

There is a clear need for a federal program to collect and publish reconnaissance scale geothermal data on low- to moderate-temperature resources, and to stimulate site-specific, detailed reservoir exploration and confirmation. This program must include funds for drill site selection and sufficient drilling to confirm reservoirs at sites where private capital would be available for full development. All information developed from this program must be made available to developers, potential users, bankers, investors, and regulatory and policy-making agencies on a timely basis.

The program plan has been designed to remove or quantify the risks for reservoir definition by federal cost sharing for a large number of projects. At the same time, utilization development is provided in areas calculated to benefit the user segment of the industry, particularly in the development of supporting infrastructure. The work breakdown structure for the overall Energy Technology Geothermal Direct Applications Program Plan is shown in Figure 7. Discussions of each element is provided below.

The Department of Energy's Resource Applications Office has primary responsibility for geothermal commericalization, and the commercialization effort specifies requirements for the Energy Technology Geothermal Direct Applications Plan (this document). A preliminary draft of requirements from the Resource Applications Office is included as Appendix C. There is also an obvious tie between geothermal commercialization and environmental direct application needs. A national plan for environmental support for direct applications does not currently exist; projects are evaluated on a case-by-case impact statement basis.

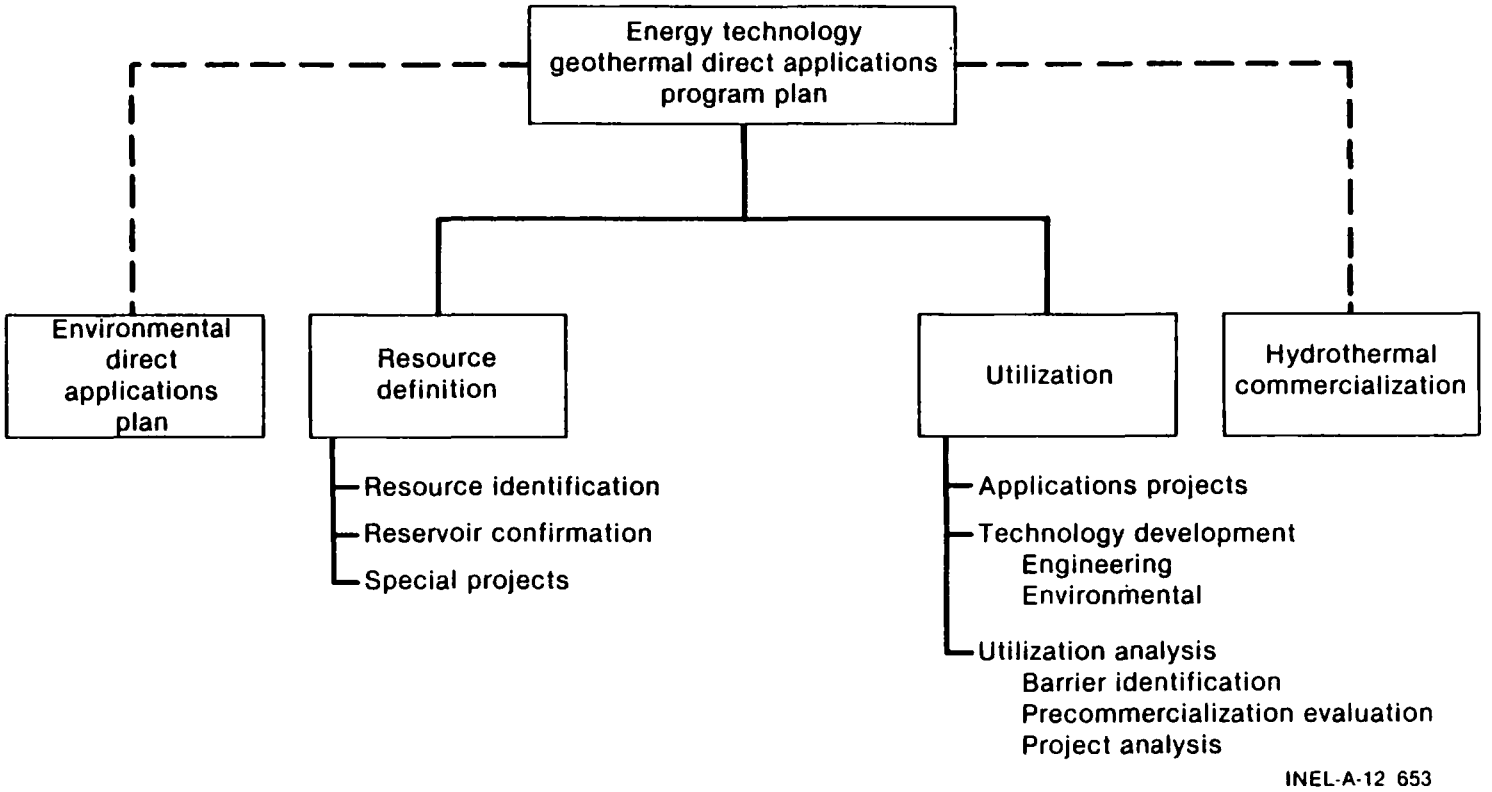

Fig. 7 Work breakdown structure for Energy Technology Geothermal Direct Applications Program Plan.

1. RESOURCE DEFINITION

Highlights of the program for reservoir definition in the Energy Technology Plan are:

1. The most important ingredient of the resource definition plan is an expanded State Coupled Program. The present data compilation and publication of maps and reports will continue through FY-84. These assembled data will form the basis for a new reservoir confirmation program that will consist of data collection and reservoir confirmation at specific sites.

2. A "bounty" program of geothermal data acquisition will be instituted. Incentive will be provided to industry for the release and publication of low-temperature resource data already in company files from prior high-temperature geothermal or petroleum exploration.

3. As another means of concentrating national utilization interest and producing data from application projects, a "special projects" program is provided. Special projects will be identified and evaluated primarily for the significance of new data expected, magnitude of the resource potential, and the energy intensiveness of each project. These projects will probably involve other government agencies and be funded on a cost-shared basis between the Department of Energy and those other agencies.

1.1 State-Coupled Program

The State-Coupled Program constitutes the Department of Energy's existing low-temperature resource evaluation effort. To date, the program has made significant progress toward identifying the low- to moderate-temperature hydrothermal resources. The program consists of four phases. Phase I is a general resource assessment, presently in

the western states, leading to the publication of maps and reports that delineate the location an expected extent of the resource base. Phase II, now underway to a limited extent, consists of detailed geologic studies and limited drilling at selected sites, for which the resource base appears favorable and potential users are available. Phase III, the Reservoir Confirmation Program, is planned to start in FY-81. It would consist of an aggressive surface exploration and drilling program aimed at confirming low- and moderate-temperature hydrothermal reservoirs throughout the nation. The objectives of Phase III are (a) to stimulate development of an infrastructure of consultants, contractors, and equipment manufacturers that will facilitate increased economic use of low- and moderate-temperature geothermal resources, and (b) to develop 0.1 quad of direct heat utilization by 1985 and 0.2 quad by 1987. These objectives will be accomplished by the Department of Energy variable cost-shared funding of reservoir confirmation through contracts with non-federal potential users and developers.

To accomplish these objectives, approximately 300 successful reservoir confirmation projects and accompanying applications will be needed. A varying success ratio (declining with time) was used to determine how many reservoir confirmation projects will be needed to obtain the 300 successes. The results forecast a need for approximately 700 project starts. With this large number of required projects, a method of cost sharing is needed to leverage Department of Energy funds while mitigating reservior confirmation risks. Variable cost-sharing is employed to meet these needs.

Successful proposals will result in variable cost-share contracts that define the cost-share agreements and a sliding-scale success criterion. The participant may then use the contract as collateral to obtain private financing. At completion of the reservoir confirmation phase, the final cost split will be determined and paid, after which the Department of Energy will be under no further obligation. The Department's share is expected to vary from 10% for successful wells to 100% for unsuccessful wells.

Reservoir confirmation is the largest unquantified risk in any geothermal project, and in most cases, is the sole deterrent to development. The above approach addresses this risk squarely by bearing the resource confirmation risk with federal funds, and at the same time leveraging these funds with private capital, which would be responsible for successful projects.

Competitive solicitations for proposals will be issued to implement the program. Activities to be funded will include surface exploration and temperature gradient hole drilling aimed at selecting successful production wells and will also include costs for drilling and testing of initial production and injection wells.

1.2 Data Acquisition and Utilization Development

A great deal of information on lower-temperature resources exists from prior high-temperature geothermal resource and petroleum exploration. These data should be obtained and made public through a bounty program to industry for its release and publication. Analysis should also be undertaken to determine ways of stimulating interest in the utilization of lower-temperature resources discovered during the course of exploration for higher-temperature resources.

1.3 Special Projects

As a corollary to promoting the direct use of geothermal energy through demonstrations, special projects are of interest since they provide an opportunity for other federal agencies to benefit from the resource definition phase of the direct heat applications program. For example, when a site which may be suitable for direct heat applications is located within a general region being considered for further resource assessments, it may be selected for geophysical and geological analysis and drilling of one or more wells, leading to a case history study pertinent to that region. Since the Department of Geothermal Energy's role in such a case is mainly to assist in the direct utilization of geothermal energy, the actual application phase

of any resultant project would be financed by the agency utilizing the resource. Examples of current activities in this category are, Hill Air Force Base (Utah) Evaluation, INEL Deep Well, and Williams Air Force Base (Arizona).

2. UTILIZATION DEVELOPMENT

Identifying technical questions, addressing solutions, producing data for industry decisions, and developing an industry infrastructure are elements receiving emphasis in the Energy Technology Plan under Utilization Development. These are accomplished with application projects, technology development, and utilization analyses discussed below.

2.1 Application Projects

The development of a data base from Application Projects is an essential element for commercialization of hydrothermal resources. This data base is being be established through the implementation of public and private sector operating systems that utilize geothermal resources.

Currently, Application Projects from the Program Opportunity Notices (PON) solicitations are the main thrust in the development of this data base. These projects are a necessary element of the Direct Applications Program Plan to establish an industrial infrastructure, focus public/industry interest, and absorb the front-end risks inherent in new applications. A modification of the solicitation and selection criteria for application projects is included in the plan to provide for those elements relating to: energy market impact potential, transferability, growth potential, cost-sharing ratio, geographic/resource expansion potential, total Department of Energy investment, and energy intensiveness. The improvement of selection criteria will provide a more effective use of funds and improve the program balance.

The purpose of this program is to provide an opportunity for interested parties, with federal assistance, to engage in direct heat utilization or combined electric/direct use utilization projects for demonstrating single and/or multiple uses of geothermal energy for industrial processing, space-heating, cooling, agricultural or aquacultural uses, and domestic hot water heating. These field experiments will continue to be needed to (a) provide visible evidence of the viability of various direct heat applications in a number of geographical regions; (b) to obtain reliable objective technical, economic, institutional, and environmental data under field operating conditions that will facilitate decisions on the utilization of geothermal energy by interested developers and users; and (c) to demonstrate a variety of different types of applications. In the future, Application Project solicitations will be reserved for new and highly promising market sectors, which economic analysis shows to be particularly promising for geothermal, or which, by nature of geographic population concentration with respect to hydrothermal systems, holds great potential for energy replacement.

The first two project solicitations focused public attention on (a) individual retrofit space heating projects, (b) district heating systems, and (c) the food processing industry. The geothermal program can be significantly accelerated by structuring subsequent solicitations to prioritize different application considerations, to evaluate new technology, and to enhance national geothermal utilization patterns.

Based on an indicated industrial interest and the potential for a large market, the third solicitation will stress industrial process applications. The fourth solicitation will stress new, innovative, or unique technical approaches to encourage continued growth in diverse applications. Space heating will have secondary importance in selection consideration unless unique utilization techniques are applied, since the first two solicitations resulted in several space heating applications.

In the future, the remoteness of many identified resources from population centers will force industrial and total community development around viable geothermal resources. Later solicitations will stress this totally integrated, new community/industrial utilization technique.

2.2 Technology Development

The purpose of technology development for direct applications is to support commercialization in the numerous potential applications that currently exist and to increase the use potential in new and untried processes, thus enlarging the future potential for geothermal energy as a viable alternate energy source. The principal area of activity is developing components and systems.

Many process temperatures today are higher than needed because they are based on fossil-fuel sources. A part of this program activity is to be directed at lowering unit and process operating temperature requirements to those more suited to geothermal sources.

The technical feasibility of harnessing geothermal energy remains a concern and a factor of indecision for many use sectors of private enterprise. New technologies and new applications of known technology are often verified by industry in pilot tests simulating actual process conditions, so that potential operating difficulties can be identified and process alternatives and feasibility evaluated before commitment of capital funds. This small-scale pilot testing continues to be an important antecedent to demonstration and full-scale applications of industrial processes. Without this opportunity for testing and/or small-scale demonstrations of technical feasibility, many potential users may ignore the geothermal energy option. Components testing, systems development, and federally supported research activities are needed for convincing arguments on technical feasibility.

The Components and Systems development work element of the energy technology plan will respond to the needs identified through the barrier identification work and to the needs of new and innovative technologies or use patterns that may impact upcoming geothermal applications. The work will include private participants, contracting organizations, and federal laboratory facilities. Private industry is an obvious preference in cases where a near-term commercialization follow-on is probable. A tabulation of activity areas for research to be considered is given in Appendix D, but this tabulation is not all-inclusive. Many of the tabulated areas have not been implemented, but might be considered with other participants in the energy technology plan.

2.3 Utilization Analyses

The utilization analyses tasks will provide a timely method for updating the direct application technical data base, provide a means of predicting future areas for technology development, and focus attention toward special problems that, left unidentified, could hinder or delay the commercialization of geothermal energy. The utilization analyses tasks will be solicited by requests for proposals (RFP). Three categories of analysis efforts can be identified: (a) project analyses, (b) barrier identification, and (c) precommercialization evaluations.

2.3.1 Project Analysis. Project analyses are evaluations of technical, economic, and operating data from application projects now underway or to be initiated. This will be accomplished as on-going projects reach completion and sufficient information becomes available. These summaries will be used to:

1. Provide early data and information to industries interested in geothermal developments, and

2. Aid national planning and policy decision-making necessary to direct proper program emphasis.

As future application projects are completed, additional analyses, data collating, and summarization will be required. In addition to providing guidance to overall program direction, this analysis effort provides excellent feedback to assure that program goals are realistic and can be met. In some cases, feedback may dictate activities needed in the direct-use components and systems development work. Starting with FY-81, four or five analyses will be needed per year through FY-85.

2.3.2 Barrier Identification. The second category of analyses effort, technical barrier identification, specifically identifies problem areas, components, and concepts that hamper geothermal utilization from a technical standpoint.

The objectives are to identify the technical barriers to geothermal development, identify new use potentials for commercialization, specify technical requirements for components and systems development to address identified technical questions, perform case studies on promising new geothermal applications, and provide a supportive role either analytically or through existing experimental and demonstration results to address industry commercialization uncertainties.

The methodology in technical barrier identification involves: (a) feedback from the Resource Applications commercialization effort, (b) feedback from the Application Projects; (c) compilation of existing studies in generic operations such as drying-crystalization-evaporation process steps; (d) interfacing with industry for technical problem searchout in coordination with regional representatives; (e) symposiums or committees of experts; and (f) publications of status. The publications will be designed for transmittal to target industries to solicit responses.

Item (d) will involve several steps for target selection: (a) large energy use surveys (or recompiling existing studies), (b) colocation identification, (c) contact with influential organizations of the selected industry, (d) process selections, and (e)

design/modification/testing needs. These activities will incorporate solicitations and cooperation with the Resource Application state planning teams.

2.3.3 Precommercialization Evaluations. The information from these evaluations will be used for commercialization by the Resource Applications Office and industry. Information will be derived from the components and systems tests and other sources. Using this information, analysis will be made to provide industry with precommercializaion data, economics, and techniques. Scale-up calculations and feasibility work will be required, and industry may require further pilot or demonstration-size facilities to validate the precommercialization evaluations. The level of support for this work will probably be low.

IV. PROGRAM COSTS AND SCHEDULES

Summary schedules and cost data for resource definition and utilization elements of the Energy Technology Program Plan are shown in Figures 8 and 9 and Figures 10 and 11, respectively. The shaded areas of Figures 9 and 11 reflect current funding levels. The larger unshaded areas represent the budget levels required for the expanded program discussed in this plan. Detailed budgets for each program element are given in Figure 12.

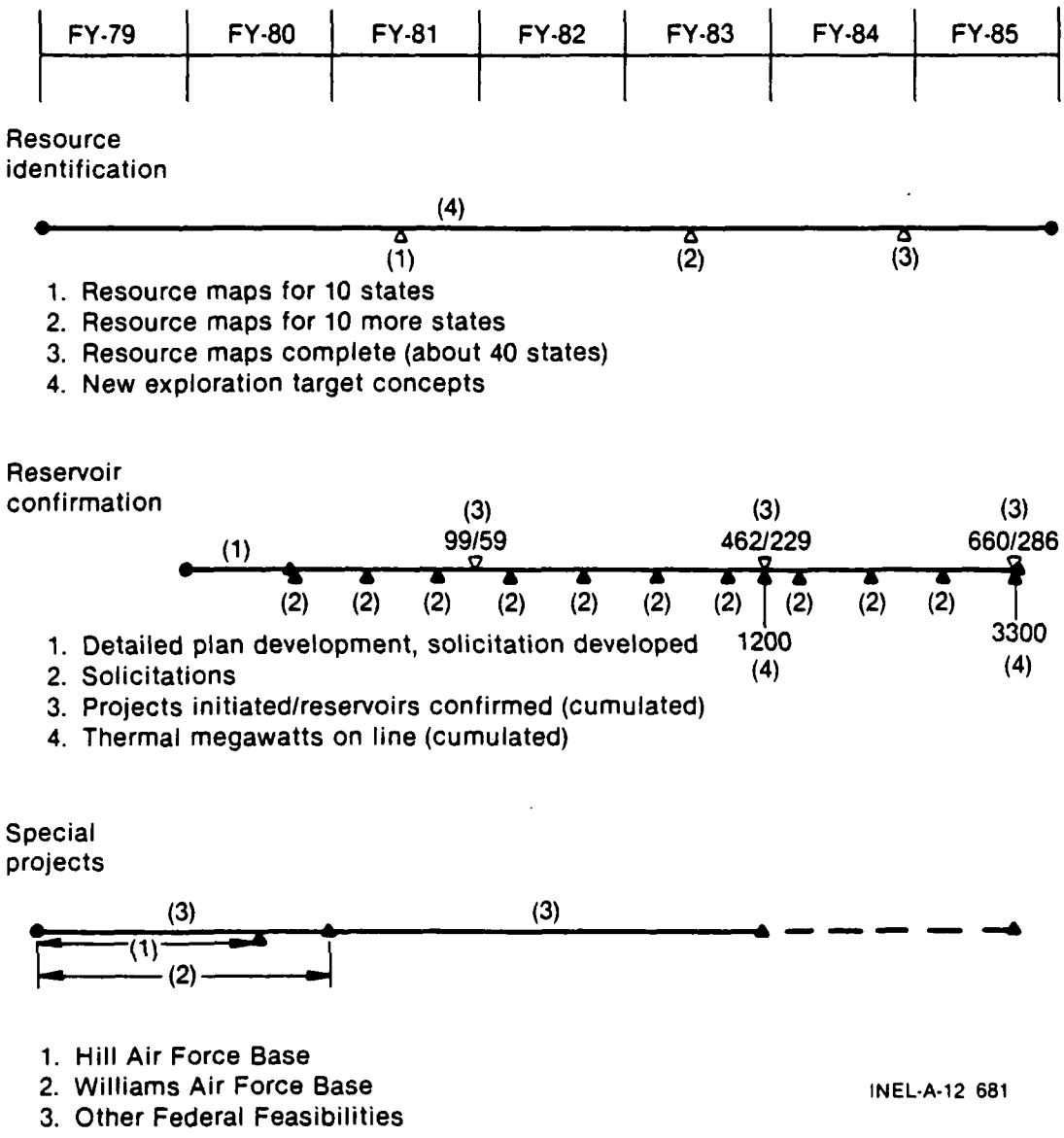

Fig. 8 Resource Definition summary schedule.

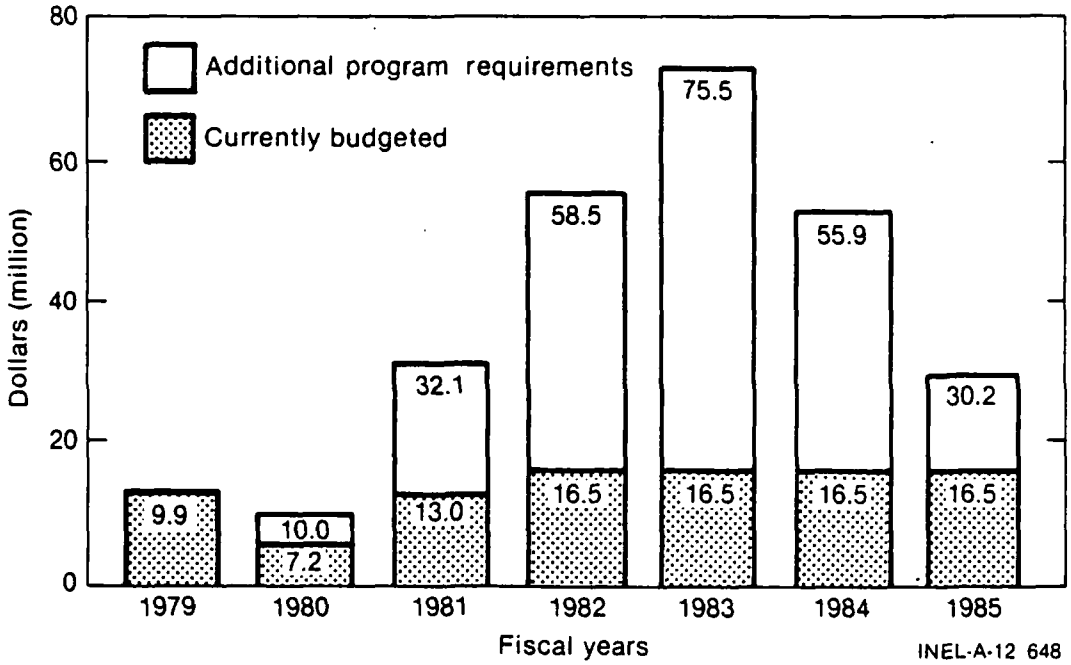

Fig. 9 Resource definition cost schedule.

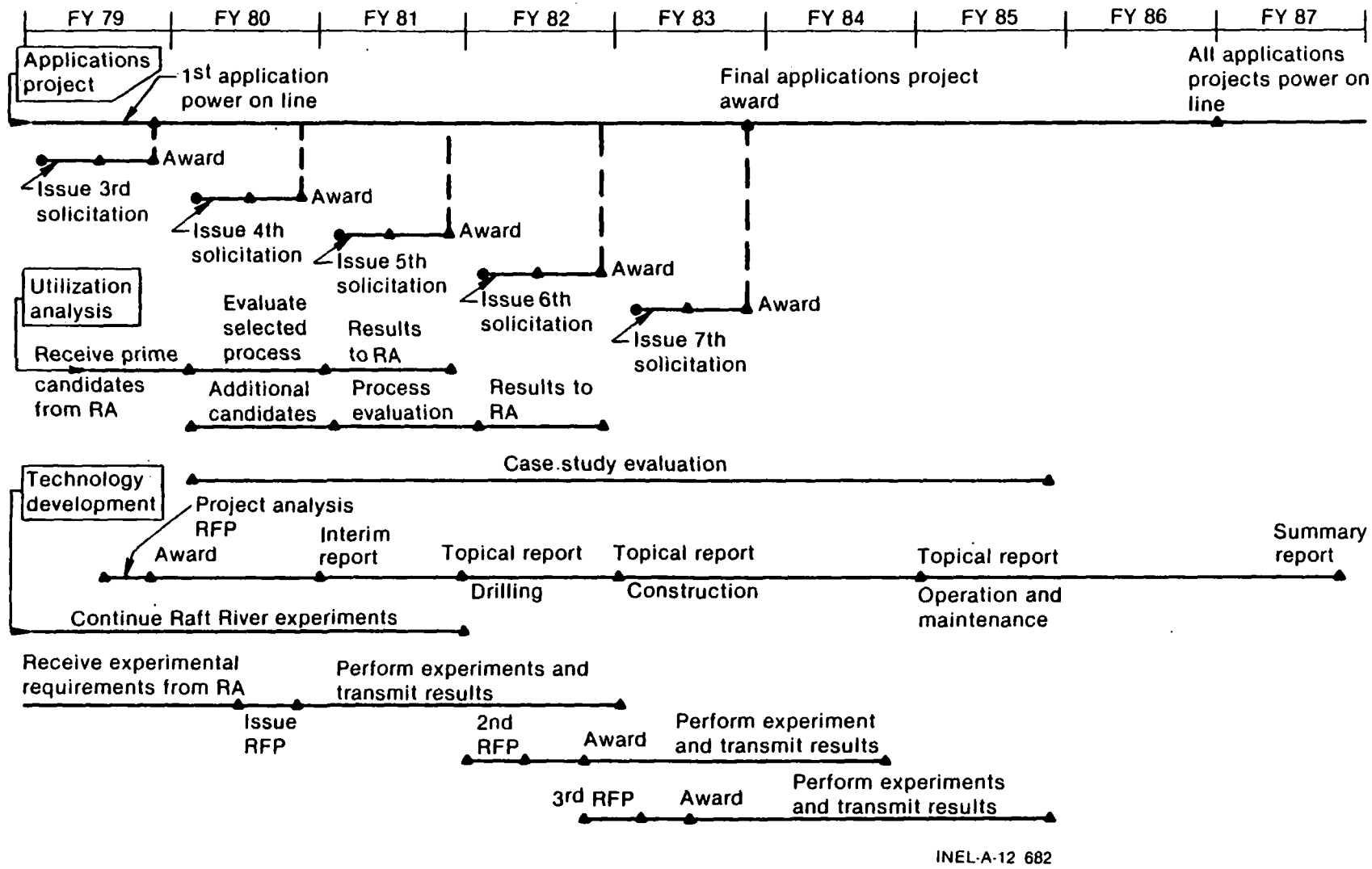

Fig. 10 Utilization development summary schedule.

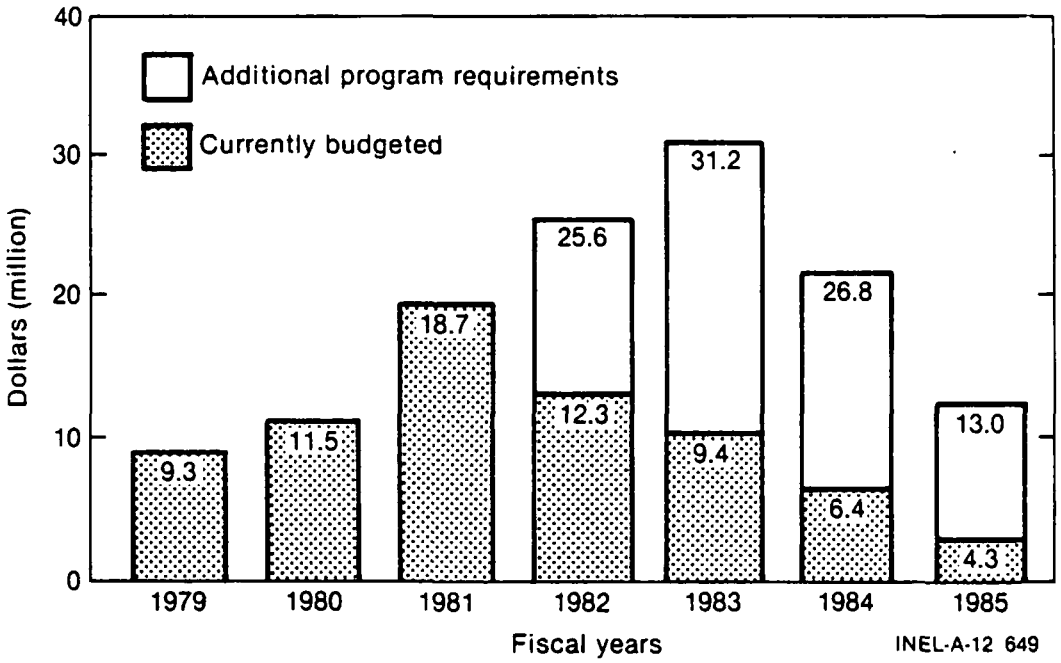

Fig. 11 Utilization development cost schedule.

Program Element	FY-79	FY-80	FY-81	FY-82	FY-83	FY-84	FY-85
Utilization:							
Applications Projects	9.0/9.0	11.0/11.0	17.5/17.5	11.0/24.3	8.0/29.8	5.0/25.4	3.0/11.7
Utilization Analysis		0.1/0.1	0.35/0.35	0.5/0.5	0.6/0.6	0.5/0.5	0.4/0.4
Technology Development	0.3/0.3	0.4/0.4	0.8/0.8	0.8/0.8	0.8/0.8	0.9/0.9	0.9/0.9
Total Utilization	9.3/9.3	11.5/11.5	18.7/18.7	12.3/25.6	9.4/31.2	6.3/26.8	4.3/13.0
Resource Definition:							
State Coupled Program	6.8/6.8	7.1/9.6	12.5/30.9	15.5/56.5	15.5/73.5	15.5/53.9	15.5/28.7
Special Projects	3.1/3.1	0/0.3	0/0.7	0/1.0	0/1.0	0/1.0	0/0.5
Data Acquisition and Utilization Development		0.1/0.1	0.5/0.5	1.0/1.0	1.0/1.0	1.0/1.0	1.0/1.0
Total Resource Definition	9.9/9.9	7.2/10.0	13.0/32.1	16.5/58.5	16.5/75.5	16.5/55.9	16.5/30.2
Grand Total	19.2/19.2	18.7/21.5	31.7/50.8	28.8/84.1	25.9/106.7	22.9/82.7	20.8/43.2

Fig. 12 Detailed costs for energy technology geothermal direct applications program plan ($ million budgeted/budgeted plus enhancements).

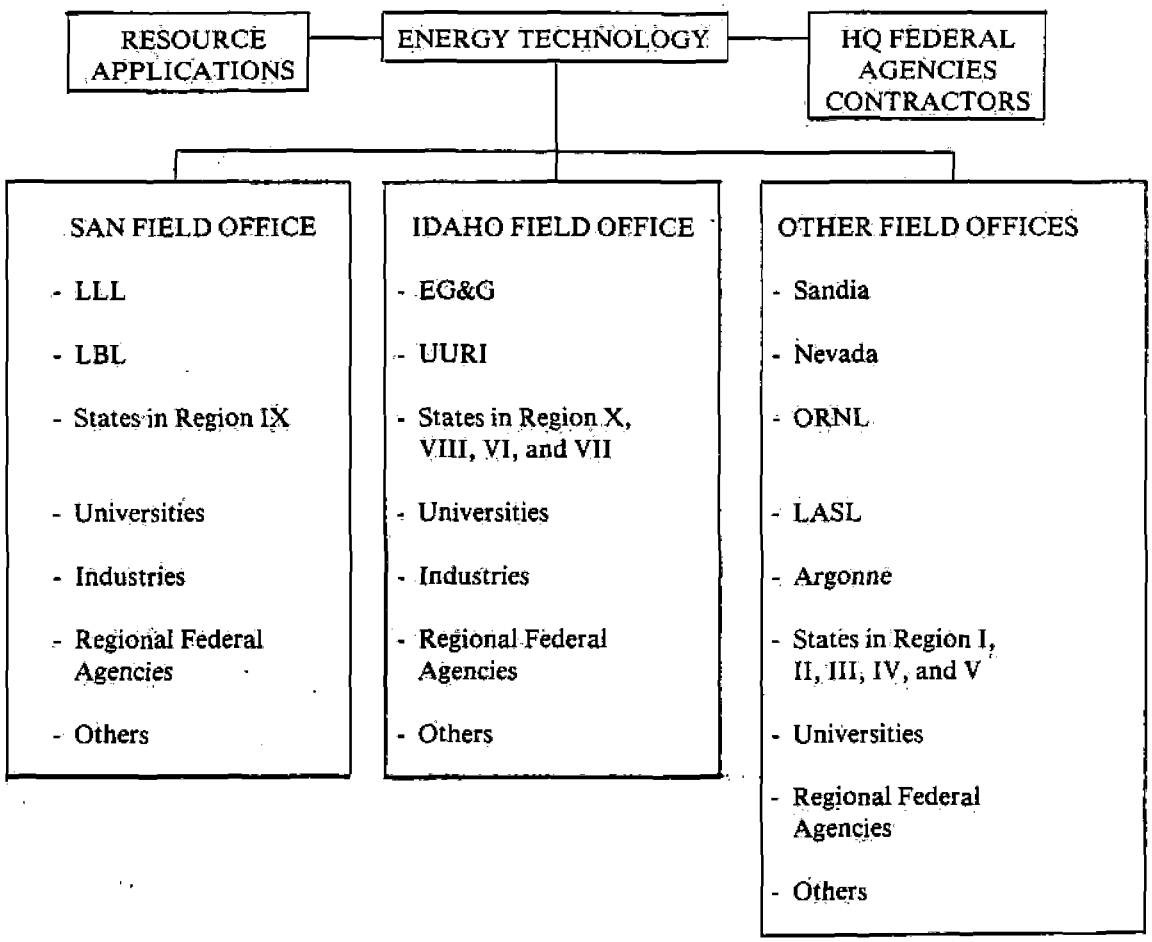

Fig. 13 Energy Technology Direct Applications Plan organization.

V. PLAN MANAGEMENT AND PARTICIPANTS

1. PLAN MANAGEMENT AND ORGANIZATION

The overall management control of the Energy Technology Program will be retained by the Division of Geothermal Energy within the Energy Technology Organization. The Energy Technology staff will rely upon the field offices to implement the program plan. Idaho, San Francisco Operations Office, Nevada Operations Office, and an East Coast representative organization have been assigned to carry out specific functions and to coordinate these activities with the appropriate participants. The overall organization for carrying out the Energy Technology Direct Applications Plan is presented in Figure 13, which indicates only the current principal participants and is not intended to be inclusive nor represent the principal participants that may ultimately be involved as the program plan evolves.

The Energy Technology direct applications geothermal headquarters staff will interface with the Resource Applications (RA) staff in matters concerning programs related to barrier removal, incentives, and planning. The principal management responsibility for some of the program plan elements will be assigned to the field offices to decentralize the program and enhance the effectiveness of Energy Technology programs.

2. PROGRAM ELEMENTS AND PARTICIPANTS

2.1 Resource Definition

The direct applications program elements and team members are described below. The Resource Definition Program is composed of several tasks which will be conducted by a variety of contractors through solicitation. Other principal parties involved in these activities are the University of Utah Research Institute, Los Alamos Scientific Laboratory, Sandia, and Livermore Berkeley Laboratory.

Most of the management responsibility for these tasks will be delegated to the field, but other reservoir definition work, including drilling and brine chemistry activities, may be managed by the Division of Geothermal Energy, Headquarters staff.

2.2 Utilization Development

The utilization development effort consists of three primary tasks as described below.

2.2.1 Application Projects. These activities are primarily the result of controlled application project solicitations developed to provide nonfederally conducted experiments in selected areas dealing with specific technologies. Application projects are formal announcements awarded at specified times. The solicitation portion of this program has been the responsibility of the San Francisco Operations Office, with the contracting and monitoring handled by the San Francisco, Idaho, and Nevada offices.

2.2.2 Technology Development. The technology development programs include engineering and environmental and components and systems development. A principal party in the technical development has been EG&G, through the Idaho Office. These programs have been related to materials testing, component development, and field experiments. As this element of the national direct applications program evolves and specific activities are identifed, the appropriate solicitation techniques will be identified for performing the work. The program responsibility will be assigned to the appropriate field office.

2.2.3 Utilization Analysis. Most of the analyses activities are expected to be solicited from qualified engineering firms.

APPENDIX A

MARKET ANALYSES FOR DIRECT HEAT USE POTENTIAL

The approximate national energy use by temperature range is given in Table A-I, and the temperature range for energy end uses is given in Table A-II (Reference A-1).

Tables A-I and A-II illustrate the obviously high pay-off potential in a vigorous federal geothermal direct heat program, with particular attention centered on the space conditioning, water heating, and lower-grade industrial processing market, which together represent about 50% of the total energy used in the temperature range below 150°C.

TABLE A-I

ENERGY USE VS TEMPERATURE

Use	Temp (°C)	Quads	% Total
1978 Total		75	100
Space/water heating	74°	17	23
Industrial (food processing)	75-99°	2	3
Other industrial	100-150°	5	6
Air conditioning	Electric	2	3
Transportation; high-temperature applications		40	65

TABLE A-II

PERCENT OF NATIONAL ENERGY USES RELATIVE TO TEMPERATURE (°C)

	75°	95°	120°	150°	205°
Energy use at or below temperature indicated	20 %	23 %	27 %	32 %	42 %

For U.S. buildings, space heating requirements are approximately 14 Quads annually. As Table A-III indicates, geothermal energy could potentially supply about 3-1/2% of this demand. This represents a benefit to about 10% of the U.S. population living within 40 miles of some 225 known geothermal resources in 11 western states (Reference A-II). Increasing attention is also being paid to East Coast market possibilities. Of the four principal resource areas studied for energy demands, the residential and commercial market approaches the equivalent of 20 million barrels of oil annually. Other demands are shown in Table A-IV (Reference A-III). Note that these figures represent present, and not future, potential demand. Most of the western states are among the fastest growing in the country, so the longer-term projected demand is more significant in terms of fossil-fuel displacement.

Although a national market analysis has not been completed, a preliminary study of 10 western states shows a large potential for direct applications of the geothermal resource. Analysis of current energy use within that region indicates that the prime market sectors for the direct use of geothermal energy are space conditioning (both cooling and space/water heating) and lowto moderate-temperature industrial processing. Currently, more than 75% of these market sectors are being served by fossil fuels, with electricity claiming the majority of the remaining sales. Energy projections for the region indicate a higher dependence upon coal, which is encountering environmental or growth constraints. A cross-matching of the geothermal resources, as known today and projected in the future on a county-by-county geographical basis with potential users, reveals that all states within the Rocky Mountain area have significant amounts of resources that correlate with potential market areas. Also, the majority of the industrial and population centers are colocated with geothermal resources. The largest potential user segments are space conditioning and water heating, which currently use 288×10^{12} Btu per year. This use could grow to about 2.5×10^{15} Btu per year by the year 2020; i.e., about 450×10^{6} barrels of oil per year.

TABLE A-III

ANNUAL POTENTIAL EXISTING DEMAND FOR GEOTHERMAL SPACE HEATING IN THE WESTERN UNITED STATES

Distance from Resources	Total Population	Heat Demand (10^{12}Btu)	Barrels of Oil Equivalent (10^6)
0-5	120,000	1.9	0.4
5-10	330,000	5.7	1.3
10-20	3,950,000	74.9	17.4
20-30	6,070,000	86.3	20.0
30-40	14,210,000	180.1	41.8
40-50	9,670,000	129.9	30.1
Totals	34,350,000	478.8	110.0

TABLE A-IV

SECTOR ENERGY DEMAND (10^{11} Btu/yr)*

Resource Area	Residential Commercial	Military	Agriculture	Industrial
S. E. New Jersey	290	25	0.2	5.2
Delaware	125	8	14.5	14.8
Norfolk (VA)	280	97	0.5	8.3
E. North Carolina	80	15	9.5	9.0

*These figures do not include projected growth.

Current energy requirements for industry are somewhat smaller than for residential/commercial space conditioning, but the region's growth potential is excellent, and it appears that industry can readily be penetrated. Current energy use in the lowto moderate-temperature process heat sector which can be served by hydrothermal energy is 74×10^{12} Btu per year, with a projected growth pattern of 177×10^{12} Btu per year by 1985, 480×10^{12} Btu per year by 2000, and 1476×10^{12} Btu per year by the year 2020.

From the foregoing considerations, it can reasonably be observed that substantial long-term markets for geothermal energy exist in the western region; that commonly found coincidence of resource occurrence with user locations promises favorable economics in competition with other energy supplies; and that hydrothermal energy can be a near-term, partial solution to a portion of the region's energy needs.

REFERENCES

A-I. Jay Kunze, "Fluid Heat Management for Direct Geothermal Energy Applications," A Symposium of Geothermal Energy and Its Direct Uses in the Eastern United States, GRC Proceeding, April 1979.

A-II. Paul Lienaw, "Space Conditioning with Geothermal Energy," A Conference on the Commercialization of Geothermal Resources," GRC Proceedings, November 1978.

A-III. Wm. Toth, "Geothermal Energy Markets on the Atlantic Costal Plain," A Symposium of Geothermal Energy and Its Direct Uses in the Eastern United States, GRC Proceeding, April 1979.

APPENDIX B

SUMMARY OF
DIRECT HEAT APPLICATION PROJECTS
AND STUDIES

TABLE B-I

DIRECT HEAT APPLICATIONS PROJECTS

(From Program Opportunity Notice Solicitations)

Industrial and Process Heating

ORE-IDA Foods Ontario, Oregon
Holly Sugar Brawley, California
Rogers Foods/Madison County Rexburg, Idaho

Space Heating/Cooling of Individual Buildings

St. Mary's Hospital Pierre, South Dakota
T-H-S Hospital Marlin, Texas
City of El Centro El Centro, California
Navarro College Corsicana, Texas
Haakon School Philip, South Dakota
Douglas High School Box Elder, South Dakota
Utah State Prison Crystal Hot Springs, Utah
Warm Springs State Hospital Deer Lodge Valley, Montana
YMCA Klamath Falls, Oregon

District Heating

Klamath Falls, Oregon
Monroe City, Utah
Boise, Idaho
Elko, Nevada (private companies)
Madison County, Idaho/Rogers Foods
Reno, Nevada (private companies)
Pagosa Springs, Colorado
Susanville, California

Agriculture

South Dakota School of Mines Midland, South Dakota
Utah Roses Salt Lake City, Utah

Aquaculture

Aquafarms Mecca, California

Livestock Raising and Processing

Geothermal Power Corp. Kelley Hot Springs, California

TABLE B-II

PROJECT STUDIES FOR DIRECT APPLICATIONS

(Engineering and Economic Studies)

Projects Funded under PRDA-DGE-76-1

Principal Organization	Primary Application
Aerojet Energy Conversion Co.	Refrigeration for food processing
Alaskan State Energy Office	Salmon aquaculture
Bechtel Corporation	Evaporation and crystalization of industrial liquids and wastes
The Ben Holt Co.	District space/water heating
City of Desert Hot Springs	Space conditioning and agribusiness
C.L.R. Consortium	Livestock production
Coury & Associates, Inc.	Sugar beet and barley processing
DeLaureal Engineers	Food processing
DSS Engineers, Inc.	Industrial complex
The Futures Group	Crop/food drying
Geonomics, Inc.	Food production and processing
International Engineering Co.	Greenhouse; fish farming
Oregon Institute of Technology	Food processing
Pacific Sierra Research Corp.	Space heating
South Dakota School of Mines	Space/water heating
TRW, Inc.	Holly Beet Sugar Refinery
WESTEC Services, Inc.	Production of fertilizer, Valley Nitrogen

TABLE B-II (Continued)

PROJECT STUDIES FOR DIRECT APPLICATIONS

(Engineering and Economic Studies)

Projects Funded Under PRDA DGE/SAN EG-77-D-03-1487

Principal Organization	Primary Application
Aerojet Energy Conversion Co.	District heating system for industrial and agribusiness applications in Susanville, California
Coury & Associates Inc.	District heating system for residential development and agribusiness
Edgemont School District, SD	Space heating for Edgemont School complex
Energetics Marketing & Management Association LTD ("EMMA")	Definition of vertically integrated meat and food production system
Puna Sugar Company LTD	Puna cane sugar refinery
Western Services, Inc.	District heating system for space industry and agribusiness, El Centro, California

APPENDIX C

DRAFT OF DEPARTMENT OF ENERGY-RESOURCE APPLICATIONS
NATIONAL DIRECT HEAT APPLICATIONS
INFRASTRUCTURE REQUIREMENTS TO THE YEAR 1987

FIRST CUT ROUGH DRAFT

NATIONAL DIRECT HEAT APPLICATIONS INFRASTRUCTURE REQUIREMENTS TO 1987

PREPARED FOR
DEPARTMENT OF ENERGY
RESOURCE APPLICATIONS
GEOTHERMAL RESOURCE OFFICE

BY
EG&G IDAHO, INC.
IDAHO FALLS, IDAHO

AND

UNIVERSITY OF UTAH RESEARCH INSTITUTE
EARTH SCIENCE LABORATORY
SALT LAKE CITY, UTAH

JUNE 13, 1979

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FIGURES

DIRECT HEAT APPLICATIONS INFRASTRUCTURE REQUIREMENTS TO 1987

A. GENERAL

The early commercialization of geothermal energy in the United States requires the development of an infrastructure. Federal goals of 0.1 to 0.2 quads of energy used for direct heat applications in 1985 can only be met with the development of an infrastructure of developers, financiers, designers, builders and operators. The purpose of this activity is to define, in a general sense, the capital expenditures required, and the manpower needed, to develop geothermal resources and construct or retrofit installations using geothermal energy.

B. APPROACH

The general approach to this effort is listed below:

1. Determine the quantity of first drill holes that will be needed.

2. Review and identify current geothermal direct application systems and prospects to determine the cost and power usage of these systems.

3. Review and identify new systems that are proposed, planned and in construction. Estimate the quantity and sizes of projects expected to be on line from now through fiscal year 1987.

4. Develop cost estimates and manpower needs for resource development, design, construction, piping, hardware and operational start-up. Average costs will be assigned to each project type to obtain total capital investment needs. Four major costing categories will be considered; (a) field development (geology, geophysics, drilling and testing), (b) project development (land, environmental, management, legal, financial), (c) design and construction, and (d) operations and maintenance.

5. Layout project time scales.

6. Chart various cost and manpower needs as a function of time.

7. First cut efforts will be generic. Later efforts should be worked into a state by state level.

8. Consider three generic systems. These are District Heating, Industrial Parks, and Single Industry.

9. Private and federally assisted projects will be shown separately, but both will be included in the totals.

C. ASSUMPTIONS

Certain assumptions have been made and are identified as follows:

1. The well drilling success ratio and the number of projects required is shown in Table I. This table includes only the first holes drilled, and does not include the additional drilling that will be required to provide adequate capacity for a given project.

TABLE I

FEDERALLY ASSISTED DRILLING SITE PROJECTS SUCCESS RATIOS

ITEM	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	TOTAL
Projects Initiated (%)	0	15	25	30	20	10	0	0	100%
Projects Initiated (No.)	0	99	165	198	132	66	0	0	660 ea.
Ave. Success Ratio	0	60	54	41	31	25	0	0	--
Number of Successes	0	59	89	81	41	16	0	0	286 ea.
Number of Failures	0	40	76	117	91	50	0	0	374 ea.
% Govt Share* Success/Failure	0	10/100	10/100	5/95	5/92	5/90	5/90	0	---

*Assumed ratio of the government's cost sharing with industry for successful/unsuccessful resource definition costs.

2. The number, size and type of facilities are shown in Table II.

TABLE II

ESTIMATED PROJECT SIZE AND TYPE DISTRIBUTION

SIZE	DISTRICT HEATING	INDUSTRIAL PARKS	SINGLE INDUSTRY	TOTAL UNITS
GOVERNMENT ASSISTED				
100 MWt	1	5	0	6
50 MWt	4	13	6	23
25 MWt	18	18	35	71
10 MWt	39	15	60	114
5 or less MWt	22	0	50	72
				286
PRIVATE				
100 MWt	0	1	1	2
50 MWt	2	4	1	7
25 MWt	2	4	7	13
10 MWt	7	5	21	33
5 or less MWt	46	0	69	115
				170

3. The average resource development and facility construction times are shown in Table III.

TABLE III

AVERAGE PROJECT DEVELOPMENT TIME

ACTIVITY	TIME (YEARS)
Resource Development	1 to 2
District Heating	3[a]
Industrial Parks	3[a]
Single Industry > 25 MWt	3[a]
Single Industry 5 to 25 MWt	2[a]

[a] After the first well is proven.

4. The estimated manpower and cost requirements for the development of the geothermal first holes only covering the geoscience portion of reservoir confirmation, and the industry infrastructure needed through fiscal year 1985, are shown in Tables IV and V. The number of total drill holes required by industry is being developed and will be shown later.

TABLE IV

RESERVOIR CONFIRMATION - GEOSCIENCE PORTION[1]
FIRST HOLE PROGRAM
($ Thousands)

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Surface Exploration	0	0	4830	9020	12,360	9160	4840
Gradient Hole Drilling	0	0	4940	9210	12,680	9350	4940
Production & Injection Well Drilling & Testing	0	0	18,970	34,680	44,630	32,450	17,200
Sub-totals	0	0	28,740	52,910	69,670	50,960	26,980
Industry Participation[2]	0	0	32,000	58,000	76,000	55,000	29,000
TOTALS			$60,740	110,910	145,670	105,960	55,980

[1] Resource identification, special projects and management costs are not included. These costs are being developed, and the total resource costs will be reflected later. These costs are only for the first holes drilled, and are based on Table I.

[2] These are approximate amounts that industry will spend in conjunction with the first hole program. Refinement of these amounts will be made in the future.

TABLE V

INDUSTRY INFRASTRUCTURE MANPOWER & EQUIPMENT
FIRST HOLE PROGRAM

	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85
Geologists	0	10	50	100	130	100	60
Geochemists		5	25	50	65	50	30
Geophysicists		5	25	50	65	50	30
Legal, Land, Environmental People	0	15	50	100	130	100	40
Drill Rigs & Crews							
Deep Production	0	0	12	46	60	43	23
Shallow Production			20	77	100	72	38
Deep Gradient			12	46	60	43	23
Shallow Gradient			10	39	50	36	19
Management		12	27	45	50	38	22
TOTALS		47	231	508	660	532	285

5. The average values shown in Table VI are in addition to resource development costs and are used to develop the infrastructure required for the projected facility installations shown in Table VII. The Regional Hydrothermal Market Penetration Analysis assumes a 25% retrofit rate, and projected costs are made on this basis. Costs and manpower projections are made for both the geothermal systems required for a plant ($300, 500 and $700 per kW), and for the geothermal system plus the plant ($2,000 per kW).

TABLE VI

AVERAGE PROJECT COSTS PER KW

PROJECT	COST $/kW
Single Industry	300
Single Industry - Total Facility	2000
Industrial Parks	500
District Heating	700

6. The current DOE funding level for FY 1980 and 1981 precludes (unless changes are caused to occur) extensive governmental assistance until FY 1982 and beyond. Project development will be estimated accordingly.

7. Assume that the private sector and other federally assisted programs will develop 0.05 quads while the first hole program is stimulating the development of 0.15 quads, between now and 1987.

D. WORK TO DATE

The following work has been performed to date:

1. The quantity of first drill holes has been estimated and a probable success ratio has been prepared.

2. Costs and power usage information has been compiled for most of the PON projects, and approximations of energy use have been made for systems identified in ten of the State Hydrothermal Commercialization Baseline Books. Estimated values for other known systems, in place or planned, have been included.

TABLE VII

PROJECTED FACILITY INSTALLATION BY NUMBER AND MWt SIZE

SIZE	MWt	No.	FY 80 a-b-c	FY 81 a-b-c	FY 82 a-b-c	FY 83 a-b-c	FY 84 a-b-c	FY 85 a-b-c	FY 86 a-b-c	FY 87 a-b-c
FIRST HOLE STIMULATED										
100 MWt	600	6						0-1-0	0-2-0	1-2-0
50 MWt	1150	23					0-0-1	1-2-1	1-5-2	2-6-2
25 MWt	1775	71					2-2-4	3-3-8	5-5-10	8-8-13
10 MWt	1140	114		2-1-3	3-2-5	10-4-10	10-4-15	7-2-15	4-1-7	3-1-5
<5 MWt	360	72	2-0-3	2-0-6	4-0-10	4-0-9	4-0-7	2-0-6	2-0-5	2-0-4
Subtotal - Units		286	5	14	24	37	49	51	49	57
Subtotal - Cumulative		286	5	19	43	80	129	180	229	286
Subtotal - MWt	5025		25	100	170	305	595	930	1255	1645
Subtotal - Cumulative	5025		25	125	295	600	1195	2125	3380	5025

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

TABLE VII (contd)

SIZE	MWt	No.	FY 80 a-b-c	FY 81 a-b-c	FY 82 a-b-c	FY 83 a-b-c	FY 84 a-b-c	FY 85 a-b-c	FY 86 a-b-c	FY 87 a-b-c
OTHER		d-e								
100 MWt	200	0-2							0-1-0	0-1-0
50 MWt	350	1-6				1-0-0	0-0-0	0-1-0	0-1-1	1-2-0
25 MWt	325	1-12			0-1-0	0-0-0	0-0-1	1-1-2	1-1-2	0-1-2
10 MWt	330	3-30		0-0-1	2-0-1	1-1-2	1-1-4	1-1-4	1-1-4	1-1-5
<5 MWt	575	10-105	1-0-2	2-0-4	5-0-10	7-0-9	7-0-9	8-0-10	8-0-12	8-0-13
Subtotal - Units		170	3	7	19	21	23	29	33	35
Subtotal - Cumulative Units		170	3	10	29	50	73	102	135	170
Subtotal - MWt	1780		15	40	130	170	165	300	460	500
Subtotal - Cumulative MWt	1780		15	55	185	355	520	820	1280	1780

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

TABLE VII (contd)

	MWt	No.	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87
TOTAL - Units		456	8	21	43	58	72	80	82	92
TOTAL - Cumulative Units		456	8	29	72	130	202	282	364	456
TOTAL - MWt	6805		40	140	300	475	760	1230	1715	2145
TOTAL - Cumulative MWt	6805		40	180	480	955	1715	2945	4660	6805

a - District Heating; b - Industrial Parks; c - Single Industries; d - Currently Planned; e - Projected.

3. Types and quantities of new systems, private and government assisted, in generic form, have been identified, and scheduled through FY 1987. These are shown in Table VII. The projected direct applications power on-line for the first hole program and other development efforts through fiscal year 1987 are shown in Figure 1. The resource development costs for the first hole program are identified as to the source of payment; i.e., federal or private. However, the federal portion of the costs for facility development is not identified.

4. Average costs have been assumed for three generic systems, and labor and material costs have been apportioned. These values have been converted to equivalent manpower needs, and the number of people needed, by major categories, are identified through FY 1987. (PON information was primarily used as the data base to develop project breakdowns into design, construction, etc.) Table VIII shows the manpower requirements for the geothermal systems only whereas Table IX includes the geothermal systems and the plant. Figure 2 graphically displays this.

   The development of the manpower required, and the years in which they are required, assumes in general that design being done in a current year is for a project that will be operational three years later. The labor and material costs are split evenly over the years of design and construction. "Other" manpower costs are assumed to be mostly plant testing and operating and are considered to occur in the year the plant goes on line. Table X summarizes the yearly expenditures required for geothermal systems and indicates the year in which the expenditures will occur after start of design. Table XI includes the geothermaal systems costs and other plant costs. Figure 3 is a graph of these expenditures.

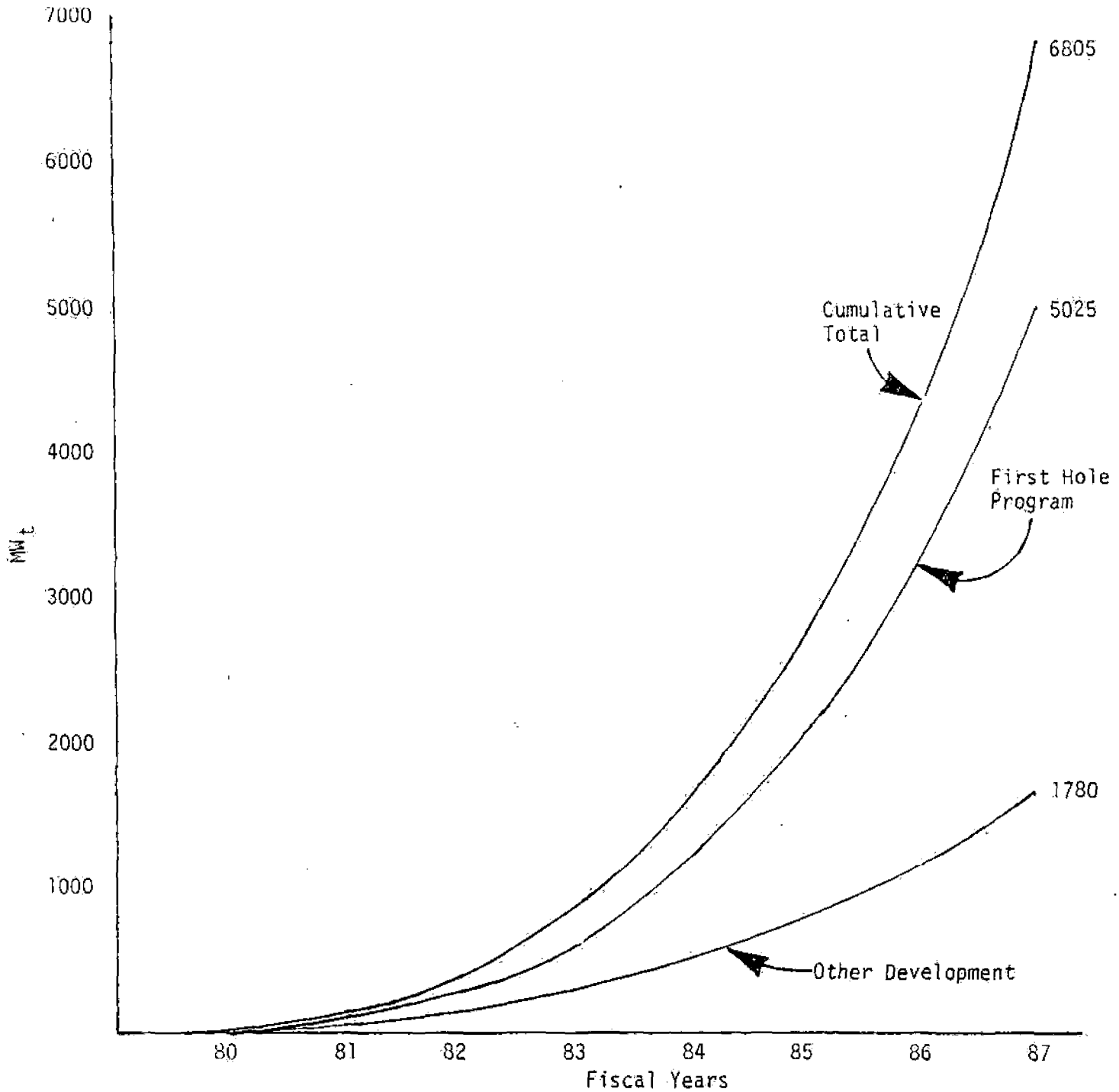

Fig. 1. Projected direct applications power on line

PRELIMINARY DRAFT

TABLE VIII

PROJECTED MANPOWER REQUIREMENTS THROUGH FY 1987 FOR FACILITY DEVELOPMENT[1]
GEOTHERMAL SYSTEMS ONLY
(Man Years)

Fiscal Year	Design	Labor	Admin.	Other	TOTALS
1980	530	610	160	20	1,320
1981	770	1,010	270	70	2,120
1982	1,240	1,590	430	150	3,410
1983	1,760	2,360	630	260	5,010
1984	2,190	3,250	860	390	6,690
1985	2,680	3,950	1,100	620	8,350
1986	3,150	4,460	1,330	860	9,800
1987	3,630	4,830	1,560	1,100	11,120

[1] These projections include geothermal systems, but do not include plant costs.

TABLE IX

PROJECTED MANPOWER REQUIREMENTS THROUGH FY 1987 FOR FACILITY DEVELOPMENT[1]
PLANT AND GEOTHERMAL SYSTEMS
(Man Years)

Fiscal Year	Design	Labor	Admin.	Other	TOTALS
1980	3,390	3,890	1,040	130	8,450
1981	4,900	6,390	1,700	450	13,440
1982	7,890	10,110	2,690	970	21,660
1983	11,140	14,950	3,990	1,690	31,770
1984	13,920	20,590	5,490	2,450	42,450
1985	17,000	25,060	6,980	3,940	52,980
1986	20,000	28,300	8,420	5,470	62,190
1987	23,000	30,600	9,900	6,960	70,460

[1] These projections include a 25% retrofit factor, and a total cost including the geothermal system and the plant cost.

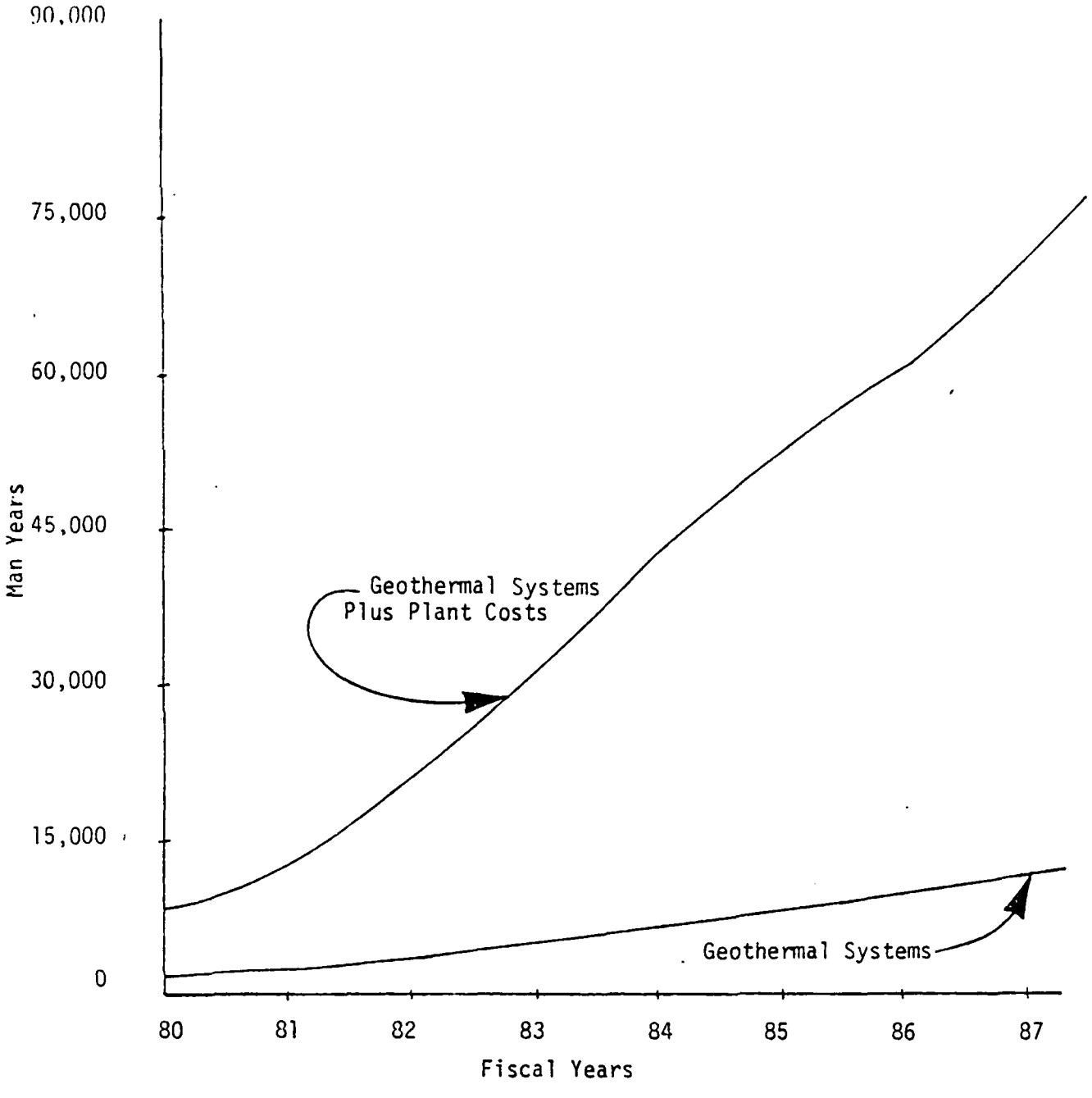

Fig. 2 Projected manpower requirement through FY 1987 for facility development.

TABLE X

PROJECTED EXPENDITURE REQUIREMENT THROUGH FY 1987 FOR FACILITY DEVELOPMENT [1]
GEOTHERMAL SYSTEMS ONLY
($ Million)

Fiscal Year	Design	Labor	Matl	Admin.	Other	TOTALS
1980	26	25	25	8	1	85
1981	40	40	40	13	3	136
1982	62	64	64	21	8	219
1983	88	94	94	32	13	321
1984	110	130	130	43	19	432
1985	118	165	165	57	31	536
1986	142	200	200	69	44	655
1987	165	237	237	82	55	776
					TOTAL	3,160

[1] These projections include geothermal systems, but do not include plant costs.

TABLE XI

PROJECTED EXPENDITURE REQUIREMENT THROUGH FY 1987 FOR FACILITY DEVELOPMENT[1]
PLANT AND GEOTHERMAL SYSTEMS
($ Million)

Fiscal Year	Design	Labor	Matl	Admin.	Other	TOTALS
1980	169	156	156	51	6	538
1981	256	256	256	85	22	864
1982	394	404	404	135	49	1,386
1983	557	598	598	200	85	2,038
1984	696	824	824	275	122	2,741
1985	750	1,047	1,047	359	197	3,400
1986	900	1,268	1,268	441	279	4,156
1987	1,050	1,500	1,500	525	348	4,923
					TOTAL	20,046

[1] These projections include a 25% retrofit factor, and a total cost including the geothermal system and the plant cost.

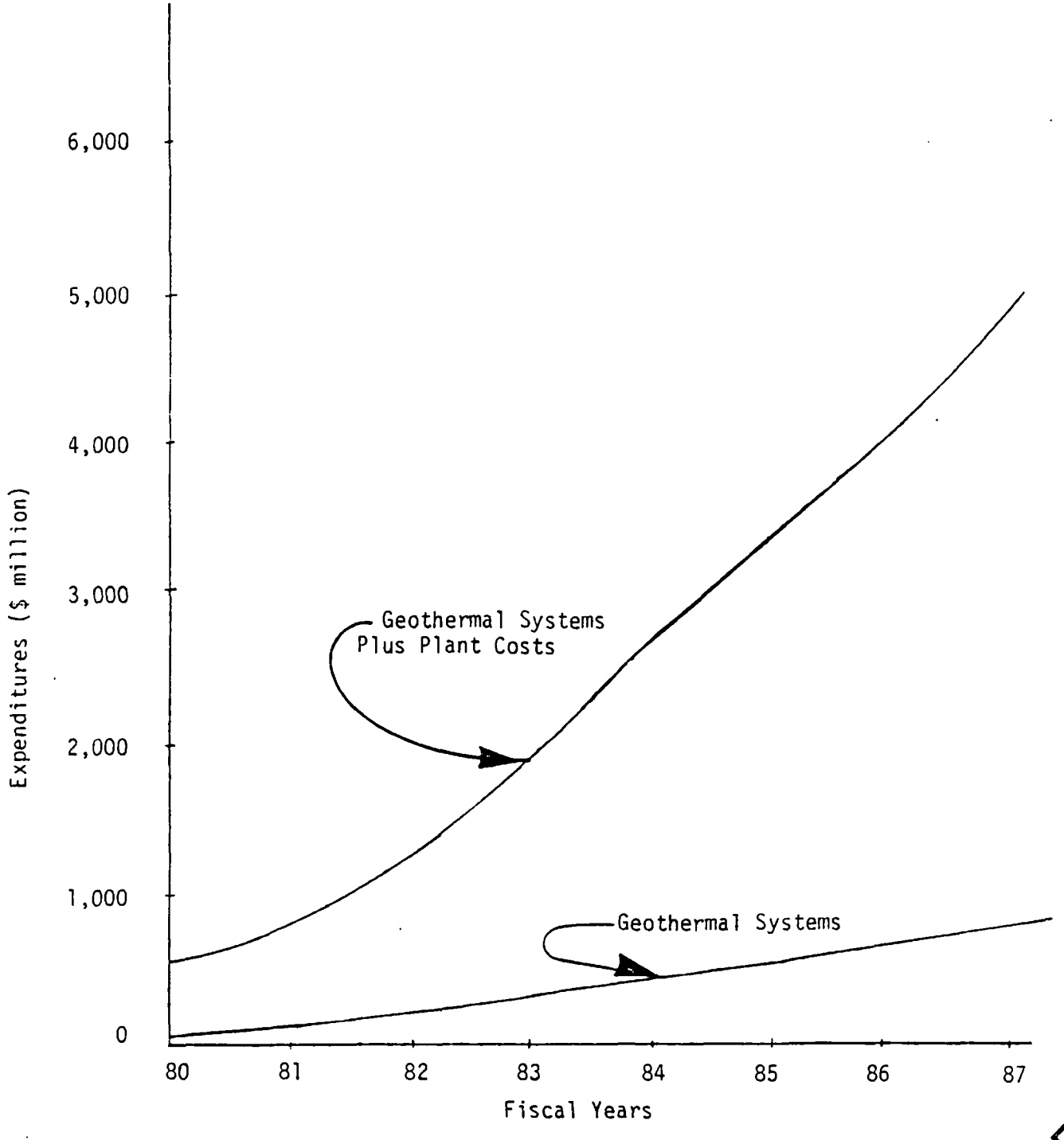

Fig. 3 Projected expenditure requirement through FY 1987 for facility development.

E. WORK PLANNED

The following will be performed to develop and refine the work done so far:

1. Develop cost estimates for resource field development, including industry participation.

2. Obtain more cost and manpower information about specific sites.

3. Look at new exploration environments.

4. Continue to refine the program requirements.

5. Continue investigation of the availability of drill rigs, and testing and logging crews. (It appears that geologists and geophysicists are available in adequate numbers within existing consultant and other firms.)

6. Resource development manpower and costs are only for the first hole program. Assess expenditures by industry to develop a resource site.

7. Develop cost estimates for average operating systems (exclusive of well development) of different types in order to obtain more refined costing data and a greater breakdown of manpower type requirements.

8. Determine the quantity of labor services, and materials that are a function of the infrastructure needed to cause early utilization of geothermal energy. Labor, material and other costs for facility development will be developed. These will include, but not be limited to; labor by crafts, basic material needs, financial structure, management needs, environmental factors, and legal and institutional considerations. In addition, unit costs and quantities will be developed for significant features.

9. Develop these data from a site specific location to a state level, thence to a national level, as more information becomes available.

10. Perform additional charting and analysis of the information (now compiled and to be developed).

11. Resource development costs shown include government and industry efforts for the first hole program. Develop other costs incurred by Industry.

APPENDIX D

DOE COMPONENTS AND SYSTEMS DEVELOPMENT WORK ELEMENTS EITHER IMPLEMENTED OR BEING EVALUATED

TABLE D-I

COMPONENTS AND SYSTEMS DEVELOPMENT WORK ELEMENTS

Work Element	Description	Justification
Wetlands Development	Research and demonstrate utilization of artificially created wetlands (marshes) to dispose of geothermal fluids. Use of aquatic plants as biological filters to remove minerals and metals. Fish culture, water fowl populations, and muskrat raising are possible economic by-products. Algae production for fuel conversion also possible.	Geothermal fluid disposal is currently unresolved and is an overriding concern for geothermal developers, particularly for small developments where reinjection costs are not feasible. Disposal regulations (state, clean water, local) are very restrictive, and wetlands could be an environmentally acceptable disposal solution.
Aquaculture	Examine the commercial feasibility of culturing aquatic species directly in geothermal fluids. Includes spawning, rearing, and marketing evaluations.	Excellent utilization of lower temperature geo-fluid directly or after other heat removal application; converts geothermal energy to transportable high protein product. Very high conversion efficiency for energy in to energy out; huge potential for future application; may be highly beneficial for aquaculture future in U.S.; can be integrated with other operations such as fluid disposal, etc.
Agriculture/ Irrigation	Examine beneficial use of geo-fluid after a primary heat extraction process; examine crop behavior, tolerances, etc,; examine soil alterations and mitigating practices; contribute to understanding environmental implications of geo-fluid disposal.	The use of geo-fluids for irrigated crop production (following industrial or power plant heat extraction processes) may reduce or eliminate need for costly re-injection, provide additional source of water for arid geothermal development areas and may enhance competitive economics of geo-energy.

TABLE D-I (continued)

Work Element	Description	Justification
Geothermal Drying	Examine/demonstrate equipment and techniques for using geothermal heat in industrial/ agriculture drying applications.	A large potential application for geothermal heat is in industrial/ agriculture moisture removal operations (crop drying, waste concentration, evaporation, and crystallization, etc). Penetrating this use category and substituting geothermal for conventional drying techniques is a significant objective that can be advanced by innovative engineering, research, and technology demonstrations.
Space Conditioning	Examine and demonstrate the use of geothermal fluids to power absorption air conditioning equipment, and examine operating conditions and parameters.	Absorption refrigeration cycles are expected to be an important utilization of geothermal energy. No conventional off-the-shelf units are currently available for most geothermal fluid operating ranges and little effort is being made by industry to satisfy the need. Stimulation is needed to penetrate the approximate 4-Quad-per-year U.S. market.
High Temperature Heat pump	Evaluate high temperature heat pumping to produce high temperature steam. Equipment, operating fluids, economics, and efficiencies will be examined.	Future industrial developments around geo-resource are expected to require high temperature steam. High temperature heat pumps appear to be competitive with fossil fuel generators in producing this high temperature source. Little industry effort on-going in this area. Federal program needed to examine and demonstrate potential.

TABLE D-I (continued)

Work Element	Description	Justification
Residential/ Industrial Heat Exchanger Evaluations	Examine design and operating parameters for various heat exchanger equipment elements.	Heat exchanger applications for geothermal fluids are expected to be central part of many future direct heat uses. No background of techno-economic data exists for accurate evaluation of problems. Federal programs should take the lead.
Distillation	Demonstrate the use of geo-fluids to substitute for fossil fluids in the essential oil extraction field or other distillation process.	Little or no private initiative in this area, and application is a good candidate for geo-heat. Federal incentive needed.
Heat Dissipation and Soil Warming	Demonstrate effectiveness of buried pipe grid for power plant cooling and overall economics of system including soil warming/ crop growing.	May compete with expensive air-cooled cooling towers in water-scarce geothermal locales. Federal programs should take the lead.
Geothermally Assisted Biomass Conversion	Demonstrate potential of using geo-heat to enhance economics of converting biomass to-fuels.	Viable boimass-to-liquid fuels program is important to U.S. interests, but no program in industry exists. Prime candidate for government demonstration and stimulation.
Downhole Heat Exchanger Evaluations	To evaluate design and operating parameters for downhole heat exchangers.	Downhole heat exchangers could become an important tool for direct applications but no viable program of design evaluation, optimization, etc., exists. Federal program needs to take the lead.
Materials Testing for Direct Applications	Study of candidate structural materials for direct applications of low-temperature geothermal fluids.	Materials selection for direct applications requires engineering tests to provide baseline selection data. No private organizations currently developing this important data.

TABLE D-I (continued)

Work Element	Description	Justification
Component Test Facility	Provide modular unit capability for geothermal direct use experimental and component testing.	Single facility offers many advantages over individually constructed experiments. Testing facility could contribute to earlier private involvement in direct heat tests and applications. Providing such test capability is a logical government function.