MTR-7137

Geothermal Energy Resource Utilization Program Planning

F.T. GROVER

MARCH 1976

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Geothermal Energy Resource Utilization Program Planning

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WESTGATE RESEARCH PARK
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A handwritten signature in black ink, appearing to read "M. S. Hall", is written over a horizontal line.

ABSTRACT

The theme of the Energy Research & Development Administration's Plan is -- "...creating energy choices for the future." Heat stored in the fluids and rocks of the earth's crust is one such potential source of energy.

ERDA's basic strategy for creating alternative energy supplies is to conduct a program of research, development, and demonstration of energy technology which induces and aids private exploitation of, in this case, geothermal energy resources (commercialization). So that the existence of (user) choice is demonstrated, and as a means of channelizing efforts for the mitigation of the Nation's gathering crisis in energy supply, specific commercialization goals have been set by ERDA.

A procedure is described for planning the achievement of the commercialization goals established for geothermal energy resources. It has been prepared for the consideration of the Office of Resource Utilization, of ERDA's Division of Geothermal Energy.

FOREWARD

This paper is presented in partial fulfillment of "Task 3: TECHNICAL SUPPORT" in the MITRE statement of work entitled, "Development and Application of Criteria For Non-Electric Geothermal Applications"(forwarded to ERDA under MITRE letter number D12-P2356, September 8, 1975), as augmented by the enclosures to MITRE letter to ERDA number W52-760, December 4, 1975. The ERDA contract number is E(11-1)-2693.

The work statement title identifies the subject of the MITRE effort to be non-electric geothermal applications. Yet, as is apparent, the title of this paper is not so restricted. It is argued, on technical grounds, in Section 3.0 of this paper that the electric and non-electric geothermal resource utilization programs are best planned conjointly. But non-agreement with this conclusion does not of itself compromise the applicability of the material contained in this paper to the narrower subject, non-electric utilization of geothermal energy resources. The discussion is applicable to non-electric applications, simply not exclusively so.

The author thanks members of the staff of the Office of the Assistant Director for Resource Utilization, Division of Geothermal Energy, ERDA: Dr. Louis B. Werner who heads that office, Mr. Donald H. Clements, and Mr. Eric A. Peterson. This paper has been benefitted by their commentary on its subject. The contents of his paper, however, remain sole responsibility of the author.

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SUMMARY

This paper is about planning the program of the Office of Resource Utilization, Division of Geothermal Energy (DGE), Energy Research and Development Administration (ERDA).

Three objectives for the Office of Resource Utilization program are abstracted from the more comprehensive DGE and ERDA objectives:

- Early commercialization of geothermal resources,
- Ultimate development of the geothermal resource for the greatest sustainable energy yield,
- Accumulation of systems development and operations data for estimating the national value of the geothermal resource.

The effective output of the Office of Resource Utilization program for achieving these objectives is information which, by virtue of its availability to private interests, will induce and assist private exploitation of geothermal energy resources.

To facilitate the development of the geothermal energy resource there will be an information flow, contributed to by the Office of Resource Utilization, between ERDA and user groups. User groups, largely unformed at the outset, will include at least these generic classes:

- Industry Managers - seeking an energy source which is superior to fossil fuels in price, long-term availability, and environmental pollution; or who wish to supply goods and services for the development of geothermal resources;
- Investors - seeking lending opportunities;
- The public - who want to know the scope and nature of industrial and urban development in association with exploitation of specific geothermal energy reservoirs;

- Government Officials - who wish to acquire data for projecting long-term contributions of the geothermal resource to the Nation's energy supply; or who wish to know what government actions are required, and on what timetable, for development of a specific reservoir; or who, themselves, gather similar data and wish to avoid duplication of effort; and the like.

The contents of the information flow which is needed for development planning by these 'users' will be very broad in its scope. It will include at least these generic classes of (largely technical) data on specific regions which contain geothermal energy reservoirs, their communities, the heat reservoirs themselves, and the engineering facilities needed to extract energy:

- engineering (performance data and specifications)
- economic
- geologic and hydrologic
- natural resource
- demographic and industrial
- legal and regulatory

With respect to the Office of Resource Utilization's contribution to this information flow, the program planning issues are these.

- What information should they fund the gathering of, so that it will be available to 'users'?
- How should priorities be assigned for scheduling the acquisition of this information?
- As information is acquired, how should it be organized for presentation to the 'users'?

Geothermal energy reservoirs are unique in terms of development opportunities and problems. Because of this uniqueness, the best content

standard and the best organization of the information output of the Office of Resource Utilization is with reference to specific energy end-uses at specific reservoirs.

For the greatest efficiency of use of geothermal heat and of the use of capital at any reservoir, the planning of high temperature end-uses (primarily electric generation) and intermediate temperature (non-electric) end-uses should be done conjointly, as integrated parts of a systems engineering approach to reservoir development.

In this paper the assemblage of technical data for a specific geographic region containing a geothermal reservoir and an associated energy-use system is given a name -- the Geothermal Energy Reservoir Prospectus. The program planning procedures, recommended to the Office of Resource Utilization, are one and the same with the planning for the preparation of a set of such prospectuses.

The term prospectus is employed in two distinct ways: (1) as a conceptual output used to analyze for information gathering requirements (the important use of the term) and (2) as the name of a document which might be used for presenting data resulting from the program plus such other data, obtained from archival sources, as are needed to fulfill the total information requirements of 'users' with respect to a specific geothermal reservoir. Use of the concept of the prospectus in the first sense is essential to the program planning procedures being presented. Recommendation of its use in the second way, as actual documents, is in abeyance.

A prospectus for a geothermal reservoir is comprised of three parts:

- the description of a reservoir development enterprise,
- a performance evaluation of that enterprise,
- a data acquisition plan (for the unavailable data items needed for the enterprise description and evaluation).

The third part of the prospectus contains information requirements.

These are to be aggregated across prospectuses-in-preparation and then regrouped to define the information requirements of studies, to be contracted for. The object of this grouping is spending efficiency: removal of redundant information requirements applying to more than one reservoir, grouping by the sites of data gathering, grouping by test facilities needed for data gathering, and the like.

The geothermal energy reservoir development enterprise is defined to be the development of an energy-use system in a specific geographic region. The region is characterized by its physical assets (including of course the geothermal reservoir), a community, an industrial base, a political organization, a set of laws and regulations under which it is administered, and such other factors as will similarly constrain the design of an energy-use system. The energy-use system is divided into an energy supply subsystem and an energy end-use subsystem. The supply subsystem breaks down into geothermal energy (the heat reservoir plus the working-fluid transport plant) and other energy sources. The energy end-use subsystem is comprised of industrial process-product couples. Each process-product couple will make demands upon the region (for raw materials, labor, community services, transportation,

fresh water, and so forth) and on the energy supply subsystem (power requirement, working-fluid input and rejection temperatures, time of use, availability/reliability requirement, interruption tolerance, and the like).

Applying a systems engineering approach to describing and planning realistic development enterprises at specific geothermal energy reservoirs will enable the identification of:

- those data items required for surety that all of the actions called for in an enterprise plan can be carried out,
- those data items required to evaluate the performance of an enterprise in terms of energy substitution, product price and process productivity, as well as environmental and social impacts.

The data item values, not to be found in archival sources, can be sorted from this total information requirement. In turn, from these unavailable data, those data items, the gathering of which by others is not imminent, can be scheduled for acquisition under the program of the Office of Resource Utilization. In this way the information gathering operations appropriate to the objectives of that program can be ascertained.

The exercise of the prospectus preparation procedures (program planning) first yields specific information acquisition requirements. In turn, the aggregate information requirements yield study requirements. From study requirements derive facility requirements (for new construction and for operations and maintenance). Priorities and schedules are set in terms of the relative valuations placed upon the prospectuses for which data are being acquired. Actual program element names can be selected for convenience in describing and budgeting the program.

This will be so because items of every description, purchased under the program, can always be traced to their information requirement antecedents; and, ultimately, to the stated objectives of the program. So the program elements might take their names from facilities, say, demonstration plants or pilot plants, or from study names, or from prospectus names, and so forth.

In concept, prospectuses in preparation by the Office of Resource Utilization would never be strictly completed. A prospectus would be subject to continuous augmentation and update to improve its comprehensiveness, its credibility, its currency, and (through conducting research and development) the indication of engineering and economic feasibility which it conveys. This process would continue until the development enterprise described in the prospectus is either commenced by private interests, or its planning is abandoned. This interpretation derives from the view that ERDA is not in business to find out if there is a use for geothermal heat. ERDA makes use practical and economic through research and development; and then demonstrates this success, to induce commercialization.

The recommendation is for an exploratory and limited implementation of the planning procedure based upon the prospectus concept -

- Plan a prospectus for a single reservoir up to the point where detailed information acquisition requirements are identified,
- Evaluate this planning process and its product,
 - prepare a critique of the planning experience
 - obtain the opinion of a sample of representatives of 'user' groups on the suitability of the procedure for meeting their planning information needs.

The purpose of such an effort should be to gather that information which the Office of Resource Utilization needs to decide the future applicability of these procedures for planning and implementing their program.

1.0 INTRODUCTION

The subject of this paper is -- procedures for planning and conducting a research, development, and demonstration program in geothermal energy resource utilization. Procedures have been designed for the Office of the Assistant Director for Resource Utilization of the Division of Geothermal Energy, Energy Research and Development Administration (ERDA).

2.0 OBJECTIVES

It is the purpose of the Federal energy research, development, and demonstration effort to create energy choices -- alternatives to currently available sources. The method of approach to this ERDA objective for the program of the Office of Resource Utilization can be outlined as follows. Available geothermal energy technology plus Federal funding will be applied in the limited development of geothermal energy reservoirs, such that the economic and engineering evidence accumulated from these enterprises -- the output of the Resource Utilization program -- induces private interests to undertake the development of these reservoirs and, subsequently, the sale of energy to customers. This process will be referred to as the commercialization of the geothermal energy resource. The primary objective of the Resource Utilization program is:

- EARLY COMMERCIALIZATION OF GEOTHERMAL RESOURCES.

Here the emphasis is upon early success.

But current technology is not adequate for commercial development of some types of geothermal energy reservoirs, in particular geopressured, very high salinity hydrothermal, hot-dry-rocks, magma, and normal temperature gradient reservoirs. Advanced planning of Federal demonstration projects is appropriate now, however, because of the lead-time expectation on such projects, and because the very great energy potential of such reservoirs suggests that these alternative energy sources be created without delay. The second objective of the Resource Utilization program is:

- ULTIMATE DEVELOPMENT OF THE GEOTHERMAL RESOURCE FOR THE GREATEST SUSTAINABLE ENERGY YIELD.

Earnest striving for commercialization of geothermal energy reservoirs will compel confrontation of the full range of impediments to their development as no purely research oriented program ever could. Such commercialization enterprises, alone, can generate realistic economic and engineering data needed to answer such questions as:

- How much energy can be obtained from geothermal reservoirs?
- At what costs will this energy be acquired?
- What kinds of reservoirs will be the most cost/beneficial to develop?

The third objective of the Resource Utilization program is:

- ACCUMULATION OF SYSTEMS DEVELOPMENT AND OPERATIONS DATA FOR ESTIMATING THE NATIONAL VALUE OF THE GEOTHERMAL ENERGY RESOURCE.

Here the emphasis is upon promoting objectivity in the distribution of Federal investments for energy resource developments.

3.0 PROGRAM OUTPUTS

How does ERDA induce private interests to develop geothermal energy resources? The primary method will be through conducting research, development, and demonstration projects which generate technical data. It will be through the provision of this information on geothermal energy utilization methods and prospects that private interests will be influenced. The Office of Resource Utilization program output will contribute to this information flow. Yet their program elements are not explicitly information acquisition. These take such names as "pilot-plant", "test facilities," and "demonstration plant," for example. However, the tacit utilization plan is to build and operate such facilities for the express and exclusive purpose of gathering data on their cost and operational performance for dissemination to interested users.

3.1 Users

A mechanism should be developed and placed in continuous operation for the identification of those generic public and private interest groups who already have a use for geothermal energy data, and those private interests whose participation in development enterprises is to be facilitated by actions of the Office of Resource Utilization. Examples of groups who can use the output of the Resource Utilization program include:

Industry Managers: seeking an energy source which is superior to fossil fuels in price, long-term availability, and environmental pollution; or who wish to supply goods and services for the development of geothermal reservoirs;

Investors: seeking lending opportunities;

Public: who want to know the potential scope and nature of industrial and urban development in association with specific geothermal reservoirs;

Government Officials: who wish to acquire data for projecting long-term contributions of energy attainable from geothermal resources; or who wish to know what government actions are required, and on what timetable, for development of a specific geothermal energy reservoir; or who, themselves, gather similar data and wish to avoid duplication of effort; and the like.

While actual users will only rarely be identifiable in advance, a continuing survey of the planning data requirement of known users, and imputation of such requirements to imagined users, of data deriving from the Resource Utilization program is in order. Finding out what representatives of potential participant groups think the technical (engineering and economic) data requirements are for promoting the development of geothermal energy resources is an important step in program definition.

3.2 Output Descriptions

The natural organization for the outputs from the Resource Utilization program is to classify data using the specific geothermal energy reservoir as the primary key.

Geological Survey Circular 726, "Assessment of Geothermal Resources of the United States - 1975," contains data supporting the conclusion that the geothermal energy reservoirs are geographically localized. The relation between the energy concentration (temperature) and the frequency of discovered anomalous heat is such that only a few of these reservoirs have very high temperatures; most have low temperatures. The same frequency relation describes the geographic distribution of total

reservoir heat. A few large systems hold most of the heat. Only the normal temperature gradient is to be found almost everywhere, but development of this reservoir is likely only in the future. So the resource is geographically distributed in more or less unitary and isolated reservoirs -- more points on maps, than areas. The reservoirs are also few in number (discovered hydrothermal reservoirs in the coterminous U.S. are on the order of 200 in number). Therefore, the scale of the resource development enterprise at any one reservoir will be very large if geothermal energy is to supplant any substantial amount of fuel usage.

Discovered reservoirs are unique in terms of those factors likely to influence the cost of deriving energy from them. The data in Circular - 726 suggests that hydrothermal reservoirs if developed would differ markedly in well head fluid temperatures, achievable flows from wells, concentrations of dissolved solids, and the like. The regions in which reservoirs are located also vary in terms of proximity to population centers, to transportation and electrical power distribution networks, in the availability of fresh water and other material and agricultural resources. This uniqueness of development problems and opportunities at the different reservoirs preclude a general systems design solution which would apply to a large fraction of the known reservoirs.

Of the shared features of reservoirs, an outstanding characteristic is negligible energy demand in proximity to any hydrothermal reservoir

listed in Circular 726. The largest community near a large reservoir is Boise, Idaho with a (1970) population of 72,090. One way to try to effect a coincidence of energy demand with a geothermal energy source is to search for reservoirs in industrialized areas. For the commercialization of the hydrothermal energy resources described in Circular 726, however, the first consideration is to relocate an energy demand to the reservoir sites.

The simplest way to convey demand to the geothermal wellhead is in the form of electric transmission lines leading off to distant customers. There are, however, at least three serious deficiencies in an exclusively electricity generation approach:

(1) The 1985 geothermal commercialization goals are not likely to be met by electrification alone:

(2) Electric generation using liquid dominated hydrothermal fluids is an inefficient use of the resource:

(3) Large amounts of capital are needed for well drilling, surface plumbing, and proving a resource long before electricity can be generated.

Transporting energy in geothermal fluid is said to be practical over distances no greater than a few tens of miles. Therefore, the exploitation of discovered hydrothermal resources for non-electric end-uses requires competitive substitution in the location of the using industry--geothermal reservoir sites for traditional locations. Industrialization of regions, presently having very small populations and little industry,

is a central issue in the development of (at least) liquid dominated hydrothermal resources for non-electric applications.

The conjoint planning for electric and non-electric end-uses is attractive, and perhaps essential, for reaching the geothermal commercialization goals. Three reasons are:

(1) non-electric processes can extract work from hydrothermal fluids at electric plant steam separator rejection temperatures, thereby achieving a more efficient use of the resource;

(2) a community with an industrial base using geothermal heat directly will also need electricity, thus will provide a local market;

(3) non-electric end-uses planned in association with electrical generation can reduce the capital costs of electrical projects by:

a) sharing the reservoir development capital costs over the amortization period of the geothermal fluid transport plant,

b) reducing financial risks by providing a fall-back market for hydrothermal fluid should the temperature decrease prematurely or should new wells not produce fluids at high enough temperatures for electric generation,

c) easing the initial capital requirement by providing an interim market for heat until a generating plant and electric distribution system can be installed (this requires that the amortization period of capital equipments for the non-electric end-uses are shorter than the well hook-up delay for electrical generation).

The need to industrialize regions and the community development

which this implies suggest that while the competitiveness of geothermal energy resources surely depend upon the cost of energy obtained from reservoirs, it also depends upon the availability at these reservoirs of all the other goods, services, markets, labor, and the like needed by the relocated industry. Variations in the aggregate costs of these non-energy items currently influence the profitability of most U.S. industry to a greater extent than do proportional variations in the cost of energy. Systematic investigation and presentation of the whole of the opportunities and the problems at specific geothermal reservoirs is the best standard for the contents and the organization of information for promoting commercialization. Outputs recommended for the Office of Resource Utilization reflect this conclusion, these include: (1) the Geothermal Energy Reservoir Prospectus for some reservoir identified by its place-name, (2) the technical report, (3) the administrative report. This last class of outputs include plans, budgets, progress reports, and the like. The administrative report will not be discussed further in this paper.

3.2.1 Geothermal Energy Reservoir Prospectus

In discussing planning of the Office of Resource Utilization program the term prospectus is employed in two distinct ways. First, it refers to a dummy output used to decide what information gathering operations the Office of Resource Utilization should undertake. This is the important use of the term. Second, prospectus is the name for a cover which might be used for presenting data resulting from the

program plus such other data, obtained from archival sources, as are needed to fulfill the total information requirements of 'users' with respect to a subject reservoir. The important point is that prospectus, as planning element, is essential to these planning procedures whether or not the Office of Resource Utilization publishes actual documents labeled with the name. The second use of the term is a matter of convenience to 'users', or of efficiency in explaining and defending the program. Without prejudice to this distinction, the prospectus will be described as though it were an actual document.

A prospectus for a geothermal reservoir is comprised of three parts:

- The description of a reservoir development enterprise,
- A performance evaluation of that enterprise
- A data acquisition plan (for the unavailable data needed for the enterprise description and enterprise evaluation).

Table I is the outline for Geothermal Energy Reservoir Prospectuses. Part 1.0 of a prospectus (the term, Part, always refers to Table I) contains a description of a possible reservoir development enterprise. This will be a feasible enterprise if certain assumptions about factors external to the enterprise pertain. These contingencies are specified in Part 1.3. The enterprise, as specified in Part 1.0, will not have the force of a Federal plan. Rather it describes a project which private interests are expected to finance and execute.

The terms of the description of the reservoir development enterprise are the CURRENT STATE (presently, or current at any given time in the

TABLE I

GEOHERMAL ENERGY RESERVOIR PROSPECTUS OUTLINE

- 1.0 DESCRIPTION OF THE RESERVOIR DEVELOPMENT ENTERPRISE
 - 1.1 RESERVOIR, REGION & ENERGY-USE SYSTEM
 - CURRENT STATE OF RESERVOIR, REGION, COMMUNITY
 - PHYSICAL
 - POLITICAL
 - SOCIO-ECONOMIC
 - TARGET STATES
 - ENERGY-USE SYSTEM
 - ENERGY SUBSYSTEM
 - END-USE SUBSYSTEM (PROCESSES & PRODUCTS)
 - COMMUNITY
 - 1.2 DEVELOPMENT REQUIREMENTS
 - INDUSTRY RELOCATION
 - LABOR
 - SERVICE INDUSTRIES
 - GOVERNMENT SERVICES
 - UTILITIES
 - COMMERCE
 - 1.3 DEVELOPMENT PLAN
 - CONTINGENCIES (TECHNICAL, ECONOMIC, INSTITUTIONAL)
 - PARTICIPATING INTERESTS
 - PARTICIPANTS ROLES
 - ACTION SEQUENCES AND TIMETABLES
- 2.0 RESOURCE PERFORMANCE OF THE ENTERPRISE
 - 2.1 ENERGY BALANCE SHEET (COMPARATIVE THROUGHPUT AND DEVELOPMENT COSTS BY ENERGY SOURCE)
 - 2.2 CAPITAL REQUIREMENTS (COMPARATIVE)
 - 2.3 MATERIALS REQUIREMENTS (COMPARATIVE THROUGHPUT AND DEVELOPMENT REQUIREMENTS)
 - 2.4 ENVIRONMENTAL LOADS (COMPARATIVE)
 - FRESH WATER USAGE
 - POLLUTION (WATER, AIR, WASTE, NOISE, VISUAL, ETC.)
 - LAND SUBSIDENCE AND SEISMIC DAMAGE
 - LAND USE
 - 2.5 SOCIO-ECONOMIC EFFECTS
 - POPULATION MIGRATION
 - JOB BALANCE SHEET (COMPARATIVE)
 - INDUSTRY PRODUCTIVITY (COMPARATIVE)
 - PRODUCT PRICES (COMPARATIVE)
 - EFFECTS ON TAX BASE
- 3.0 INFORMATION ACQUISITION REQUIREMENTS OF THE ENTERPRISE (DATA ITEMS)
 - USERS
 - SOURCE OF VALUE (OR METHOD FOR EVALUATING DATA ITEM)
 - ACCURACY STANDARD
 - CURRENCY STANDARD
 - ACQUISITION DATE

future), the TARGET STATE (at which the energy yield of the reservoir is the maximum sustainable), the DEVELOPMENT REQUIREMENTS (which is the change in state needed to transit from the CURRENT to the TARGET state), and the DEVELOPMENT PLAN (which is a sequence of timed actions for the state transition, with these necessary actions being imputed to PARTICIPANTS).

A detailed outline, based upon Part 1.0, created for a particular reservoir will specify the data content for that prospectus. The data items to be contained in the description sections of prospectuses will represent a number of generic classes. The geologic, hydrologic, thermodynamic, and chemical characteristics of the geothermal energy reservoirs themselves are expected to be included. Engineering specifications and cost estimates are appropriate for such data types as: well designs, geothermal fluid transport equipments, scale control measures, and the like. Industrial use data will form a substantial fraction of the enterprise description: end-use temperature ranges, flow requirements and their time dependence (diurnal, weekly, seasonal variations), availability/reliability requirements on heat flow, expected distances from the wellheads, and so forth. Region data item types sure to be represented include: climate, agronomy, hydrology, vegetation, agriculture, mineral resources, and topography. Community data item types will include: demographic, industrial, business and commerce, markets, transportation, labor, political, relevant laws and regulations, land use plans and zoning ordinances, mineral and water rights -- all could be appropriate to any given prospectus.

The test for deciding whether to include a particular data item in a given prospectus, and to set an accuracy standard for its reported value, is the following. A data item should be included in a given prospectus if it must be known in advance of a commitment to implement: for surety that all of the actions called for in the development plan of the prospectus can be carried out, or if it must be known to estimate the ultimate (or interim) performance of the enterprise.

The anticipated results, should the enterprise be undertaken and consummated, are contained in Part 2.0 of a prospectus. Where the term COMPARATIVE appears, the idea is that performance be measured as a net change in the relevant variable for the entire community (industry, public, business, and so forth). This 'community' is now located somewhere (operating at the "old" performance) and it will be relocated to the geothermal reservoir (where it will operate at the "new" performance). The comparative performance is, of course, the difference between the "old" and the "new" performance with respect to those variables to be found listed under Part 2.9.

Part 3.0 of a prospectus is the acquisition plan for those data items comprising the contents of that prospectus. This plan says who needs what data, anticipated sources (or methods) for obtaining these data, accuracy and currency standards, and the estimated date of their acquisition. The data plan is made an integral part of a prospectus for two reasons. First, it provides convenient access for prospectus users to dates of planned acquisitions and supercessions of data which they may need for their decisions. Second, the data acquisition

schedule and the prospectus itself cannot be completed because they both (in concept) require continual modification.

The first reason for modifying a prospectus is the obvious need for updating its contents. The CURRENT state of the reservoir-region-community is ever changing. The second reason for modification is the evidence of prospectus inadequacy. Namely, if the prospectus exists (that is, it is in preparation) then the reservoir development enterprise does not. In that event the information in the prospectus is, by definition, insufficiently comprehensive, insufficiently credible, or insufficiently indicative of the engineering and economic feasibility of the enterprise to induce anyone to implement it. This definition has its basis in the opinion that ERDA is not in business to find out if there is a use for geothermal heat. ERDA makes use practical and economic through research and development; and then demonstrates this success, to induce commercialization.

For a prospectus in preparation, which private groups are not seeking to implement, the remedies are: incorporate new data items in the prospectus; acquire data item values of greater credibility; undertake research, development, and demonstration to enable substitution of more favorable engineering or cost data; arrange for indemnification in the event of private capital losses; or arrange new incentives for private interests to undertake the venture. The Office of Resource Utilization action options on this list are those which would add to or modify the data contained in the prospectus. The idea is that once a prospectus is

commenced the data remedies discussed here are continuously applied until that prospectus is either implemented, or abandoned.

3.2.2 Geothermal Resource Utilization Technical Reports

Technical reports are the outputs of data gathering projects, large or small, funded by the Office of Resource Utilization. The subjects of studies are taken from the data acquisition plans for one or more geothermal energy reservoir development enterprises. Thus the technical report is the form in which data, gathered by (or for) the Office of Resource Utilization, is presented to 'users' for their commercialization planning. The style and organizational standards of technical reports can be those of conventional engineering, economic, or scientific reports.

3.3 Output Acquisition

Figure 1 depicts a process which can result in the accumulation of the outputs which have been defined in this paper. These outputs are produced for the 'users', illustrated on the far right of Figure 1. These 'users' accessing outputs are shown in the context of the annual program planning and budgeting cycle. There is no representation in the diagram, however, of the several successive annual programs all in various stages of the program definition and approval process: the authorized and funded program on the right side of the diagram, the next years program undergoing congressional review and action, and so forth.

Of the many information feedback loops which will shape the Resource Utilization program, the two which will probably have the greatest impact

¹ PL 93-410, Sec 105, (b)

² PL 93-410, Sec 302, (b)

GLOSSARY

DGE: ERDA, DIVISION OF GEOTHERMAL ENERGY

ERDA: ENERGY RESEARCH & DEVELOPMENT ADMINISTRATION

ERDA-48: A NATIONAL PLAN FOR ENERGY RESEARCH, DEVELOPMENT & DEMONSTRATION

ERDA-86: DEFINITION REPORT - NATIONAL GEOTHERMAL ENERGY R,D&D PROGRAM

FEA: FEDERAL ENERGY ADMINISTRATION

OMB: OFFICE OF MANAGEMENT & BUDGET

PL 93-410: GEOTHERMAL RESEARCH, DEVELOPMENT & DEMONSTRATION ACT OF 1974

POX: PROGRAM OPPORTUNITY NOTICE

RESOURCE UTILIZATION: ERDA, DGE, OFFICE ASSIS. ADMIN. RESOURCE UTILIZATION

RIA: RESEARCH INVESTIGATION ANNOUNCEMENT

RFP: REQUEST FOR PROPOSAL

USGS: U.S. GEOLOGICAL SURVEY

FIGURE 1
INFORMATION FLOW--ANNUAL PLANNING-PRODUCTION CYCLE FOR ERDA,
DIVISION OF GEOTHERMAL ENERGY, RESOURCE UTILIZATION PRODUCTS

on the, so called, 'out year' planning are illustrated. Given the lead-times for prospectus preparation, facility construction and, ultimately, reservoir development it is evident that the important shaping influences upon the program will not occur in the budget year under congressional review. Which is to say that these influences will effect program definitions for the 'out years'.

The first of these feedback loops will convey guidance to Resource Utilization from many government agencies. To the extent that this guidance is in response to any Resource Utilization output, these will most likely be in administrative report form. New legislation, court decisions, Executive Orders, rulings of regulatory bodies, tax rulings, foreign and domestic political actions, all of these kinds of institutional events could be called to the attention of Resource Utilization for their consideration during program definition. The second feedback loop will convey the results of the evaluations of program output along with specific requests for data received from users. In terms of the formulations advanced here, this second feedback loop will carry information reflecting on the information status of the set of prospectuses in preparation.

The preparation of a prospectus for a specific geothermal energy reservoir is the nucleus concept for deciding what information the Office of Resource Utilization should fund the gathering of, so that it will be available to 'users'. This use of the term is illustrated on the extreme left in Figure 1. There, information requirements are identified and

organized into projects (studies, demonstrations, and the like). Ultimately these information requirements will be grouped under program element names, the form in which they will transit the review and approval portion of the process depicted in Figure 1. This is the important use of the concept of prospectus as developed in the preceding section of this paper, as a guide to planning and program definition.

The term prospectus appears again on the far right hand side of Figure 1. In this reference a prospectus is an actual document containing data from technical reports produced under studies funded by Resource Utilization and data from library sources (that is, technical reports not paid for by Resource Utilization). Adoption of the prospectus idea in the first (planning guide) sense is the chief recommendation in this paper. Production of prospectuses in this second (and subordinate) usage is a matter of efficiency in explaining and defending the program, and of convenience to uses. A recommendation of this second use of the idea, as a class name for actual documents, is in abeyance (see Section 4.0).

Table II lists nine recommended program definition functions which are built upon the first of these uses of the term -- prospectus. The program definition functions in Table II are sequenced in their intended order of execution. The idea is that these functions be accomplished sequentially, in the order shown, for each planning and budgeting cycle. The procedures in Table II yield study requirements and facility requirements, for operations and maintenance of facilities as well as for their construction. The procedures happen not to yield program element names,

TABLE II

FUNCTIONS FOR RESOURCE UTILIZATION PROGRAM DEFINITION

Functions Are Listed in Order of Execution Precedence and
Criteria Are Listed Below Each Function

- (A) SET THE NUMBER OF GEOTHERMAL ENERGY RESERVOIR PROSPECTUSES
 TO BE IN PREPARATION DURING THE PLANNING AND BUDGETING YEAR

<u>FACTORS</u>	<u>DESIRED QUALITIES</u>
<ul style="list-style-type: none"> ● RESERVOIR TYPE (geology, hydrology, chemistry thermodynamics, by-products) 	SIGNIFICANT COMPREHENSIVENESS ADDED TO THE SET
<ul style="list-style-type: none"> ● ENERGY EXTRACTION TECHNOLOGY 	"
<ul style="list-style-type: none"> ● ENERGY END-USE 	"
<ul style="list-style-type: none"> ● REGION 	"
<ul style="list-style-type: none"> ● RESOURCE COVERAGE 	SIGNIFICANT INCREASE

- (B) SET PRIORITY ON PROSPECTUS TYPES

<u>FACTORS</u>	<u>DESIRED QUALITIES</u>
<ul style="list-style-type: none"> ● COST (to Resource Utilization) 	LEAST
<ul style="list-style-type: none"> ● COMMERCIALIZATION LEAD TIME (research & development required) 	LEAST
<ul style="list-style-type: none"> ● INSTRUMENTATION REQUIRED (facility costs) 	LEAST
<ul style="list-style-type: none"> ● GENERALITY 	APPLICABLE TO THE GREATEST RESOURCE

TABLE II (CONTINUED)

(C) SELECT RESERVOIRS FOR PROSPECTUSES WHICH ARE BEING INITIATED IN THIS PLANNING AND BUDGETING YEAR

<u>FACTORS</u>	<u>DESIRED QUALITIES</u>
• COMMUNITY ACCEPTANCE	RESIDENTS SUPPORT DEVELOPMENT
• TECHNICAL FEASIBILITY	MOST CERTAIN
• COST/BENEFIT	BEST RATIO
• LONG-TERM NATIONAL NEEDS	LARGEST ENERGY FLOW & FUEL SUBSTITUTION
• ENVIRONMENTAL IMPACT	LEAST
• POTENTIAL FOR TECHNOLOGY TRANSFER	MOST GENERALITY
• COOPERATIVE AGREEMENT WITH INDUSTRY	AVAILABLE
• FEDERAL PARTICIPATION	LEAST INVESTMENT, FEWEST ACTIONS
• LEGAL & REGULATORY RESTRICTIONS	FEWEST

(D) PREPARE A DETAILED PROSPECTUS OUTLINE (SPECIFY DATA ITEMS) FOR PROSPECTUSES WHICH ARE NEW IN THIS PLANNING AND BUDGETING YEAR

<u>FACTORS</u>	<u>QUALIFYING CONDITIONS</u>
• SURETY OF DEVELOPMENT ENTERPRISE SUCCESS	REQUIRED FOR
• INPUT TO ENTERPRISE PERFORMANCE ESTIMATE	REQUIRED

TABLE II (CONTINUED)

(E) SET PRIORITY ON DATA ITEM ACQUISITIONS

<u>FACTORS</u>	<u>QUALIFYING CONDITIONS</u>
• LOGICAL PRECEDENCE (paired comparisons)	REQUIRED FIRST
• LOGICAL PRECEDENCE (dependent data items)	GREATEST NUMBER
• PROSPECTUS PRIORITY	HIGHEST
• PROSPECTUSES REQUIRING THE SAME DATA ITEM VALUE	GREATEST

(F) ASSIGN DATA ITEMS INTO ENGINEERING & ECONOMIC STUDIES

<u>FACTORS</u>	<u>QUALIFYING CONDITIONS</u>
• DATA ITEM VALUES NOT IN AVAILABLE PUBLICATIONS	TRUE
• DATA ACQUISITION NOT PLANNED BY OTHERS	TRUE
• AGGREGATION OF DATA ITEMS	LEAST COST

(G) SET PRIORITY ON STUDIES

<u>FACTORS</u>	<u>DESIRED QUALITIES</u>
• FACILITY REQUIREMENTS	CLOSEST AVAILABILITY DATE
• NUMBER OF DATA ITEMS	LARGEST NUMBER

(H) ESTABLISH REQUIREMENTS FOR FACILITY OPERATIONS & MAINTENANCE
AND NEW CONSTRUCTION STARTS

<u>FACTORS</u>	<u>QUALIFYING CONDITIONS</u>
• REQUIRED FOR A SCHEDULED STUDY	TRUE
• NONE AVAILABLE FOR HIRE	TRUE

TABLE II (CONCLUDED)

(I) SET PRIORITY ON NEW FACILITY CONSTRUCTION STARTS

<u>FACTOR</u>	<u>DESIRED QUALITY</u>
<ul style="list-style-type: none"> • NUMBER OF DATA ITEMS REQUIRING FACILITY FOR VALUE ESTIMATES 	GREATEST

but these can be assigned to suit the circumstances; for example, using study names, or facility names, or reservoirs names, or region names, and so forth.

The functions listed in Table II imply Resource Utilization decisions. Criteria for these decisions are listed, in association with each of the functions, in Table II. These criteria are expressed in the form of a set of factors (suggested for consideration in making these decisions) and the qualities of these factors which should be valued. An examination of the criteria will establish that frequently they are non-independent: being sometimes overlapped (redundant), sometimes in conflict. Yet methods are not being suggested for resolving these defects or for deciding the relative importance which should be attached to the several criteria of any function. On the contrary, no purpose will be served by obfuscation of the fundamentally subjective nature of these Resource Utilization decisions.

The proper bases for choosing criteria are, of course, the program objectives. So each test in Table II is traceable to one or more of the objectives defined in Section 2.0, above. The criteria applied for Function (A) (which will promote diversity in the reservoir types, energy end-uses, technologies, and regions) have obvious connections with the second and the third objective imputed to Resource Utilization: to obtain the greatest ultimate yield from all forms of the geothermal energy resource, and to gather data for input to estimates of the national value of geothermal energy resources. The criteria listed for

Function (B) will shape the program for achieving the primary objective of early commercialization of geothermal resources by assuring that effort is devoted to prospectus types in direct relation to their potential for early preparation and implementation. The selection of tests for Function (C) was made so as to conduct reservoir selection on the basis of the totality of considerations essential to early and successful reservoir development. The purpose is to promote coincidence of the Federal objective of early commercialization with the private objective of profitability by naming reservoirs to prospectus types which have the best chances for early exploitation and the least risk. The criteria for the remaining functions (Function (D) to (I)) will have more indirect effects upon meeting the objectives. They have been selected mainly to facilitate the preparation of prospectuses and to ensure their quality. There is, however, a very important interface between the Federal program and industry at Function (D). Nominations of data items for consideration of inclusion in prospectuses should be solicited from industry representatives. The appropriate query is just the first criterion of Function (D), namely -- what data do you believe to be essential for surety that the reservoir development enterprise will succeed? If this query is put to industry representatives and if their answers be taken into account in specifying the data contents of prospectuses, this could contribute greatly to the achievement of the early commercialization objective. In the end, these are the people who have to be convinced if the basic ERDA objective -- the creation of an energy choice from the geothermal resource -- is to be achieved.

Budgeting operations can be related to the functions in Table II. Prices are estimated for the budget items: studies, facility operations and maintenance, facility construction (in progress and new starts), staff operations, and perhaps something like general program support. The sum of these expenses is then adjusted within budget guidelines with reference to the priority of studies. Removing studies reduces the total request by the cost of the study and may release facility requirements.

At this point in the program definition and budgeting process being described, few restrictions have been placed upon future contracting. Studies and facility contracts could be let, each under its own scope of work. On the other hand, there are some obvious possibilities for organizing studies: by prospectus type, by reservoir, or by region. And these also apply to facility contracts as well. So both studies and facility items could easily be grouped for execution by a reservoir contractor, or a region contractor, should these prove to be efficient and cost beneficial.

4.0 PROCEDURE IMPLEMENTATION AND RECOMMENDATIONS

A highly idealized method has been described for defining a resource Utilization program to satisfy certain objectives and for carrying out the resultant program plans. The recommendation is for a systems engineering approach to the exploitation of geothermal resources. The creation of prospectuses keyed to the individual geothermal reservoirs -- containing the emerging systems design itself, the design evaluation, and the design development and maintenance plan -- is the central concept in the recommended method. The material implementation issue is -- should the Office of Resource Utilization adopt the program planning procedures outlined in this paper? Two implementation steps are recommended as a trial of the suitability of these procedures. These steps are described with reference to Table II which contains the list of program definition functions.

First, the following sequence of functions from Table II should be carried out:

- (A) Set the number of geothermal reservoir prospectuses to be in preparation during the planning and budgeting year,
- (B) Set priority on prospectus types,
- (C) Select reservoirs for prospectuses which are being initiated in this planning and budgeting year,
- (D) Prepare a detailed prospectus outline (specify data items) for prospectuses which are new in this planning and budgeting year.

The resulting product can then be evaluated before proceeding further with prospectus preparation. For Function (A), selection should be made of a reservoir type, a technology type, and an energy end-use (or uses) which

are best suited to the 'early commercialization' objective. Since there will be only one prospectus in preparation, Function (B) can be passed. At Function (C) a reservoir should be selected which appears to have a reasonable chance for early exploitation. Under Function (D) a detailed prospectus outline (specification of data items) should be written. The product of this step can be described by reference to the prospectus outline in Table I. An analysis should be conducted to ascertain: the identities of interests (private and public) who will participate in the reservoir development enterprise, their roles, and their information requirements (Part 1.3). Another analysis should be conducted to ascertain the data item requirements for Part 2.0, the performance estimate of the enterprise. Merging these two lists of required data items, the data acquisition plan (Part 3.0) should then be prepared. For each listed data item the following information should be supplied to complete the product of this step: source of (or method for acquiring) values for the data item, an accuracy standard, a currency standard, and an acquisition data (given relative to a declared start of prospectus preparation).

Second, the experience of conducting Function (A) through (D) and the resulting output should be evaluated. A critique should be prepared by the group which has exercised the procedures in the first step, above. The description of the program planning procedures and the results of applying these procedures should then be reviewed by a sample of representatives of likely 'users' groups. Their opinions should be obtained on the suitability of these procedures from the point of view of the anticipated information needs of 'users'. The results of this evaluation

should be prepared for a decision on the future use of these procedures by the Office of Resource Utilization. Some of the alternative actions which could emanate from that decision include these:

(1) Continue program definition action based upon the model prospectus by exercise of Functions (F) through (I) of Table II. Further reviews of the results would be scheduled;

(2) Proceed with the model prospectus and commence program planning based upon a set of these ;

(3) Take either action (1) or (2), above, and commence the preparation of the model prospectus for publication as an Office of Resource Utilization output document;

(4) Abandon the planning procedure, as such, and employ the concept of the prospectus and the model specification already prepared in a purely passive way, as a checklist, as a set of criteria, to be referred to while writing work statements for facility construction, engineering study, or economic study contracts.