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INTERNATIONAL PROGRAMS AND AGREEMENTS
IN GEOTHERMAL ENERGY

An Interim Report

prepared for

Department of Energy
Division of Geothermal Energy

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1. INTRODUCTION

This report contains the interim results of a study for the Division of Geothermal Energy on the Division's international programs and activities. The complete research program, which is scheduled to be finished in November 1978, will have the following elements:

- An assessment of objectives that have motivated the formulation of international programs and an explanation of any changes in the evolution of those programs. These objectives will be assessed for their internal consistency, degree of governmental consensus, their practicality, the current status of their accomplishments, and the implications of their accomplishments for the role of DGE.
- An assessment of organizational structures and teams, including the identity of key decisionmakers, the nature of the interagency process, procedures for generating nongovernmental support for international programs and the success of these procedures, and the effectiveness of the interface with foreign partners.
- Assessment of results of international cooperative programs, which will involve the development of an overall balance sheet of benefits and disbenefits attributed to each international program.
- The formulation of future international cooperative programs based on the assessments described above. These programs may involve the development of new exchanges, alteration or elimination of existing exchanges, and revisions in the management of exchanges by U.S. government agencies.

The present interim report includes results obtained during approximately three months of research. In this period 21 interviews were held with people in the Division of Geothermal Energy, the Office of International Programs, and the United Nations.* The interviews were supplemented by documentation

*A list of those interviewed is given in Appendix A.

on international geothermal programs, including the draft final report on the CCMS activity, the texts of the various international agreements, and assorted internal memoranda and embassy cables.

The interview materials and documents have provided information on the origins of present international agreements and activities, on the formal responsibilities of various government agencies, and on the range of specific programs and projects being pursued. Our research has drawn us toward certain tentative conclusions concerning the objectives that explain the recent growth of formal international agreements, the extent to which these objectives have been realized, the degree of reciprocity that the agreements have achieved, and certain administrative barriers to their success. Finally, we have developed some interesting information on other bilateral and multilateral activities in which the United States is engaged not at all or peripherally and which may provide some clues as to future opportunities for U.S. international programs. These leads will be pursued actively in our subsequent research.

We must emphasize the tentative nature of these conclusions because of the incomplete status of our research. Interviews have yet to be conducted with non-DOE U.S. government officials, and we believe that discussions with representatives of the Department of State and AID may be particularly useful. Furthermore, discussions have not yet been held with representatives of the geothermal industry or the various geothermal laboratories. Thus, any conclusions concerning the relative balance of benefits gained through international activities, the effectiveness of the interagency and the government/industry/R&D community interfaces, and the shape of a revised international program must await the conclusion of our research. The present report, therefore, should be viewed as indicative of the direction of our effort and of our current thinking based upon a limited interview sample.

The report is divided into two main sections: Section 2 contains a description of current geothermal energy international agreements and activities; Section 3 gives an interim evaluation of the international programs.

2. DISCUSSION OF INTERNATIONAL AGREEMENTS AND ACTIVITIES ON GEOTHERMAL ENERGY

The United States has entered into a number of multilateral and bilateral arrangements with special relevance to geothermal energy. In general, the agreements call for an exchange of information, exchange visits of scientists, and examination of areas for joint cooperative activities. In this section, the background to each agreement is discussed, and past and present activities are summarized. In some cases, where formal agreements have not been signed, the current status of negotiations is reported. Additionally, several informal foreign activities are reported, so that the chapter contains a view of the primary international activities of the United States in geothermal energy.

A brief discussion of some relevant non-U.S. geothermal activities is presented in Appendix B.

CCMS Geothermal Pilot Study

The Geothermal Pilot Study, organized under the auspices of the NATO Committee of the Challenges of Modern Society (CCMS), was the first international program devoted to R&D of geothermal resources. The program is currently at an end. It was first initiated at the 1973 Spring Plenary Session of CCMS in Ottawa, Canada, where Russell Train proposed that CCMS apply their "action oriented" approach to the development of solar and geothermal resources.

Under the direction of James Bresee, the United States, in October of 1973, sponsored an international meeting of experts in California to discuss and draft a proposal for the Geothermal Pilot Study. At this meeting, five

areas were designated as useful for cooperation. These areas included:

1) Computer-Based Information Systems, 2) Direct (nonelectric) Uses of Geothermal Energy, 3) Multipurpose Processing and Disposal of Geothermal Brines,* 4) Small Geothermal Power Plants, and 5) Hot Dry Rock Concepts. The CCMS Plenary Committee and the North Atlantic Council approved these five areas of study; the United States became the pilot country and Italy and Turkey, co-pilot countries for the NATU-CCMS Geothermal Pilot Study.

The short-term objective of the Geothermal Pilot Study was to accelerate the world use of geothermal energy. The rationale for international cooperation was that advances along the learning curve would presumably be accelerated by opening up a dialogue between foreign colleagues in the geothermal field, facilitated by their working together on short-term programs that emphasized grappling with specific technical areas. A more broadly based objective was to encourage international cooperation in advanced energy R&D in general.

United States domestic objectives are to accelerate industrial exploration of our geothermal resources by reducing uncertainties in the available information on the resource, technology, and its environmental impacts. In the Geothermal Pilot Study, the United States hoped to gain from the experiences and technical "know-how" of countries more advanced in the use of geothermal energy. The United States had been lagging behind Italy particularly in the development of geothermal resources. While the United States had gone further than other countries in certain technologies relating to the development of geothermal energy, actual production experience and information had to be sought elsewhere. The only domestic production experience was with the

*The third project was subdivided into Reservoir Engineering and Geothermal Fluid Injection, and these were later incorporated into one substudy area, Reservoir Assessment.

Geysers, which had been operating for only seven years. Italy, on the other hand, had over 60 years of on-line production experience and data from their Larderello facilities, which closely resembles Geysers. In addition, the United States had only limited experience in the diverse applications of geothermal energy. The Geysers utilize dry steam, which comprises only a tiny fraction of our total geothermal resources; hot dry rock and liquid dominated resources are far more abundant. An effective international program providing exchanges of experience and technical and resource data with other countries was seen as substantially reducing R&D costs as well as expediting the development of a domestic geothermal industry.

The countries involved in the CCMS were comprised primarily of NATO member countries. Fourteen countries adopted the program proposals set forth in the 1973 organizational meeting. These countries were Canada, the Federal Republic of Germany, France, Greece, Iceland, Italy, Luxembourg, Mexico, Netherlands, the Philippines, Portugal, Turkey, the United Kingdom, and the United States. In addition, other countries, not officially part of the CCMS Pilot Study, participated as observers or contributors in the substudy activities.

The Computer-Based Information Systems Substudy was initiated at the New Zealand Conference. It consisted of a one-year test of information exchange between computer centers located in the United States and Italy, and led to the bilateral agreement between Italy and the United States (discussed below) under which the activities were continued. The objective of this substudy program was to collect, evaluate, and disseminate the voluminous but scattered data being generated in diverse activities in geothermal resource assessment, well drilling, plant construction and maintenance, and analyses

of environmental impact. Management of the Computer Based Information System was conducted by Alan Clark of the U.S. Geological Survey (USGS), Sidney Phillips of Lawrence Berkeley Laboratory (LBL), James Swanson of USGS, and E. Stefenelli of Centro Nazionale Universiterio di Calcolo Electronico (CNUCE), Italy.

The data centers involved in the program were 1) Centro Nazionale Universiterio di Calcolo Electronico, University of Pisa, Pisa, Italy; 2) the National Geothermal Information Resource (GRID), Lawrence Berkeley Laboratory, Berkeley, California; and 3) GEOTHERM, United States Geological Survey, Reston, Virginia (now in Menlo Park, California).

The specific task objectives for this one year trial study included

- the collection of bibliographic data on factors of geothermal energy and development, including 1) subsidence, 2) hydrogen sulfide, 3) geothermal resources, and 4) direct (nonelectric) applications.
- the acquisition of numerical data on geothermal field/area, chemical analysis, geothermal well/drill hole.
- developing formats based on international accepted standards by CNUCE, GEOTHERM, and GRID.
- transmittal of computer tapes and other data files by diplomatic pouch.

The results of the trial study included

- development of a format for recording bibliographic information based on the International Nuclear Information System (INIS) descriptive cataloging procedures, indexing rules, and authority listings.
- development of formats for site-dependent numerical data for fields drill holes, and chemical analysis.
- a pilot bibliographic file by GRID and a pilot numerical file by GEOTHERM.
- establishment of a mechanism for tape exchange between the United States and Italy via diplomatic pouch.
- identification of problem areas involving the exchange of geothermal energy data on an international basis between the three data centers (CNUCE, GRID, GEOTHERM).

Direct Applications of Geothermal Energy Substudy members undertook an exploration of the economic feasibility and technical alternatives of using low- to moderate-temperature geothermal resources in space heating and cooling, industrial processes, and for agriculture.

Management of the Direct Applications of Geothermal Energy was conducted by John Howard of Lawrence Livermore Laboratories (U.S.) and Paul Singier, Delegation Generale a la Recherche Scientifique (DGRST), France.

This substudy was in two phases. The first phase involved the preparation of a summary report on the status of direct (nonelectric) uses of geothermal energy around the world. The second phase was initiated by a workshop on space heating in 1976 sponsored by France, which was concerned with an analysis of the value of geothermal energy for district heating and cooling. The substudy was concluded in a workshop in Washington, D.C. in which the economics of direct uses of geothermal energy were analyzed.

During the write-up of the first phase it became evident that the primary obstacles to the direct uses of geothermal energy are not technical "know-how" per se, but rather uncertainties concerning institutional barriers and the economics of its application relative to alternative energies (e.g., fossil fuels). In the second phase France, Iceland, and the United States exchanged data for a cooperative analysis of the value of geothermal energy for district heating and cooling. Using information obtained from France and Iceland, the United States developed and tested a computer simulation model for including the economics of geothermal district heating applications. Simulations were done on French, Icelandic, and German data. In each simulation the analyses were fairly specific to the respective case and of no direct relevance to the United States.

The Reservoir Assessment Substudy was initiated at the first International Geothermal Implementation Conference at Wairakei, New Zealand (1973) in which the objective was to identify problems of common interest for international cooperative efforts. Reservoir engineering and geothermal fluid injection were identified as useful areas for cooperative investigation in this substudy.

The manager conducting geothermal fluid injection was Ken Fulcher of the U.S. Bureau of Reclamation. Paul Kruger of Stanford University, Paul Witherspoon of LBL, and Leland Mink of the U.S. Department of Energy were co-managers of the reservoir engineering phase of the Reservoir Assessment Substudy.

Three workshops on the state of fluid injection technology were sponsored by New Zealand and the U.S. Bureau of Reclamation at Wairakei, New Zealand (1974), El Centro, California (1975), and Taupo, New Zealand (1976). At the first workshop, participants drafted an informal agreement to exchange information between the two countries. At the following two workshops, experts from El Salvador, Mexico, France, and the Philippines joined those from the United States and New Zealand.

The workshops involved exchanges of data, meetings with technical and scientific personnel at geothermal installations, and review and development of injection programs. Activities in reservoir engineering under the substudy were helpful in establishing the bilateral agreement between Mexico and the United States (discussed below) for cooperative investigation of the Cerro Prieto fields.

The Small Geothermal Power Plants Substudy was initiated by the Group of International Experts at the CCMS Geothermal Pilot Study Planning Meeting in October 1973. It was concluded that cooperative investigation of small geothermal power plants (in the 0.5-3.5 megawatt range) would be a fruitful undertaking. It was felt that smaller power plants requiring smaller capital

commitments and less lead time to implement would allow for the cost-effective production of electricity in sparsely populated areas.

Management for the Small Geothermal Power Plants Substudy was conducted by Anders Lindberg of LLL. The substudy was co-chaired by the United States and Portugal. Other countries expressing an interest in the program were France, Iceland, Italy, Mexico, New Zealand, and Turkey.

This substudy was in two phases. Phase 1 involved two international conferences in 1975 at Berkeley, California and the Azores, Portugal, where a system concept for a 5 MWe power plant was reviewed. In Phase 2, Rogers Engineering Company, Inc. (USA) in cooperation with a committee of experts from Italy, Japan, New Zealand, Turkey, and the United States prepared a set of guidelines to assist in the design, procurement, and construction of a small geothermal power plant.

The Hot Dry Rocks Concepts Substudy was initiated by J. C. Bresee, then of the U.S. Atomic Energy Commission (AEC), and by M. C. Smith of the Los Alamos Scientific Laboratory (LASL).

The objectives of the Hot Dry Rock were first to stimulate international interest in hot dry rock; second, to stimulate cooperative efforts to make the most effective use of the limited pool of experts; and finally, to disseminate information on the U.S. Hot Dry Rock Program for use in foreign programs to help minimize duplication of efforts in the field. Since hot dry rock is the most abundant and universally distributed geothermal resource, it is of great interest for domestic development, especially in the eastern United States. By bringing together international expertise on the subject, it was hoped that complementary foreign programs in the exploitation of this vast potential resource might expedite our own efforts.

The first meeting of the Hot Dry Rock Substudy was held at LASL on September 17-19, 1974. It was attended by representatives of Canada, the Federal Republic of Germany, France, Italy, New Zealand, Nicaragua, Sweden, Turkey, and the United States. The second meeting of the Hot Dry Rock Substudy took place at LASL on June 28-30, 1977 and was attended by representatives of the Federal Republic of Germany, France, Indonesia, Italy, Sweden, Switzerland, the United Kingdom, and the United States. Both meetings were attended by representatives from U.S. federal and state departments and agencies, national and independent laboratories, universities, and industrial organizations. At the second meeting, reports were presented on various U.S. and foreign activities and interests in hot dry rock utilization and research.

The primary accomplishments of the NATU-CCMS Hot Dry Rock Substudy was a heightened international interest in the subject. Among other things, the Hot Dry Rock Substudy helped lay the groundwork for the IEA Programs on Man-Made Geothermal Energy Systems (MAGES) (discussed below).

International Energy Agency

The International Energy Agency (IEA) was established in November 1974 under the aegis of the Organization for Economic Cooperation and Development (OECD). Nineteen of the twenty-four member countries of the OECD participated in the IEA, with the Commission of European Community taking part by special arrangement. The IEA member countries are Austria, Belgium, Canada, Denmark, the Federal Republic of Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

The IEA was established as the implementing body of International Energy Program (IEP), which was adopted by the participating countries on November 18,

1974. The objectives of the IEP are: 1) to take measures to meet oil supply emergencies, 2) to reduce dependence on imported oil by undertaking long-term cooperative efforts on conservation of energy, on accelerated development and demonstration in the energy field, 3) to promote cooperative relations with oil-producing countries and other oil-consuming countries including those of the developing world through purposeful dialogue.

As part of IEA's long-term cooperation program, the participating countries have agreed to pursue national programs in energy research and development. Further, the participating countries are urged to undertake cooperative efforts in energy research, demonstration, and development on specific task-sharing or jointly financed programs and projects. The stated long-term goal in October 1977 was for the 19 participating countries to achieve a collective demand not to exceed 26 million barrels of oil by 1985. (This date was later pushed up to 1990.)

The subject areas that have been agreed upon by the participating countries are as follows:

- Conventional Energy Systems

- ° Energy Conservation Technology
- ° Coal Technology
- ° Nuclear Power Safety
 - Radioactive Waste
 - High-Temperature Reactors for Process Heat

- Nonconventional Energy Systems

- ° Geothermal Energy
- ° Solar Energy
 - Heating and Cooling of Buildings
 - Electric Power Generation
- ° Biomass Conversion
- ° Ocean Thermal Energy Conversion
- ° Wind Power
- ° Fusion Power
- ° Hydrogen Production
- ° Wave Power

Depending on the interest, needs, and/or expertise, IEA member countries select the subject areas in which they will participate. The country or countries involved in a given subject area comprise a group that is chaired by a country or international organization with a particular program interest in the areas concerned. Any two or more countries may elect to participate in a given project, which then becomes subject to contractually binding agreements that specify respective contributions, obligations, and rights.

Financial support of the project is the responsibility of the participants rather than that of a central IEA fund. The majority of the projects are task-sharing, in which each participant bears the cost of his particular task. Another common approach is the jointly funded project, whereby all project members contribute to a common fund administered by one of the participants as the "Operating Agent."

Italy is the lead country for the Working Party on Geothermal Energy. Other participating countries are Austria, Canada, Federal Republic of Germany, Japan, the Netherlands, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. The Working Party on Geothermal Energy was initiated on November 21, 1975.

The geothermal group is investigating possibilities for cooperation in the further development of geothermal resources. Four panels have been formed; they include studies on

- Low-Enthalpy Geothermal Sources for Nonelectric Applications
- High-Enthalpy Geothermal Sources for Small Electric Power Plants
- Man-Made Geothermal Energy Systems
- Geophysical Exploration Techniques.

The panel on low-enthalpy geothermal sources for nonelectric uses includes representatives from the Federal Republic of Germany, Italy, Switzerland, the United Kingdom, and the United States. On April 30, 1976 these representatives agreed to design, construct, and test direct heat exchangers for nonelectric applications. The suggested site was the Vienna suburb of Aspern where there is a 100°C geothermal reservoir of high salt content. At the second meeting of the Geothermal Working Group, June 3-4, 1976, Eric Willis noted that the United States had made substantial headway on direct contact and other advanced heat exchangers, and that this information was available to all panel members.

The panel on high-enthalpy geothermal sources for small electric power plants has not yet determined its specific research program. The CCMS report, "Modular 5 MW Geothermal Power Plant: Design Considerations and Guidelines," was evaluated by the panel members. At the June 3 meeting, Mitsubishi Heavy Industries offered a 3 MWe geothermal turbine generator or an alternative to a 5 MWe generator, but apparently this power plant will require more design development before it will meet IEA requirements. The Japanese have sent panel members a report entitled "5 MWe Geothermal Power Plant Design and Consideration" to help them determine whether there is need for intergovernmental R&D.

The panel on geophysical exploration techniques has not gone much further than to ascertain that the United States and Italy would co-chair the panel.

The only really active project of the Geothermal Group is the Program of Research and Development of Man-Made Geothermal Energy Systems (MAGES). MAGES, reportedly, was a direct outgrowth of the Hot Dry Rock Substudy of the NATO-CCMS Geothermal Pilot Study.

The Federal Republic of Germany became the lead country (i.e., the Operating Agent) providing the majority of technical staff for the MAGES project. The project is a five-party agreement with equal dollar contributions from each of the members (the United States, the Federal Republic of Germany, Sweden, Switzerland, and the United Kingdom). In its organizational phase, contributions were the equivalent of \$600,000, but this figure has since increased.

The first meeting of the Steering Committee for MAGES took place in February 1976 with Rudolph Black as U.S. representative. At the meeting, talks involved organizational and directional aspects of the project as well as discussion about MAGES doing field experiments in Europe, probably Germany.

Under the MAGES agreement, Hot Dry Rock Systems will be explored in different rock structures than have been explored in the LASL program. MAGES is intended to explore alternate ways of hot rock utilization where the rock media has negligible natural permeability and reservoir fluid, but where permeability can be induced to permit the passage of heat transfer fluid in sufficient volume to constitute an economic heat source.

Italy, despite its interest in hot rock, is not a participant in MAGES. It may be that the Italians feel that the Germans, as the Operating Agent, have little to offer in hot rock utilization to make it worth their while. The Italians seem to have a general aversity to working in multilateral programs; perhaps this is because they wish to guard technologies they offer for sale in the world market. Whereas the U.S. official position is to favor multilateral as opposed to bilateral cooperation in energy development, the Italians have shown a definite bias toward the latter. It also may be that Germany would prefer a bilateral arrangement with the United States in hot dry rock research. Germany is currently negotiating with

the United States for a bilateral agreement in which Germany will provide both technical and financial support for LASL's hot rock program. (This possibility is discussed below.)

Some activity also has been generated under IEA auspices with regard to U.S.-developed geothermal technologies. Recently, representatives from Italy, Turkey, the United Kingdom and New Zealand came to DGE to consider testing the U.S. advanced heat exchanger and helical screw expander. DGE hopes for an agreement to test these experimental devices in some of the European geothermal fields.

U.S.-Italy (ENEL/CNR) Bilateral Agreement

The International Geothermal Information Exchange Program (IGIEP) was begun at the first geothermal implementation conference held in New Zealand in 1974. The objective of the IGIEP was to provide for the exchange and dissemination of worldwide data on geothermal resources. Much information on geothermal resources development is widely scattered, difficult to access, and largely unevaluated. A computerized geothermal data base could provide rapid and economical means for the collection and dissemination of data on a worldwide basis. Access to such a comprehensive and detailed geothermal data bank could allow for an efficient exchange of geothermal technological information and could supply data needed for developing a comprehensive understanding of geothermal phenomena.

Initial work done under the IGIEP was the effort made by the Computer-Based Information System Substudy of the NATO Committee on the Challenges of Modern Society Geothermal Pilot Study. The substudy project was a one-year study of two linked regional centers. During the course of the study, it was hoped to develop common formats and methods for the exchange in

dissemination of geothermal data and information. Information generated in one center would be transmitted to the other, so that each center would have a complete data file of all available information. In the course of the substudy, locations for the two regional data centers were chosen to be Italy and the United States.

These initial activities led to the signing of a bilateral agreement between the Energy Research and Development Administration and Consiglio Nazionale delle Ricerche (CNR), and with Ente Nazionale per l'Energia Elettrica (ENEL) in May 1976. Under this agreement each country agreed to exchange and maintain a computerized file containing bibliographic and numerical data on geothermal wells and fields throughout the world. The U.S. Department of Energy (successor to ERDA) is to be responsible for collecting data from the Americas, Oceania, Iceland, and Asia (except for the Soviet Union) and CNR/ENEL is responsible for information for Europe (except for Iceland), Africa, and the Soviet Union. Each country (the United States and Italy) is expected to work out its own formal or informal relations with those countries from which each is collecting data. To date, Italy has reported that negotiations for the collection of data with Sweden, Denmark, France, Hungary, Greece, and the USSR are proceeding, while the United States has reported that contacts have been established with Bolivia, Canada, Costa Rica, Guatemala, Mexico, and the United Nations. Because the agreement grew out of the NATO-CCMS, there is the expectation that it will ultimately become a multilateral activity absorbed by the International Energy Agency.

In the United States the program is administered under the Industrial Relations Section of the Division of Geothermal Energy. Henry Rosenthal is the responsible officer.

Central to the agreement is the Department of Energy Geothermal Information Center (GRID). GRID, established at the Lawrence Berkeley Laboratory, was coordinated with the IGIEP program; and during the year the study was under CCMS sponsorship, the main effort was the development of input and output formats for the storage and retrieval of bibliographic references (including abstracts, key terms, and annotations). GRID interfaces with the Department of Energy Technical Information Center at Oak Ridge (TIC) for bibliographic data and with GEOTHERM (the U.S. Geological Survey Properties File containing numeric and descriptive data on various aspects of geothermal energy and presently operating at the USGS facilities in Menlo Park, California) for numerical data. GRID is also intended to have access to some specialized university geothermal banks. On the Italian side, information is to be processed at the computer center at the Centro Nazionale Universitario di Calcolo Elettronico (CNUCE) at the University of Pisa. Pisa is a general center for informatics, being the location of CNUCE, Istituto per l'Elaborazione dell'Informazione, the Clinical Physiology Laboratory of CNR, and other related research institutions.

Information exchange is meant to take place under the agreement every four months. Continuing problems in working out agreeable computer formats information exchanged has limited the development of the data base. In July 1976 the United States sent the Italians computer tapes containing geothermal bibliographic data from TIC and a file of hydrogen sulfide data extracted from a survey of current literature. For some time there was no information coming back from Italy; part of the problem was believed to be that the Italians were confused by which format to use, the one developed

by Lawrence Berkeley Laboratories or the TIC format. The TIC format was ultimately selected for the information exchange under the terms of the agreement. In December 1977, the Italians sent to the United States information in the TIC format. This information is now at Oak Ridge, but there are still problems in interpretation, and it has not yet found its way into the GRID program. The information sent by the Italians consists of all of the articles in GEOTHERMICS. Discussions are continuing in an attempt to straighten out what now appears to be relatively minor computer formulating problems. Information exchange via diplomatic pouch apparently has not yet been taken advantage of, and lengthy delays in communication have occurred simply because of the time required by conventional mailing.

A second transmission to Italy took place in June 1977, consisting of numerical data on geothermal fluid taken from the existing literature. This file covered many U.S. fields, as well as the Cerro Prieto field, and included information on the owner of the field, the type of well, a number of physical characteristics, and a chemical analysis of the fluid.

The agreement calls for the exchanging of existing bibliographic files and for continuing exchange of augmented files between each country. As of a year ago, however, the Italians did not plan on sending anything except what is in their journals, while the United States planned on sending out a bibliography of all that appears in the TIC collection. At a meeting in July 1977, this imbalance was corrected by the Italians agreeing to look at other reports in their possession and not limit themselves just to what was in their journals. The Division of Geothermal Energy also has been encouraging private U.S. oil and gas companies to exchange

geothermal information, pointing that this will be to their common interest, and hoping in this way that such information would find its way into GRID.

There is as yet no mechanism to judge the effectiveness of the exchange. There is no information on how many U.S. requests have been made for GRID information, or whether the Italians are making use of the U.S. data. While contacts have been made with a number of countries (as referred to above), no other countries except the United States and Italy are involved at this time in direct support of the information exchange agreement. The GRID program is fully supported by the Department of Energy. The budget for the bilateral exchange itself, however, is not a specific line item. Annual costs for the exchange are estimated for fiscal 1978 and 1979 to be about \$40,000.

U.S.-Italy (ENEL) Bilateral Agreement

This bilateral agreement for coordination in the field of geothermal energy research and development grew out of the activities of Paul Kruger of the National Science Foundation, who saw an opportunity for the United States in making available the Italian long-standing geothermal experience. Discussions were carried on by Eric Willis of ERDA, and the agreement was signed in June 1975. Coordinators for the project were Eric Willis (later succeeded by James Bresee) for ERDA, and Professor T. Leardini for ENEL.

Under the agreement ERDA and ENEL were to pursue an intensive program of cooperation for research, development, and demonstration of applications of geothermal energy in the following areas:

1. Stimulation of hot dry rock and hydrothermal reservoirs
2. Utilization of hot brine resources
3. Reservoir physics and engineering

4. Deep drilling
5. Environmental control technology
6. Other related fields of mutual interest that might be agreed upon.

Major cooperation under the agreement was to be for the development of technology for both electric power applications as well as for the development of improved equipment and techniques for assessing geothermal resources.

Cooperation under the agreement was stated to take the following forms:

1. Exchange of information on scientific and technical development
2. Meetings to discuss and exchange information
3. Visits and exchanges of scientists, technicians, and other experts
4. Exchange of project and experimental plans for review and comment
5. Exchange of important technical reports on geothermal energy
6. Conduct of joint projects programs
7. Joint funding of cooperative projects for the agreed upon purposes under the agreement.

It was further stated under the agreement that the overall contributions to and benefits from the cooperation will be approximately balanced between the two parties.

The principal motivation for the United States to enter into the agreement was to use the Italian experience with vapor-dominated fields as a basis for testing U.S. technology and analytic models. The Larderello fields have been exploited for the purpose of generating electricity since the entrance into service in 1913 of the first power station with a capacity of 250 kw. Reasonably good documentation for these geothermal

fields goes back over two decades. The comparable field in the United States, the Geysers, has been used for generating electricity only since 1968. A further problem with information from the Geysers appears to be that not all of the information is freely available, since the development is in private hands. The agreement with Italy was seen as providing the United States with a field laboratory for studying reservoir behavior and for obtaining insight into the potential environmental effects of noxious emissions (hydrogen sulfide and radon) on an exposed population. For their part, the Italians were interested in making available to them U.S. methods and technology.

Five projects were formally defined under the agreement and a program outlined for each was developed. Project 1, the stimulation of hot dry rock and hydrothermal resources, was signed in June 1976. Project leaders were Morton Smith of Los Alamos Scientific Laboratory, and Pietro Ceron of ENEL. While there has been a number of exchanges of information between the United States and Italians on the proposed work, little further progress on Project 1 has been made, possibly because of current uncertainties in the direction and scope of the LASL program.

Project 2, utilization of hot brines, does not yet have an agreed program. Possibilities of examining sites at the Niland Test Facility in the United States and at Cesano in Italy, both of which produce high-temperature, high-salinity brines, could result in a mutually beneficial cooperative program. Discussions of such a program have been carried out by G. Allegrini and Dr. R. Cataldi of ENEL and John Featherstone of DOE.

Project 3, reservoir definition, has been by far the most active of the five projects defined under the agreement. Project leaders for Project 3 are Paul Witherspoon of Lawrence Berkeley Laboratory and R. Cataldi for ENEL.

Agreement on Project 3 was signed in April 1976. Leland Mink of DGE is the Project Coordinator.

Eight subprojects have been defined for Project 3:

1. Methods of regional assessments of geothermal reservoirs
2. Assessment of geothermal potential of Central and Southern Tuscany
3. Analysis of reservoir pressure and decline curves in Serrazzano zone of Larderello
4. Well testing of Travale-Radicondoli geothermal field
5. Thermodynamic study of Bagnore Field
6. Study of effects of reinjection with a mathematical model
7. Modeling of vapor-dominated geothermal reservoirs
8. Workshop on geothermal reservoir assessment and reservoir engineering.

In general, the scope of Project 3 has been to select certain Italian reservoir experience in the Larderello fields for analysis and to test U.S. reservoir models with the Italian geothermal data. Both of the project leaders from the United States and Italy have been active in setting up the project work statements and following through on their implementation. Procedurally, under the terms of the bilateral agreement, each government approves project proposals and their funding; the Division of Geothermal Energy reviews all the proposed work for the United States. Last September an international meeting was held in Larderello. At this meeting, problems were reviewed related to well productivity and longevity, the two principal areas of investigation of Project 3. There also were some reports at this meeting on exploration methods, with particular emphasis on Italian-developed techniques. A project report as of December 1977 has been completed.

There has been no activity under Project 4, deep drilling. Italy wants the United States to share the cost of the deep hole project, but the Department of Energy is unable to spend large sums of money for this purpose overseas.

Project 5, dealing with environmental problems, was signed in May 1976. Under this project, two programs were established: the examination of the distribution of the hydrogen sulfide in the Larderello-Castelnuovo zone, and an examination of the radon distribution in test zones of the Larderello field. Project leaders for these two programs are Ronald Loose of DGE and G. C. Stefani of ENEL.

Studies under Project 5 are intended to give a baseline from which changes in environmental quality can be assessed. This work is expected to provide a framework for examining long-range, cause-and-effect relationships with respect to environmental impacts. The initial part of the study is to characterize the concentrations of hydrogen sulfide and radon in the ambient atmosphere at both Larderello and the Geysers. Succeeding stages of the study will develop a meteorological model to predict these concentrations. Using the model to backfit available historical data, correlations will be sought with past geographic concentrations and historical health records on cancer and respiratory diseases.

The programs under Project 5 were developed in an atmosphere of some confusion and pressure, due in part to the lack of coordination between the Italians arriving in the United States to negotiate the projects and the responsible U.S. participants, who were not made aware of the details of the agreement and who had insufficient time to prepare for the negotiations. Implementation of the program has been impeded further by difficulties in obtaining foreign travel permits under existing Department of Energy foreign

travel ceilings. The problem of sending U.S. experts to Italy to work on the programs (thus far only two people have gone to Italy to work on the environmental project in a period of two years) has made it difficult for the United States to hold up its share of the agreements made on Project 5 with the Italians.

The international meeting on Project 3 held in September was a recognition of the desire to share the information developed under the bilateral agreement. In the body of the agreement itself, there is a statement that because both parties to the agreement are also participants in the CCMS study and in the International Energy Agency, they will keep these organizations informed of progress of their cooperative R&D activities. Further, the statement in the agreement stipulates that upon the establishment of a working group in geothermal energy in IEA, the United States and Italy will strive to place their cooperative efforts under the auspices of the International Energy Agency. As yet, however, there has been no move for this to take place.

The U.S.-Mexico Bilateral Agreement

The U.S.-Mexico bilateral agreement grew out of initiatives taken by Paul Witherspoon of Lawrence Berkeley Laboratory in 1975 at the Second UN Symposium on the Development and Use of Geothermal Resources held in San Francisco. Conversations on cooperative research efforts between Dr. Witherspoon and Jorge Guize of the Commission Federal de Electricidad of Mexico, furthered by support from James Bresee of DGE, led to the signing of the treaty two years later. The CCMS geothermal pilot study provided the forum for the cooperative discussions between the United States (Lawrence Berkeley Laboratory, the U.S. Geological Survey, and the

Bureau of Reclamation) and Mexico during this two-year period. Discussions were held under the existence of the 1972 Science and Technology Treaty between the two countries.

One of the difficulties in formulating the agreement was the working out of a satisfactory resolution of the problems involving third-party liability. (Unlike the U.S.-ENEL treaty, the problem of liability is addressed in a separate article in the U.S.-Mexico bilateral agreement). The treaty was signed in July 1977. Leland Mink of DGE is the U.S. coordinator. The investigators under the terms of the agreement are Lawrence Berkeley Laboratories, U.S. Geologic Survey, and University of California at Riverside.

The treaty is a five-year agreement under which the United States and Mexican scientists and geologists agree to conduct an extensive survey of the Cerro Prieto geothermal fields. These cooperative studies are to be aimed at determining the most economical and productive methods to be used in further developing the reservoir. The Mexican field, which lies close to Imperial Valley, has a liquid-dominated system operating in a geothermal environment similar to that of the Imperial Valley. The data from several years of experience with a 75 MWe generator operating at the site is expected to be of great interest to the United States. Under the agreement, problems of subsidence, seismicity, and the development of reinjection techniques will be studied. It is hoped that the information developed under the bilateral agreement will stimulate industrial development in the Imperial Valley and guide government-industry joint projects there. For the United States, the agreement provides a field laboratory in which studies can be made of geothermal resource exploration, exploitation, and well performance.

For their part, the Mexicans are expected to benefit by gaining the use of U.S. technology. One of the areas where American method technology has already made an impact is in encouraging use of geothermal fluid reinjection in the Cerro Prieto field. This is a technique that is expected to be followed in the future developments of many U.S. geothermal fields. The Mexicans, however, had anxiety about tampering with geothermal fields through reinjection. Simulation studies by the U.S. scientists have impressed them, and it is probable now that they will go ahead with experiments in reinjection.

The Mexicans are interested in learning about U.S. geothermal instrumentation, and particularly in the availability of high-temperature measuring equipment that is being developed by Sandia Laboratories for use in the Cerro Prieto fields. In fact, the Mexicans are already purchasing some U.S. instruments as a result of being made aware of their capabilities by the activities of this agreement.

A principal benefit of the agreement has been the expeditious transfer of data from files stored in Mexico City (where the data was not in the most amenable form for analysis) to computer tapes. About two thirds of the historic data has been analyzed and published, and one third is yet to be gathered from Mexico City. Early data is spotty because of the unavailability of the high-temperature measurement equipment and the lack of data gathering in the beginning of the Cerro Prieto project in 1968. However, this early data will be of use in defining the original conditions of the well.

Under the terms of the agreement, joint projects are to be agreed upon by both sides. The projects have not been as formalized and detailed as those in the U.S.-ENEL agreement, nor are the cost-sharing arrangements as

spelled out as they are in the Italian agreement. In general, the Mexicans are expected to provide local labor and interpreters and, of course, the use of the fields. The estimated project costs to Lawrence Berkeley Laboratories and subcontractors for FY 1978 and 1979 are \$350,000.

The Mexicans are very eager for technology transfer to take place, and perhaps as a result there has been a certain awkwardness in procedural arrangements, because it is necessary to involve equivalent Mexican agency personnel to whatever U.S. people are engaged in work at the Cerro Prieto. The Mexicans appear to be sensitive to this protocol in their desire to have everyone who possibly can profit from the visits of U.S. scientists.

An international meeting for reporting the results of the U.S.-Mexican activities is scheduled for September 20-23, 1978 in San Diego. The proceedings for this meeting will be published.

The agreement continues through July 1982, after which the United States may seek assurance that there is a continuation of the transfer of data. After this time, there would be much less active DGE involvement in actual field work. Maintenance of the field data bank would be supported by the Department of Energy, as would the gathering of subsidence and reinjection data. But direct involvement of U.S. scientists in field exploration and exploitation under Department of Energy sponsorship may not be necessary. Rather, at this point it may be attractive for private industry and other nongovernmental people to participate in continuing Cerro Prieto work at points where conditions of mutual benefits between them and the Mexicans can be found.

U.S.-Iceland Bilateral Agreement

Agreement for an information exchange grew out of discussions between the Atomic Energy Commission and the Icelandic National Energy Authority. Initial emphasis was on exchanging information on utilization of energy from geothermal resources. Early discussions for the United States were carried on by Gerald Johnson, Director of the U.S. Atomic Energy Commission's Division of Applied Technology. The agreement was signed in November 1973 and then amended in 1974 to include cooperative projects.

The agreement may have been stimulated by the desire to have the U.S. military facilities at Keflavik use Iceland's plentiful supply of geothermal resources for space heating. While this may have provided an initial point of interest, there have been few activities under the agreement. Technical information on various aspects of resource experience and energy recovery were exchanged under the joint auspices of the bilateral agreement and CCMS Geothermal Pilot Study. Both the information exchange and the cooperative project agreement are presently inactive, though there has been some discussion of exchanging information on advanced heat exchangers.

U.S.-Japan Umbrella Agreement

A general agreement for cooperation in energy R&D was signed in July 1974 between the United States and Japan. This agreement included geothermal energy as one of the topical areas. Negotiations have been proceeding for a specific agreement on geothermal energy with the Japanese Agency of Industrial Science and Technology. A program to assist in the development of geothermal technology for power and direct applications as well as for studies on the environmental impact of siting and operating geothermal

power plants has been approved in principle. Questions concerning the handling of patents growing out of activities under the agreement have delayed the signing. These problems appear to have been worked out, and it is expected that the signing will proceed sometime during the late spring or early summer of 1978.

Coloring the negotiations is the fact that both countries are competitors for business from third parties in several areas of technology, including geothermal energy. The problem is to achieve a balance in benefits, in which the United States must recognize that at present Japan is ahead in the area of marketing geothermal technology. DOE has been concerned that a balanced exchange be achieved in terms of its implications for U. S. exports to third parties. This is felt to be important, particularly because the development of foreign markets can give stimulus to the development of domestic geothermal industry infrastructure.

One of the strong U.S. interests behind the agreement is access to information on the Japanese experience with reinjection. Further, the Japanese have expressed interest in the helical screw expander developed in the United States under the Division of Geothermal Energy sponsorship. Cooperative work is expected to be performed under the agreement using technical personnel of both countries under the direction of a joint steering panel.

U.S.-New Zealand Umbrella Agreement

A five-year agreement for scientific and technological cooperation relating to energy research was concluded between ERDA and New Zealand in 1974. Originally the National Science Foundation was involved in setting up the agreement; but when ERDA was formed, NSF indicated it would relinquish

its role as Executive Agent for energy matters to ERDA. In February 1976 ERDA confirmed the understanding that its Office of International Affairs would serve as U.S. Executive Agent for all energy matters under the agreement.

Geothermal activities under the agreement have been hindered in the past by a lack of funds on both sides, and by the fact that New Zealand's interest in geothermal energy had diminished somewhat because of discoveries of plentiful supplies of natural gas. Recent proposed exchanges of visitors have not come to fruition largely because of an unavailability of funds in New Zealand for this purpose.

While there has been a limited exchange of technical information on the development and utilization of geothermal energy under the agreement, New Zealand industry has been experiencing difficulty obtaining information by means of DOE Geothermal Energy Information Requests.

U.S.-USSR Umbrella Agreement

On June 1974 the United States and USSR signed a general agreement for cooperation in the field of energy. The geothermal implementation agreement, which was to cover technology exchange, is presently inactive. While much of the Russian experience with geothermal energy has been in the form of direct heat, particularly for space heating and hothouses, the Russians are believed to have done some interesting work in developing hydrothermal power. However, the initial exchange of visits under the agreement (planned for 1974) failed to materialize due to the Soviets' refusal to allow U. S. scientists access to the Kamchatka Geothermal Power Plant, presumably for reasons of national security.

The United States continues to feel that a visit to the Soviet Union is technically justified, though there is some question as to the fruitfulness of a site visit to Kamchatka without assurances that there would be access to operating records and personnel. In March of this year, a letter was sent by Eric Willis, Acting Deputy Assistant Secretary of DOE, to I. T. Aladyev of the Krizhanovskiy Power Engineering Institute in Moscow advising him that the protocol of the Second US-USSR Joint Committee on cooperation in the field of energy recommends that the Geothermal Energy Joint Coordinating Committee identify possible areas for cooperation, and that if no clear area were identified, the Joint Committee officially terminate the geothermal project. The letter emphasizes the U.S. desire to send a delegation of geothermal experts to the Soviet Union, where they can become better acquainted with Soviet work and facilities, in order to comply with the directives of the Joint Committee.

U.S.-Federal Republic of Germany Bilateral Cooperative Program

The Federal Republic of Germany has exhibited particular interest in the application of hot rock technology largely as a result of becoming well informed about the Los Alamos hot dry rock program through participation in CCMS. Germany feels it can learn a great deal from the Los Alamos program, eventually leading to possible commercial application of U.S. techniques. The Federal Ministry of Research and Technology has proposed contributing to the financial support of the work being done at LASL to help assure continuation of the hot dry rock experiments.

The Ministry originally suggested that the joint project be executed under the auspices of IEA. A bilateral agreement is now in the process of

being worked out under which Germany would provide 20 percent (up to \$1 million a year) of what Los Alamos spends on its hot rock program. Under this agreement German scientists would participate at the working level in all aspects of the LASL program, gaining experience in hot rock technology they can apply to the West German hot dry rock program.

The agreement was expected to be in effect by July 1978 and to run through 1980. There is a desire on the part of the U.S. Department of State to make the arrangements at the LASL hot rock program multilateral rather than bilateral. The Germans, however, fear that if participation were open to more countries, the total effort in the LASL program would be dissipated.

The German expression of interest in the LASL dry hot rock program has given support to belief in the commercial applicability of the program. Reevaluation of the direction and the scope of the hot rock work at LASL has had some effect on delaying the agreement, and as yet the full terms and conditions have not been negotiated.

International Energy Development Program (IEDP) for Less-Developed Countries

IEDP was created to support President Carter's desire to provide non-nuclear technical assistance to aid in the development of indigenous energy sources in lesser developed countries. The program calls for activities in two phases: 1) a study of the energy sources in the candidate LDC based on data available in the United States; and 2) depending upon the outcome of the results in Phase 1, sending to the LDC a team of U.S. experts who, working with experts from the host country, will complete an assessment of that country's total energy prospects. Candidate countries are selected by the

Department of State. Recommendation to proceed to Phase 2 is based upon a review of the work in Phase 1 by both the Department of State and the Department of Energy. Management responsibility for the assessment activities carried out in the IEDP is in the Department of Energy.

The program is intended to produce only an assessment of the potential for development of an LDC's indigenous energy sources. Upon conclusion of the study, the LDC may seek funding to develop specific projects. Such proposals for projects growing out of the study could be handled by the International Program Implementation Office of the Department of Energy. However, the country is not bound to seek further aid from the United States. Funds for projects may be requested under Title 5 of the Non-nuclear Proliferation Act from AID, from the World Bank, or from any available foreign sources. In general, the process carried out under IEDP of assessing the energy options in LDCs is intended to increase the interest of international financial institutions in supporting actual energy developments in the non-nuclear area.

Thus far, teams have been sent to only two countries, Egypt and Peru. (Phase 1 evaluation was done of Turkey, but Phase 2 was never entered into). The work for Phase 1 was done by Argonne National Laboratories, Brookhaven National Laboratories, and the United States Geodetic Survey. The teams formed for Phase 2 are now completing and examining the results of their studies in these two countries, and a report is expected to be submitted to the President in August of 1978. All non-nuclear energy potentials have been examined, including geothermal energy. The Division of Geothermal Energy and the USGS have provided the support for the IEDP assessment for geothermal resources, particularly in Peru, which has expressed interest in developing its geothermal resources.

The two current efforts under IEDP are aimed at demonstrating that the United States can assist lesser developed countries to develop a set of creditable energy strategies using a systematic analytical approach. The effectiveness of the program is to be assessed by the President upon the completion of the two studies.

Agency for International Development

The Agency for International Development (AID) has been involved in geothermal development in developing countries for over ten years. AID has worked in El Salvador, Nicaragua, Indonesia, the Philippines, and Kenya. Establishing an American presence in the Philippines probably contributed to the succeeding work now being done for the 110 Mw plant in the Tiwi area by the Union Oil Company.

Section 119 of the Renewable Energy Act gave AID \$18 million for FY 1978 to provide support for cooperative programs in rural LDC areas. While energy is not a primary area for AID (like food or health), there is congressional pressure for AID to get into energy assistance programs. AID, however, does not have the solar or geothermal expertise to do so effectively. Arrangements have been made for AID to provide funds to DOE for management and technical support for programs in LDCs primarily for solar development, although geothermal development also is included.

U.S. DOC Geothermal Applications Mission

A seminar mission was sponsored by the U.S. Department of Commerce to Mexico, Guatemala, and Costa Rica in November 1977. U.S. industry representatives included Geonomics, Inc.; Ben Holt Co.; Eliot Turbines; WKM; and

Turner, Collie, and Braden, Inc. The Division of Geothermal Energy representative was F. Gilman Blake. The mission was put together by Walter Bastian of the Bureau of International Commerce.

The format of the mission was to spend three days in each of the countries visited. During the first day, technical presentations were made by the Division of Geothermal Energy and Industry, and during the second two days individual appointments were made between host-country local interests and U.S. representatives. Some of the companies represented on the mission did make sales; WKM, which specializes in valves, found purchasers as a result of the mission activity.

Informal International Activities

Inga Paik of the Division of Geothermal Energy is working with people from Brown University and Rogers Engineering Corporation of San Francisco on an economic analysis of geothermal power plants abroad. The study will analyze the operations and economics of water-dominated geothermal power plants in El Salvadore, the Philippines, as well as in other countries from which information may be made available. The ultimate purpose of the study is to translate the economics of power production in these countries into cost components that can be related to U.S. costs. The task will be complicated by the widely differing criteria existing in each country for evaluating costs, but it is hoped that the results of such studies will provide relevant economic analyses for the operation of such plants in the United States. This program, initiated by Dr. Paik, is not under the auspices of any particular formal government-to-government agreement.

As part of her study of economic incentives useful for development of domestic geothermal energy, Dr. Paik has been examining the incentives used

by other countries to accelerate the geothermal development. Japan, where geothermal industry is in private hands, is of particular interest; the Pacific Northwest Laboratories are currently under contract to help her examine institutional and economic incentives in Japan. This study, which is just beginning, is independent of any formal arrangement with Japan.

3. INTERIM EVALUATION OF INTERNATIONAL AGREEMENTS AND ACTIVITIES IN GEOTHERMAL ENERGY

This chapter is concerned with the identification and relative importance of various objectives that have been associated with the formulation and evolution of international agreements and activities. Tentative conclusions concerning the practicality of these objectives, their internal consistency, the extent of their achievement, and barriers to their realization also are included.

Motivating Objectives

In developing a list of objectives that have prompted the formulation of international programs and in arranging these objectives in a hierarchy, we faced a number of problems that are indicative in themselves of the characteristics of international geothermal programs within DOE. First, we were confronted with agreements that reflect multiple objectives, with their relative importance unclear. Typically, various agencies or DOE divisions with different but not incompatible objectives have come together in support of particular programs. While such multiplicity does not characterize all agreements, it is increasingly the case as technology comes to be perceived as an important diplomatic instrument, as demands for transfer of technology between developing and developed countries increases, and as the U.N. Conference on Science and Technology for Development approaches. Thus, for example, in the LDC program it is difficult to separate objectives related to economic development of LDCs, nonproliferation of nuclear weapons, exchange of information, and promotion of the U.S. geothermal exports. The possibility that institutions for international programs are evolving from the discrete and technical toward more

diffuse and complex combinations of commercial, technical, and diplomatic objectives presents DGE with some important choices. These will be addressed in our subsequent research.

A related problem in identifying and ranking objectives is to distinguish between those that actually motivated the formulation of agreements and those that are conscious or unconscious rationalizations designed to justify the agreements within or outside the Department. The lack of a rigorous process within DGE for demonstrating the need and concrete benefits of proposed agreements complicates the task of making this distinction and is itself a problem that should be remedied. In addition, agreements that can be justified on the basis of multiple objectives are difficult to assign to a specific goal.

A third problem arises from the natural tendency to rationalize behavior, in this case international agreements, which may be the result of obscure, idiosyncratic forces. While demonstrable objectives (stimulate exports, exchange information, assist developing countries, etc.) may be given to justify the programs, certain exchanges may have originated as spontaneous, personal initiatives. The need to establish clearly the benefits to the United States is now seen as a strong factor for insuring the success of any international program.

Finally, there is the question of diversity among agreements, both in terms of the foreign partner (developed versus underdeveloped), the number of foreign partners (bilateral versus multilateral), and the extent of cooperation either achieved or envisioned (exchange of information, exchange of scientists and administrators, joint studies and explorations, etc.). This diversity is an important constraint on broad generalizations about the origins and evolution of international agreements.

Despite these problems, we have been able to discern certain priority objectives that have weighed heavily in the formulation of most of DGE's international programs and activities. We also have discerned certain trends in the relative importance of various objectives over time. These items are discussed in the following pages.

Exchange of Information and Improved Knowledge of Geothermal Energy

The simplest and most frequently suggested rationale for current international programs and activities is the exchange of information with countries having active geothermal programs. The U.S.-Mexican bilateral under which information has been exchanged on reservoir behavior in conditions similar to those at Imperial Valley; the ERDA-ENEL agreement, particularly the substudies on reservoir engineering and environmental impacts; the potential exchanges of information on hot rock programs among the United States and various European countries; the potential exchanges with Japan and New Zealand in the field of reinjection; studies of the economics of geothermal production in El Salvador, and of official government incentives to develop geothermal energy in various countries; and the CCMS program were all described as important for the general exchange of information, and motivated in part by this objective.

The particular need for the United States to seek information from foreign countries is attributed to two factors. The first is the fact that information on steam fields is held by private companies and treated as privileged data. Private firms in the United States are particularly protective of geothermal information while their leasing situation is being established. The situation with leasing is in fact unclear in virtually all of the present geothermal areas in the United States. A second factor is the relatively

greater degree of foreign experience with geothermal production. The ERDA-ENEL agreement, and to a certain extent the U.S.-Mexican agreement, are explained in terms of the availability of historic data on reservoir behavior and environmental impacts that would be valuable in developing a U.S. geothermal program.

Another theme was the barrier to geothermal commercialization in the United States posed by ignorance about the resource. Information on reservoir behavior in particular is crucial for industrial development. This could conceivably involve precommercial drilling by the government or cost-sharing of drilling with industry, with the resulting information distributed to actual and potential developers. International agreements for the exchange of information were explained in terms of improving our ability to predict reservoir behavior, thus enhancing the confidence of industry in developing the resource.

Closely related to the exchange of information is the possibility of using foreign geothermal sites as field laboratories for the testing of U.S. technology. The testing of U.S. high-temperature-resistant measuring equipment at Cerro Prieto is one example; another would be the IEA program under which the advanced heat exchanger and the helical screw expander may be tested in Europe.

Formalization of the exchanges has been guided by the need to establish patent agreements to facilitate exchange of proprietary data and to include liability clauses to permit site visits of foreign nationals. Further motives for making formal treaties lie in the fact that in most countries development of geothermal resources is a government activity.

Export Promotion

Another objective of secondary but growing importance is the desire to stimulate exports of U.S. geothermal technology and equipment by arranging for joint testing of U.S. technology, assisting LDCs in assessing their energy choices, and bringing the U.S. industry into direct contact with potential foreign buyers. Although commercial motivations were absent from some of the earlier international programs and activities, the more recent emphasis on commercialization of geothermal domestically has aroused interest in international agreements as potentially important marketing devices.

The notion that international activities should have as one of their objectives the promotion of U.S. exports rests on the conviction that U.S. geothermal exports can generate a growing U.S. industry in lieu of domestic sales. Exports, it is argued, can help to create an industry infrastructure, assist industry in gaining production and sales experience, and accelerate the innovation of new geothermal technologies. If we accept this contention, the U.S. government would appear to have a legitimate role in improving the access of the U.S. industry to world markets. This role could involve concessional export financing, trade shows, and, of course, formal bilateral and multilateral agreements.

In support of these commercial objectives, high estimates have been made for the future Central and South American geothermal market. The Italian government is believed to see Latin America as a \$10 million per year market presently and as a \$100 million per year market in a few years. The U.S. industry is described as presently on the fringes of this market, though lagging badly in South America, where Italy appears to enjoy a favored position. U.S. firms are described as not hardware/product oriented, concentrating primarily on exploration, consulting and management.

It is important to emphasize that these commercial objectives and the associated market estimates and analysis of present U.S. market position are not the primary attributes of current international programs, but are, in the opinion of some people at DOE, appropriate rationales for future programs. Virtually all agree that the commercial element in current international agreements is modest. One example is the recent agreement between the United States and a limited number of IEA countries to test the helical screw expander and an advanced heat exchanger and to share the test results. This particular program has potential commercial spin-off, both with respect to marketing this equipment in IEA countries and in penetrating South American and East European markets to which the IEA countries have access.

Another example is afforded by the LDC program, which, of course, is not a DGE initiative, but in which the Division participates. Although this program embodies a variety of objectives including economic development, non-proliferation of nuclear weapons, and improved diplomatic relationships with LDCs, commercial benefits for U.S. geothermal industry are possible, and in fact may present the Division with important opportunities for export promotion. Indeed, prior to the President's announcement of the International Energy Development Program, Dr. Seamans had proposed an LDC program to achieve, among other objectives, "commercialization of small-scale power systems by U.S. private industry for the mutual benefit of the United States and the developing countries."*

We should note that the LDC program as ultimately formulated and implemented in Egypt and Peru is not designed explicitly to promote U.S.

*W. Yen, Internal Memorandum, September 20, 1977.

exports or geothermal technology and equipment. The program, at least prior to the President's annual assessment, is designed primarily to assess non-nuclear energy options of LDCs through analysis of existing documentation. However, preliminary discussions of technical options for exploiting non-nuclear energy sources are contemplated and may contribute in the future to U.S. exports.

An interesting concomitant to the emphasis on commercial goals may be anxiety over transferring technology and strengthening the global market position of our principal competitors. This objection has been raised specifically with respect to the ERDA-ENEL agreement and the currently negotiated accord with Japan.

Improved diplomatic relationships. Diplomatic objectives, like export promotion, are secondary as motivations for existing international geothermal programs, but are increasingly prominent in international energy agreements and activities generally, and are likely to become important for international geothermal activities. Indications of this trend include the International Energy Development Program, which involves geothermal as well as other non-nuclear energy sources, and Section 119 of the recent foreign assistant legislation, which encourages U.S. assistance to LDCs in promoting the development of unconventional energy sources. Unlike the case of export promotion, however, pressure for consideration of diplomatic criteria in the formulation of programs comes from outside the Division, principally from the Department of State and the National Security Council. While DGE may sign on for commercial or technical reasons, the fact remains that the inception of LDC programs involving geothermal are based primarily upon diplomatic considerations.

Among the assortment of diplomatic goals that have been associated with international geothermal agreements, the following are most salient:

- Signal an intention to improve diplomatic ties. The signing of an international geothermal agreement may add luster to a summit conference and may symbolize a determination to improve diplomatic relations.
- Develop energy resources in non-OPEC countries. The development of geothermal energy can contribute modestly to total world energy supply and decrease dependence on dwindling supplies of petroleum. This objective is consistent with the broadening of DOE's mandate from the ERDA period and also with the Department of State's concern with the diplomatic consequences of global energy dependence on OPEC.
- Stimulate the economic development of LDCs. Geothermal development also may benefit those LDCs that are well endowed with geothermal resources, thereby contributing to a long-standing U.S. foreign policy objective--accelerating LDC development. Section 119 of the recent foreign assistance legislation reaffirms this commitment with particular emphasis on nonconventional energy sources.
- Nonproliferation of nuclear weapons. This objective, which has gained increased prominence since the Indian nuclear explosion, is a prime motivation for the IEDP. Assuming that the presidential assessment for the first year of this program is favorable, a major expansion is possible, thus making nonproliferation goals more important in international energy cooperative programs with LDCs.

We have observed that the majority of current international programs cannot be explained primarily in terms of diplomatic considerations, although the interaction between diplomacy and technical goals is complex. For example, the International Energy Agency itself represents a U.S. diplomatic initiative designed to bring coherence to developed-country responses to the OPEC cartel, and simultaneously to exercise greater U.S. leadership over international energy developments. The formation of CCMS within NATO also can be viewed as an effort to improve the U.S. diplomatic posture, in this case by infusing NATO with a presumably more durable, nonstrategic rationale. On the other hand, geothermal programs within both of these organizations have not been especially important diplomatically and, questions of their technical merit aside, appear to have been initiated primarily for reasons of information exchange.

Although technical considerations remain ascendant in the present array of international geothermal programs, there are some important trends in this area that have emerged from our interviews and that command the Division's attention. Although these trends will be pursued in greater depth in our subsequent research, they deserve to be described briefly at this point:

- There is a trend toward the introduction of broader diplomatic objectives into the formulation of international energy agreements. The growing appreciation of U.S. technology as an important diplomatic instrument and growing LDC demands for a transfer of technology between North and South have served to broaden formally technical criteria for the development of international programs. This will afford the Division with increased opportunities for justifying international agreements and activities with LDCs, but raises questions as to the technical benefit of such programs to the U.S. geothermal effort, and considerably complicates the achievement and/or measurement of reciprocity in such programs. Although there are, of course, potential commercial benefits inherent in LDC programs, as noted above these programs have not been designed to maximize commercial advantages.
- As a result of this trend, the interagency process that unfolds with respect to international energy agreements generally has become much more complex. The increased prominence of nontechnical criteria has introduced State, AID, and the NSC into the process of formulating agreements with a geothermal content. To the extent that such LDC programs expand, the Division will be faced with a set of more complicated and controversial interagency issues.

The LDC program does not provide the only illustration of this trend toward the politicization of international energy programs. The President's trip to Venezuela, Brazil, and India, during which international energy exchanges were discussed, provides another example. The Vice President's trip to the Philippines, which generated increased interest in U.S. cooperation with the Philippines in geothermal, affords another. The LDC program itself has been described in these terms within the Division as

an instance where ERDA's technical divisions are requested to develop international cooperative programs in support

of diplomatic and economic assistance objectives. The preliminary task of DGE's staff is to assist in the definition of a program for geothermal and hydropower that gives effective support to the nontechnical objectives, which at the same time maximizes the benefit (or minimizes the cost) to the domestic programs.*

Evaluation of Objectives

As noted previously, this evaluation is tentative, and somewhat impressionistic. Interviews with the industry and the research and development community will serve to strengthen or contradict our initial impressions and should add to the range of conclusions on the practicality of objectives, their internal consistency, and levels of achievement.

Concerning the practicality of the objectives discussed above, there does not appear to be any reason conceptually that information exchange cannot be pursued effectively through international programs, particularly with governments that are traditionally protective of their data. Formal international agreements can serve to legitimize the exchange of information and increase U.S. government leverage in obtaining necessary foreign information. There have indeed been useful interactions and exchanges under the U.S.-Mexican and the U.S.-Italy agreements, although it is too early to reach conclusions concerning the ultimate utility of any of these agreements.

We do not believe that the conceptual feasibility of export promotion through international exchanges is as convincing. Despite frequent enunciation of commercial goals as important for current and particularly future agreements, it does not appear that the potential size of foreign markets for U.S. geothermal technology and equipment were motivating factors in the

*W. Yen, Internal memorandum, September 20, 1977.

formulation of existing programs. Nor have we been able to locate the type of marketing or technical studies that would be necessary to formulate rational international programs based upon export-related objectives. Furthermore, it is far from obvious to us that government agreements of the type within the Division's purview would be effective instruments for foreign market penetration. The barriers to such penetration are numerous and include the structure of the U.S. industry, its lack of export consciousness, limited LDC financial capabilities, and foreign competition, particularly from Italy and Japan. It is questionable whether international agreements are capable of reducing these barriers. International arrangements that provided a package of technical assistance, information exchange, resource assessment, and concessional export financing would be more effective in this regard, but such programs for geothermal energy currently do not exist. — ?

Concerning the degree of compatibility among these various objectives, some interesting potential contradictions emerged during our study, and we believe these will become increasingly apparent as the number of government agencies with interest in these programs expands and as the range of objectives being sought through international agreements broadens to include diplomatic and developmental goals. These existing or potential contradictions include the following:

- Information exchange with developed countries versus increased U.S. exports to LDCs. The possibility was raised on a few occasions that exchanging information with the U.S. chief commercial competitors, particularly the Italians and the Japanese, would transfer technology to these countries and strengthen their market position with developing countries. Were export promotion to become the prime objective in geothermal international programs, a reevaluation of exchanges with our principal competitors would seem to be warranted. ←
- Technology exchange versus exports. Even if we assume that exchanges with other developed countries will not compromise

the U.S. competitive position in developing country markets, the fact remains that there is a lack of congruence between countries with which the United States has technical exchange programs and countries where foreign markets for U.S. geothermal technology are located. In effect, the present structure of international agreements has not been synchronized with commercial objectives, although, of course, these programs may be justified on other grounds.

- Nonproliferation of nuclear weapons versus development assistance to LDCs. Although both these objectives have been mentioned as of increasing importance in international energy programs, they are incompatible to the extent that LDCs capable of producing nuclear weapons are probably less needful of development assistance, particularly the type emphasized by the problem surrounding the recent Foreign Assistance Act, and the question as to whether AID funds can be applied towards geothermal programs in those countries that may go nuclear. This suggests that the IEDP may be a more effective vehicle for DGE than the AID legislation in expanding cooperation with LDCs, since those countries that can be justified under the nonproliferation objectives of the LDC program, in most cases, also are those with the largest potential geothermal markets.

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still so, but should consider future

It is too early in this research, and probably too early in the evolution of these programs, to reach definitive conclusions on the extent to which these various objectives have been achieved. Our impressions, which are purely a function of comments by our interview respondents, are as follows:

- There is a general consensus that the U.S.-Mexican agreement is sound in concept, and has produced some very useful information on initial reservoir conditions at Cerro Prieto and which can be applied to conditions at The Imperial Valley. On the other hand, much of the earliest historical data is of dubious quality because of the lack of high-temperature-resistant equipment for measuring reservoir conditions.
- A number of the projects in the ERDA-ENEL agreement have run into problems, with the environmental assessment study in particular being frustrated by a lack of travel funds; the hot dry rock stimulation program delayed because of uncertainties concerning the LASL program; the project on utilization of hot brines inactive because of a lack of U.S. interest; and the project on deep well drilling unlikely to develop because the United States cannot finance

overseas drilling programs. On the other hand, Project 3 on reservoir definition has evidently contributed to improved U.S. understanding of reservoir behavior and important refinements in our predictive models.

- The information exchange agreement with ENEL and CNR has facilitated the exchange of information, primarily from the United States to Italy, but the effective translation and utilization of the Italian data is still impeded by computer formatting problems.
- The information exchange agreement with Iceland, and the geothermal exchange program with the Soviets under the Energy-R&D Agreement, are dormant.
- The CCMS activity is winding down, but has been valuable in making the U.S. government and the R&D community aware of geothermal development in other countries, publicizing growing U.S. activities, and clarifying the nature of specific bilateral symmetries of interest that contributed to the ERDA-ENEL and the U.S.-Mexico agreements.
- The IEA activity, which apparently is now the Department of State's favored instrument for international cooperation in geothermal and other energy sources, has not progressed to the point that a meaningful evaluation is possible.
- Programmatic benefits may be relatively less for multilateral arrangements than they are for bilateral arrangements. The Italian decision not to participate in the IEA hot rock project may stem from their greater emphasis on programmatic benefits rather than on indirect (e.g., political/diplomatic) benefits. Multilateral programs, by involving a greater number of people, may create committee inertia and as a result add only marginal experience/knowledge to the existing pool.
- At the conclusion of the Phase II study in Peru, an examination will be made by the President to determine whether IEDP should continue, and in what form. The problems encountered in Turkey are not auspicious; but the Peruvians have indicated an interest in geothermal, and this program, therefore, may give rise to further international activities.

Reciprocity

The notion of reciprocity as applied to international agreements and activities in geothermal is a complex one. The objectives do not lend themselves to quantification, and frequently involve downstream benefits that are as yet unclear. We believe that subsequent interviews with the industry and the research and development community will clarify the approximate balance of benefits achieved through these formal activities.

The concept of reciprocity is perhaps best understood not as an exact equivalence of benefits, measured in terms of flows of information, scientists and engineers, commercial sales, etc., but as a mutuality of benefit in which both sides adhere to their obligations and important benefits accrue to both, though not necessarily in equal proportions. While this definition is more realistic, it is sufficiently diffuse to justify some rather gross imbalances in international exchanges. Nevertheless, opinions were registered concerning the degree of reciprocity achieved in various agreements, and we record these below.

The ERDA-ENEL agreement was described as of benefit to both sides, with the Italians gaining U.S. expertise of direct assistance in increasing production from geothermal wells, and the United States obtaining historical data on reservoir conditions and environmental impacts that, in the former case, should assist the estimating of well production capabilities. While benefits were described as mutual, they also were characterized as unevenly distributed, with the benefits weighted in favor of the Italians. It was noted at the same time, however, that the value of the Italian data was worth this imbalance, and that the funds expended on the agreement therefore

were justified. It was claimed, in particular, that U.S. understanding of the behavior of steam-dominated reservoirs was much improved by virtue of the cooperative agreement with ENEL.

The degree of reciprocity achieved through the U.S.-ENEL/CNR agreement is difficult to evaluate, given current problems with computer formatting, which have seriously delayed the exchange of information. The agreement does call for the exchange of existing bibliographic files and for a continuing exchange of augmented files between each country. As of one year ago, however, the Italians had planned to send only the contents of their published journals, while the United States had indicated an intention to send whatever was available in the TIC collection, which represents a considerably richer data base. A meeting between the parties in July 1977 may have corrected this imbalance, but currently the only Italian transmittal has been the journal, Geothermics, while the various U.S. transmittals, including bibliographic and technical data on hydrogen sulfide and geothermal fluids data on selected wells in the United States and in Cerro Prieto, seem considerably more generous.

Opinions on the benefits obtained through the U.S.-Mexican agreement were generally quite favorable. It was noted in particular that the historical and future behavior of Cerro Prieto would be of great value in understanding and predicting conditions in the Imperial Valley and that the Mexican fields would serve as an invaluable laboratory for the testing of U.S. geothermal technology. It is interesting that one respondent specifically attributed the success of the U.S.-Mexican accord to the planning that preceded the agreement (including discussions within CCMS) and to the effort that went into the definition of specific projects contained in the annex to the agreement.

The degree of reciprocity achieved in other agreements is impossible to describe, even qualitatively. The U.S.-Iceland agreement is dormant, as is the U.S.-Soviet activity under the Energy R&D Agreement. The U.S.-Japan agreement is expected to be signed; and although concerns have been expressed about the possible commercial benefit to the Japanese, it will be some time before such concerns can be verified or refuted. The multi-lateral activities, including the CCMS and the IEA, involve many participants for reciprocity to be measured easily. The most active project at present under the IEA agreement, MAGES, is expected to provide a cost-effective return to the United States, but this ultimately will depend on U.S. commitment to the work on hot dry rock at LASL.

As difficult as it is currently to reach conclusions concerning reciprocity, the concept may become increasingly difficult to apply in evaluating exchanges. As noted above, this possibility is a result of the trend towards a multiplicity of objectives and to the inherently nonquantifiable characteristics of the diplomatic goals. At the same time, there seems to be an increased tendency within DOE to scrutinize carefully the degree of reciprocity likely to result from proposed international agreements, as indicated by the recent memorandum from the Acting Assistant Secretary for Energy Technology calling for a statement on the balance of benefits as a precondition to the conclusion of international energy agreements.* Whatever the motivation for the obviously more rigorous requirements embodied in that memorandum, they are likely to have an impact upon the extent to which diplomatic or developmental objectives can be used as rationales for agreements, at least within the Department.

*R. D. Thorne, Memoranda on Preparation of International Agreements, April 5, 1978.

Barriers to Success

The satisfaction of the objectives discussed in this report may be impeded by a number of factors, the most important of which are the following:

- Agreements may be entered into for reasons unrelated to anticipated technical benefits, may reflect inadequate preparation and planning, and may be too general in terms of schedules and specific projects for accountability to be established.
- The continuing management of agreements may be ineffective. This may result from inadequate specificity in the agreement itself, a failure to allocate sufficient funds for the implementation of projects, or a staff overburdened with responsibilities unrelated to the agreements. Some of the problems with the ERDA-ENEL agreements, particularly with respect to the environmental and the hot rock programs, were attributed to ineffective management within the Division. The continuing problems with computer formatting in the data exchange agreement, the extremely slow pace of discussions with the Italians over the resolution of these problems, and a lack of clarity within the Department and the industry concerning the inter-relationship among GRID, TIC, and GEOTHERM, may also be attributable to managerial problems.
- Industry may not benefit sufficiently from the outputs of international agreements. Given the prime mission of DGE, which is to expedite the commercialization of geothermal within the United States, it is vital that both the formulation and the results of international agreements consider the various requirements of industry. It is unclear to us at this point as to whether this is the case, but it is unfortunate that the information exchange agreement with the Italians, for example, includes no mechanism for involving industry concerning the utility of any information obtained from the Italians. Interviews with the industry during the subsequent phases of the research will pursue this potential problem.

A more cohesive approach to international agreements would appear to be desirable. In general, a clear perception of benefit to the Division's work is necessary for any international agreements to be fruitful. Commitment to international programs can be expected if negotiated projects are seen as desirable by domestic program managers. Adequate support by the

Division must follow to insure that agreed-upon arrangements are carried out; in turn, a mechanism for periodic evaluation must be established to assure their continuing cost-effectiveness.

Appendix A

PEOPLE INTERVIEWED

Joseph Barnea
Institute for Training and Research
United Nations

Rudolph Black
Director, DGE

F. Gilman Blake
DGE

James Bresse
Former Director, DGE

William Carter
Office of International Programs

Clifford Carville
DGE

Pat Frank
Office of International Programs

Robert Ichord
Office of International Policy
Development

Peter Paul Jodoin
International Energy Development
Program Office

Ronald Loose
DGE

James McNitt
Center for Natural Resources,
Energy, and Transportation
United Nations

John Metzler
Office of International Programs

Leland Mink
DGE

Inja Paik
DGE

William Porter
Internal Energy Development
Program Office

Henry Rosenthal
DGE

Ronald Toms
DGE

Jack Vanderryn
Director, Office of International
Programs

Lou Werner
Deputy Director, DGE

Paul Witherspoon
Lawrence Berkeley Laboratories

Winefred Yen
Lawrence Berkeley Laboratories

Appendix B

A NOTE ON NON-U.S. GEOTHERMAL
ACTIVITIES AND ORGANIZATIONS

A number of international activities and organizations have paralleled or in some cases antedated U.S. international programs. Some of these activities and organizations might provide viable avenues for further U.S. international cooperation for research and development as well as potential opportunities for marketing for the domestic geothermal industry.

The United Nations has been promoting geothermal energy development and has a history of activities in geothermal resource exploration and evaluation. The UN, principally the United Nations Development Program (UNDP), has been financing geothermal exploration, feasibility studies, and development since 1965--particularly in the developing countries. The UNDP has spent about \$10 million for geothermal projects in eight different countries. These funds were matched by individual host government contributions totaling the equivalent of between \$8 and \$9 million.

In El Salvador, UNDP conducted feasibility studies, helped finance and advised on the construction of three geothermal generators between 1965 and 1977. Total contributions by the UNDP amounted to about \$2 million. The UNDP has provided technical and financial assistance for geothermal exploration and/or development for Turkey (1966-1972), Chile (1965-1975), Kenya (1970-1976), Ethiopia (1969-present), Nicaragua (1972-1976), and India (1976-present).

In 1974 a joint mission to Central America--sponsored by UNDP, the Economic Commission for Latin America (CEPAL) and the Secretariat for

Economic Integration of Central America (SEICA)--recommended that those countries concentrate their efforts on developing geothermal resources to lessen the impact of escalating oil imports. Soon afterwards, El Salvador began construction of two additional 30-megawatt generators. El Salvador's success encouraged Nicaragua to carry out exploration in 1974 and Guatemala, Costa Rica, and Panama to step up activity in geothermal development.

A recent reorganization at UNDP has reduced money being collected specifically for geothermal energy. Under the "old system," UNDP had greater input in lobbying for specific projects to be undertaken. Money is allocated to each country now for broad programs in energy, education, health, etc., giving the recipient government greater autonomy in deciding specific projects to be supported. Under this system it has become more difficult for UN representatives to persuade governments that geothermal development is a worthwhile investment.

In addition to UN activities in geothermal development in less-developed countries, the UN also has been involved in dissemination of information on geothermal R&D. The UN sponsored two conferences--one in 1970 held in Pisa, Italy, and the other in 1975 in San Francisco--at which representatives from virtually all countries having an interest in geothermal energy presented papers in recent research and development. To further the UN role as a proponent of geothermal energy, the suggestion has been made for the establishment of an International Geothermal Institute linked to the UN University to collect worldwide data and experience on geothermal resources, especially for its multipurpose uses.*

*J. Barnea, "Multipurpose Geothermal Resource Development-An Overview," Proceedings, Second UN Symposium in Development and Use of Geothermal Resources, San Francisco, May 20-29, 1975; p. 2197.

An important prospect for increased U.S. involvement with the UN geothermal activities concerns the UN program called the Revolving Fund for Natural Resources, founded in 1974. The Revolving Fund helps to finance exploration and development of mineral resources in less-developed countries. Under this scheme, when UN-funded exploration of mineral resource proves successful, the benefited country would return to the Revolving Fund a percentage of revenues earned by subsequent resource development. At present, the fund does not include geothermal resource development; but with increased allocations, a similar fund could become operational for development of geothermal resources.

The International Bank for Reconstruction and Development (the World Bank) has shown interest in the financing of geothermal power plants. The World Bank helped finance the construction of geothermal power plants in El Salvador; it approved two loans of \$27 million in 1973 and \$30 million in 1976 to finance in a large part the construction of a geothermal power plant and at Ahucchaeon, El Salvador. In addition, the 75 megawatt geothermal power plant in Cerro Prieto, Mexico, completed in 1973, was financed in part by a loan from the World Bank. However, the World Bank has not been interested in financing geothermal exploration, due to the serious financial risks involved.

OLADE, the Latin American Energy Organization, was established in November 1973 in Lima, Peru. The objective of this organization is to provide a forum for promotion and coordination of studies on new alternate energy sources in the member states. In September 1977, the Permanent Secretariat met in Quito, Ecuador, where special attention was given to geothermal energy. In March 1978, OLADE representatives met again to discuss and exchange information on geothermal energy.

In July of 1974 the European Economic Community (EEC) began discussions concerning R&D in new nonconventional energy sources of which geothermal power was raised for consideration. Interest was focused primarily on the exploitation of hot rock resources. In January of 1977 the Commission of European Communities began the second phase of the energy research program (extending from January 1977 to June 1979) in which, among other things, the field of geothermal energy was included. The program actions for work to be done in Europe include

- acquisition and collation of existing and new additional geothermal data.
- improvement and/or adaptation of existing prospecting methods of specific geothermal requirements, and development of new methods in prospecting exploration.
- compilation of geothermal models in the regions concerned.
- full-scale experimental verification of theoretical models.
- utilization of tests on sources of hot water for district and agricultural heating.
- construction of geothermal models in the areas concerned.
- improvement of measuring and drilling techniques for experimental work at high temperatures.
- study of new simulation models.
- studies and experiments on fracturation of hot rock exploitation.
- studies and experiments on heat extraction from hot rocks.