I.G.C.C. BRIEFING BOOK

Meeting of 28 APRIL - 1988

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28 APRIL 1988

BRIEFING BOOK

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL (IGCC)

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Division, Department of Energy
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IGCC MEMBERS

March 24, 1988

Honorable Donna R. Fitzpatrick
Chairman
Assistant Secretary for Conservation
& Renewable Energy
Department of Energy
Forrestal Building - Room 6C-016
1000 Independence Ave., SW
Washington, DC 20585

586-9220

Honorable George S. Dunlop
Assistant Secretary for Special
Services
Department of Agriculture
14th Street and Independence
Avenue, SW - Room 217E
Washington, DC 20250

447-7173

Honorable Charles E. Cobb, Jr.
Assistant Secretary for
Trade Development
Department of Commerce
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14th and E Streets, NW
Washington, DC 20230

377-1461

Honorable Jack Katzen
Assistant Secretary for Production
and Logistics
Department of Defense
The Pentagon - Room 3E-808
Washington, DC 20301

695-6639

Honorable Vaun A. Newill
Assistant Administrator for
Research and Development
Environmental Protection Agency
Room 911, West Tower
401 M Street, SW
Washington, DC 20460

382-7676

Honorable Jack R. Stokvis
General Deputy Assistant Secretary
for Community Planning and
Development
Department of Housing and
Urban Development - Room 7100
451 7th Street, SW
Washington, DC 20410

755-6690

Honorable James W. Zigler
Assistant Secretary for Water and
Science
Department of the Interior
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18th and C Streets, NW
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343-2186

Honorable Michael R. Darby
Assistant Secretary for Economic
Policy
Department of Treasury
Room 3454
15th Street and Pennsylvania
Avenue, NW
Washington, DC 20220

566-2551

IGCC Staff Committee

March 24, 1988

Mr. Ralph E. Burr
Chairman, Staff Committee
Geothermal Technology Division
Room 5F-081
Department of Energy
1000 Independence Avenue, SW
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586-5335

Mr. Bruce Ramsey
Fluid Minerals Program Manager
U.S. Forest Service, Room 606 RPE
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P.O. Box 2417
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235-8011

Mr. Raymond D. Robinson
Sr. International Trade/Marketing
Specialist
Office of Energy, Room 4413
Department of Commerce
14th Street & Constitution Avenue, NW
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377-0610

Mr. Dennis Hanneman
Naval Facilities Engineering
Command Headquarters
Department of Defense
Code 111B
Hoffman II Building, Room 10S07
200 Stovall Street
Alexandria, VA 22332-2300

325-0362

Mr. Alfred Galli, (RD-681)
Chief, Air and Energy Staff
Environmental Protection Agency
Room 631, West Tower
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Washington, DC 20220

382-2583

Mr. Truman Goins
Water Resources Coordinator
Office of Environment and
Energy, Room 7160
Department of Housing and Urban
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Washington, DC 20410

755-7894

Mr. William Stewart
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Office of Economic Policy
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IGCC Budget & Planning Working Group

March 24, 1988

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Chairman, IGCC Budget & Planning
Working Group
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Washington, DC 20585

586-5335

Mr. Bruce Ramsey
Fluid Minerals Program Manager
Room 606 RPE
U.S. Forest Service
Department of Agriculture
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Mr. Raymond D. Robinson
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325-0362

Mr. David Moses, EH-22
Office of Environmental Analysis
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Department of Energy
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586-2061

Mr. John Carlin, Program Manager
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Alternate Fuels
Energy Information Administration
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Department of Energy
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Washington, DC 20585

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Director, Office of Electric
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Office of Economic Policy
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OCTOBER 31, 1985

CHARTER

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL

I. COUNCIL MEMBERS

The Council shall be composed of eight members as follows:

- A. An Assistant Secretary of the Department of Energy
- B. An Assistant Secretary of the Department of Interior
- C. An Assistant Administrator of the Environmental Protection Agency
- D. An Assistant Secretary of the Treasury Department
- E. An Assistant Secretary of the Department of Agriculture
- F. An Assistant Secretary of the Department of Defense
- G. An Assistant Secretary of the Department of Commerce
- H. An Assistant Secretary of the Department of Housing and Urban Development

II. COUNCIL CHAIRPERSON

The Council shall be chaired by the Department of Energy member.

III. PURPOSES OF THE COUNCIL

In accordance with the provisions and intent of Public Law 93-410, the Geothermal Energy Research, Development and Demonstration Act of 1974, as amended by P.L. 95-238 and Public Law 95-91, the Department of Energy Organization Act, the Council shall coordinate a national energy research, development and demonstration program and shall serve as a forum for discussion of those Federal plans, activities and policies which are related to or impact on geothermal energy, including ancillary activities of agencies not represented in the Council membership. Such other agencies shall be represented as appropriate on working groups and panels assigned the responsibility for specific efforts on problems, policies, or programs in which those agencies are involved or have an interest. The Council, through the Chairperson, may make recommendations to the appropriate agencies and the President with regard to alternative policies or actions considered necessary or desirable to expedite research and development of technologies leading to the development and utilization of geothermal energy resources. The Council shall meet once a year to approve the report required by P.L. 93-410 and for such other reasons as appropriate.

IV. STAFF COMMITTEE

There shall be a Staff Committee composed of eight members, one of whom shall be appointed by each member of the Council. The Staff Committee shall be responsible for the formulation of Coordinated Federal Program Plans and for directing and coordinating the activities of the Budget and Planning Working Group and the panels provided for in paragraph VI and for reporting periodically to the Council on those activities. The Chairperson shall be the DOE representative and will serve as Executive Secretary to the Council.

V. BUDGET AND PLANNING WORKING GROUP

There shall be a Budget and Planning Working Group responsible for:

- A. Formulating long-range geothermal energy utilization goals and a comprehensive program of Federal activities and initiatives and associated budget requirements to meet these goals;
- B. Coordinating annual program plan updates and budgets of the Council agencies and other agencies participating in the Federal Geothermal Program;
- C. Preparing the Annual Report on the Geothermal Energy Program progress and future plans identified in paragraph VIII;
- D. Identifying programmatic and policy issues and other relevant information resulting from interagency planning coordination activities requiring Council resolution; and
- E. Monitoring and reporting to the Council on the progress of the Federal program and the response of the non-Federal sector toward achieving the goals.

VI. PANELS

Ad hoc panels may be formed and abolished as needed by the Council. Each panel will be responsible for coordinating Council functions, developing recommendations, and periodically reporting to the Staff Committee on its assigned area of interest. Each panel shall be composed of representatives of such Federal agencies and bureaus as are appropriate, including those that are not on the Council membership.

VII. AMENDMENT TO CHARTER

The provision of this Charter, including paragraph IX, may be amended at any time by majority vote of the Council members.

VIII. ANNUAL REPORTS

In accordance with the provisions of Section 302 of Public Law 93-410, the Council shall prepare and submit to the President and Congress by June 30 of each year a report on Federal activities and programs in geothermal energy.

IX. DURATION OF THE PROJECT

This charter shall terminate on December 31, 1990.

Functions and Activities of Coordinating Council

Functions and Activities

In accordance with the provisions and intent of Public Law 93-410, the Geothermal Energy Research, Development and Demonstration Act of 1974, as amended by P.L. 95-238 and Public Law 95-91, the Department of Energy Organization Act, the Council shall coordinate a national energy research, development and demonstration program and shall serve as a forum for discussion of those Federal plans, activities and policies which are related to or impact on geothermal energy, including ancillary activities of agencies not represented in the Council membership.

Council Members

The Council shall be composed of eight members as follows:

- An Assistant Secretary of the Department of Energy
- An Assistant Secretary of the Department of Agriculture
- An Assistant Secretary of the Department of Interior
- An Assistant Administrator of the Environmental Protection Agency
- An Assistant Secretary of the Treasury Department
- An Assistant Secretary of the Department of Defense
- An Assistant Secretary of the Department of Commerce
- An Assistant Secretary of the Department of Housing and Urban Development

Council Chairperson

The Council shall be chaired by the Department of Energy member.

Overview of Legislative Mandate

Public Law 93-410, The Geothermal Energy Research, Development and Demonstration Act

- Sec. 101 o Established the National Geothermal Coordination and Management Project (Presently the IGCC).
- Sec. 102 o Authorized and directed the Project (IGCC) to prepare a comprehensive program definition for developing geothermal resources.

- Sec. 103 o Authorized to initiate a resource inventory and assessment program of geothermal resources.
- Sec. 104 o Initiate an R&D program to resolve technical problems inhibiting utilization of geothermal resources.
- Sec. 105 o Initiate program to design and construct geothermal demonstration plants.
- Sec. 106 o Encourage development and maintenance of programs to perform required geothermal R&D activities.

Statutory Basis for Ongoing Coordination

- o P.L. 95-91, the Department of Energy Organizational Act -- abolished ERDA, FEA, and the Federal Power Commission and transferred their respective functions along with other agencies in the Department of Interior to the Department of Energy.
- o P.L. 95-238, the Department of Energy Act of 1978 -- Title V amended the Geothermal RD&D Act of 1974; re-established the Interagency Geothermal Coordinating Council (IGCC) and enlarged its jurisdiction.

INTERAGENCY GEOTHERMAL COORDINATING COUNCIL
ANNUAL MEETING
April 28, 1988

Department of Energy
Room 8E-089
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC

AGENDA

- 9:30 a.m. Opening Remarks and Review of Minutes of Last Meeting--Donna R. Fitzpatrick, Chairman, IGCC, and Assistant Secretary for Conservation and Renewable Energy, Department of Energy
- 9:35 a.m. Reports of the Staff Committee and the Budget and Planning Working Group--Ralph E. Burr, Chairman; Geothermal Technology Division, Department of Energy
- ° Twelfth Annual IGCC Report for Fiscal Year 1987--for approval
 - ° Federal Geothermal Program Plan for Fiscal Year 1988--for acceptance
- 9:45 a.m. Presentation on the Department of Energy's Geothermal Research and Development Program--John E. Mock, Director, Geothermal Technology Division, Department of Energy
- 10:15 a.m. Presentation on Department of Defense Geothermal Energy Activities--Carl F. Austin, Head of the Geothermal Program Office, U.S. Naval Weapons Center, China Lake, California.
- 10:45 a.m. Presentation on the Status of the U.S. Geothermal Industry--David N. Anderson, Executive Director, Geothermal Resources Council, Davis, California
- 11:15 a.m. Presentation on the Committee on Renewable Energy Commerce and Trade--Robert H. Annan, Director, Photovoltaics Technologies Division, Department of Energy
- 11:45 a.m. New business; Plans for Next Meeting
- 12:00 noon Adjournment

OPENING REMARKS AND REVIEW OF THE MINUTES OF THE LAST MEETING

Miss Donna R. Fitzpatrick, Chairman of the IGCC and Assistant Secretary for Conservation and Renewable Energy of the Department of Energy, will give the opening remarks and lead a review of the minutes of the April 30, 1987 meeting (TAB E).

MINUTES
INTERAGENCY GEOTHERMAL COORDINATING COUNCIL
APRIL 30, 1987

The meeting was called to order at 9:30 am by Miss Donna Fitzpatrick, Assistant Secretary, Conservation and Renewable Energy, of the U.S. Department of Energy, in Room 8E-089 of the Forrestal Building, 1000 Independence Avenue, SW, Washington, D.C. A list of attendees is provided in Attachment I and the meeting agenda in Attachment II.

ACTION ITEMS

Items

Date

o	Approval of the Eleventh Annual Interagency Geothermal Coordinating Council Report for FY 1986 and acceptance of Federal Geothermal Program Plan for FY-1987	April 1987

Meeting

Date

o	IGCC Annual Meeting	April 1988

Miss Fitzpatrick, Assistant Secretary, Conservation and Renewable Energy and Chairman of the Interagency Geothermal Coordinating Council (IGCC), welcomed the attendees to the IGCC meeting. In response to Miss Fitzpatrick's invitation, the minutes of the April 29, 1986 Council meeting were unanimously approved as read with no corrections or additions. Miss Fitzpatrick requested Mr. Ralph Burr of the Department of Energy/Geothermal Technology Division (DOE/GTD) to give the report of the IGCC Staff Committee.

Mr. Burr, Chairman of the IGCC Staff Committee and Budget and Planning Working Group (BPWG), directed the meeting's attention to copies of the Eleventh Annual Report (Tab H of the briefing books) provided to the attendees. Mr. Burr pointed out that the report follows the format of previous years and is a compilation of the activities of all participating agencies for Fiscal Year 1986. With no questions raised on proper motion, Miss Fitzpatrick declared the Eleventh Annual Report approved for submittal to Congress.

Mr. Burr then explained that the Fiscal Year 1987 Program Plan is pro forma and is an outline of this year's proposed activities, as compiled by the BPWG. Since the Program Plan is not submitted to Congress, it does not require formal approval. Miss Fitzpatrick suggested that the attendees read the Program Plan for their own information.

Miss Fitzpatrick then introduced Dr. John E. Mock, Director of DOE/GTD, who presented an overview of the Department of Energy's Geothermal Research and Development Program. Dr. Mock's presentation is provided in Attachment III.

Dr. Mock began his update on DOE/GTD activities by recommending that all attendees review DOE's recently released Energy Security report. Dr. Mock briefly summarized the key points of the document relating to geothermal interests. He then recommended to the Council two other reports soon to be

completed: one by the National Academy of Sciences dealing with mechanisms for cooperative research and development, and another by the Environmental Protection Agency concerning potentially hazardous wastes generated by exploration, development, and production of geothermal energy.

The four major geothermal resources -- hydrothermal, geopressured, hot dry rock, and magma -- were reviewed by Dr. Mock. Dr. Mock showed in a diagram that only a small fraction of potentially available geothermal resources have been exploited as a source of energy, namely high-temperature hydrothermal resources. Then, he presented a map of the United States showing that geothermal resources are widespread, followed by a chart depicting the maturity of each of the geothermal technology areas.

He then went on to summarize research initiatives, technological barriers, objectives, and strategies of the GTD effort. Dr. Mock described the FY-1986 major highlights for GTD as being (1) completion of EE-3A at Fenton Hill Hot Dry Rock site, (2) reservoir testing with scale control at the Gladys McCall geopressured wellsite, (3) completion of the 2-mile deep Salton Sea Scientific Well, and (4) seismic studies showing the most promising magma well site in the Long Valley Caldera.

New exploration techniques, high-temperature electronics, improved drill bits, improved turbodrills, high-temperature concretes, and other achievements were cited by Dr. Mock as examples of the results of major R&D programs that have made significant contributions in the commercialization of geothermal resources. Other activities cited were those relating to technology transfer accomplishments. After describing the energy trends that can impact the GTD program, Dr. Mock closed with relevant quotes from Dr. Carel Otte, President of

the Geothermal Division of Unocal Corporation and Secretary of Energy Herrington.

Miss Fitzpatrick introduced Dr. Lucien Bronicki, President of Ormat, Inc. Dr. Bronicki presented a status report of the Ormesa Geothermal Electric Power Project at East Mesa, in the Imperial Valley of southern California. The project objective, he said, is to demonstrate that a moderate-temperature (150⁰-200⁰C) geothermal resource can be used with a binary modular system to produce 30 MW of electricity. A copy of Dr. Bronicki's report, including a description of the modular power plant, is provided in Attachment IV.

Dr. Bronicki stated that, as of March 1987, the Ormesa project is on schedule and within budget. After receiving project approval in July of 1986, all 26 Ormat Energy Converters (OEC) were installed, tested, and verified for automatic functioning. In addition, most of the supporting subsystems were installed and a power purchase agreement was signed with Southern California Edison.

The modularization advantages cited by Dr. Bronicki included:

- o fast-track activity
- o factory tested modules
- o reduced risk, labor cost, and quality cost.

Dr. Bronicki also stated that the cascading-type system achieves thermodynamic advantages, and the utilization of independent units reduces the possibility of plant failure, since one unit's failure does not affect the function of any other unit.

Dr. Bronicki said that Ormat modular units have also been installed at Wabuska, NV, Sulphurdale, UT, along the Alaskan pipeline, and near the Red Sea at a solar pond power plant.

Dr. Bronicki pointed out that one of the most important results of this project, carried out through the Geothermal Loan Guaranty Program (GLGP), is that Ormesa II, a project based solely on private funding, is in the final planning stages. Therefore, according to Dr. Bronicki, the intent of the GLGP, to attract private developers and investors, was achieved by the Ormesa I project. Dr. Bronicki closed by saying that moderate-temperature geothermal resources should continue to be developed, thereby adding considerably to the U.S. exploitable geothermal resource base.

Dr. Bronicki was asked whether he felt that the field's productivity is close to what had been expected. Dr. Bronicki responded by stating that the reservoir's natural recharge was higher than expected, and that the average temperature of 310°F was within the expected temperature range. He went on to say that the modular units have the advantage of being flexible (for instance if lower temperature fluid existed, a flow rate increase could compensate), and that a reserve drilling budget exists in case additional wells are required. Therefore, Dr. Bronicki thinks the productivity of the East Mesa field is very close to the amount expected.

Dr. Bronicki was also asked to describe the Ormesa II project. The project, he said, is a joint Ormat/Harbert agreement under the same power purchase agreement with Southern California Edison. The turbines are already being constructed, but the investor contracts are not yet closed. Dr. Bronicki expressed his enthusiasm for the Ormesa II project adding that the lessons learned from Ormesa I will provide valuable information.

Miss Fitzpatrick thanked Dr. Bronicki and congratulated him on his successful project. She then introduced the next speaker, Michael Wright from

University of Utah Research Institute. Dr. Wright was to speak on joint DOE/DOD geothermal activities. His report is presented in Attachment V.

Dr. Wright began by making the point that coordination at the Federal level is extremely important, especially in providing researchers with data usually kept confidential by industry. After presenting general geothermal resource information, Dr. Wright described past DOD/DOE projects, followed by a detailed description of the status of the work being done on Ascension Island for the United States Air Force.

This project, carried out jointly by the DOE Idaho Operations Office, the University of Utah Research Institute, and EG&G, is an effort to assess the geothermal resource potential on Ascension Island. A high thermal gradient, favorable chemical geothermometers, a zone of low electrical resistivity within a rift zone, and proximity to the U.S. air base were considerations for choosing the Ascension #1 deep well site. According to Dr. Wright, the Ascension #1 well has a measured temperature of greater than 400°F at a depth of 8,000 ft. He said that current plans are to begin to deepen the well in May 1987, and that subsequent plans include drilling another production well.

Dr. Wright went on to describe geothermal development at Coso Hot Springs at the Naval Weapons Center, China Lake, CA. Third party developers for the project are California Energy Company, Inc. and the Los Angeles Department of Water and Power, and the power purchaser is Southern California Edison. Dr. Wright said the eight production wells drilled since 1981 and additional wells will support a 25 MW double flash plant that is under construction and scheduled to be completed in 1987. Advanced plans include the construction of additional power units to a total of 50 MW.

After thanking Dr. Wright for his informative presentation, Miss Fitzpatrick introduced the final speaker, Ms. Pam Matthes of the National Park Service, who addressed the issue of the temporary geothermal leasing moratorium on federal lands enacted in October of 1986. She noted that the Act required the Secretary of the Interior to publish a list of significant thermal features within the National Park system in the Federal Register within 120 days after enactment of the moratorium. This list is presented in Attachment VI. Following a 60-day public comment period, the final list will go to the respective House and Senate Committees within two weeks, Ms. Matthes said, slightly later than the authorized period.

She outlined the criteria for determining significant thermal features as (1) size, extent, and uniqueness; (2) scientific and geologic significance; (3) extent to which features remain in a natural undisturbed condition; and (4) significance of thermal features to authorized purposes for which the National Park System was created. Ms. Matthes continued by saying that a monitoring program for each of the significant thermal features would be maintained and the determining criteria would be as follows:

- o significant adverse effect - land withdrawn
- o adverse effect - strict stipulations on leases issued
- o no effect - leasing conditions of the Geothermal Steam Act prevail.

The fact that a separate monitoring program must be designed for each listed feature, which will cost the government approximately \$750,000 to \$1.5 million, was brought to the group's attention. Ms. Matthes concurred with the comment and closed her presentation.

Miss Fitzpatrick called for new business to be brought before the Council, but received no response. She concluded by noting that the IGCC now meets on an annual basis, and the next meeting is scheduled for April 1988. Miss Fitzpatrick asked for suggestions and comments from the Council Members. Since none were raised, the meeting was adjourned at 11:45 am.

ATTACHMENT I

<u>Name</u>	<u>Department/Organization</u>	<u>Phone</u>
Truman Goins	Housing and Urban Development	755-7894
Craig K. Losche	Agriculture	235-9873
Raymong D. Robinson	Commerce	377-1466
Ralph E. Burr	Energy/GTD	586-5335
P. Michael Wright	Univ. of Utah Research Institute	(801) 524-3439
Ronald R. Loose	Energy	586-8084
Donna R. Fitzpatrick	Energy	586-9222
John E. Mock	Energy/GTD	586-5340
Lucien Bronicki	Ormat, Inc.	(702) 356-9111
Marshall Dick	Environmental Protection Agency	475-7393
Pam Matthes	Interior/National Park Service	523-5120
Dennis Hanneman	Navy	325-0362
Jeffrey Jones	Defense	697-9419
Marshall Reed	Energy/GTD	586-8076
Jean Pellegrini	Interior	653-2205
Ron Toms	Energy/GTD	586-5344
Carole Beeman	Meridian Corporation	998-3691
Hezy Ramm	Ormat Inc.	(702) 352-9111
Bob Blackett	Meridian Corporation	998-3689
Raymond Wallace	Energy/GTD	586-8082
Donald Klick	U.S. Geological Survey	862-6709
David Lombard	Energy/GTD	586-8084
Gene Beeland	Meridian Corporation	998-3692
Raymond LaSala	Energy/GTD	586-4198
Lew Pratch	Energy/GTD	586-1512
Al Jelacic	Energy/GTD	586-4952
Dennis Ford	Meridian Corporation	998-3684
Gladys Hooper	Energy/GTD	586-1146
Raymond Fortuna	Energy/GTD	586-1711
Kerry Schwartz	Meridian Corporation	998-3693

ATTACHMENT II
INTERAGENCY GEOTHERMAL COORDINATING COUNCIL
ANNUAL MEETING

April 30, 1987

Department of Energy
Room 8E-089
Forrestal Building
1000 Independence Avenue, S.W.
Washington, DC

AGENDA

9:30 am	Opening Remarks and Review of Minutes of Last Meeting - Donna R. Fitzpatrick, Chairman, IGCC, and Assistant Secretary for Conservation and Renewable Energy, U.S. Department of Energy
9:35 am	Reports of the Staff Committee and the Budget and Planning Working Group - Ralph Burr, Chairman, U.S. Department of Energy o Eleventh Annual IGCC Report for Fiscal Year 1986 - for approvalo Federal Geothermal Program Plan for Fiscal Year 1987 - for acceptance
9:45 am	Presentation on the Department of Energy's Geothermal Research and Development Program - John E. Mock, Director, Geothermal Technology Division, U.S. Department of Energy
10:15 am	Presentation on the Ormesa Geothermal Electric Power Project at East Mesa, CA - Lucien Bronicki, President, Ormat Systems, Inc., Sparks, NV
10:45 am	Presentation on Joint DOE/DOD Geothermal Activities - P. Michael Wright, University of Utah Research Institute, Salt Lake City, UT
11:15 am	Presentation on the Geothermal Leasing Moratorium - Pam Matthes, National Park Service, U.S. Department of the Interior
11:45 am	New Business; Plans for next Meeting
12:00 noon	Adjournment

U.S. DEPARTMENT OF ENERGY

**INTERAGENCY GEOTHERMAL
COORDINATING COUNCIL**

April 30, 1987

DOE GEOTHERMAL PROGRAM OVERVIEW

Presented by

**DR. JOHN E. MOCK
DIRECTOR, GEOTHERMAL
TECHNOLOGY DIVISION**

ENERGY SECURITY

**A REPORT TO THE PRESIDENT OF THE UNITED STATES
March 1987**

**"THE NATION FACES NEW CHALLENGES TO ITS ENERGY SECURITY - AND
NEW CHOICES."**

**John S. Herrington
Secretary of Energy**

ENERGY SECURITY (CONTINUED)

WORLD ENERGY OUTLOOK

- TRENDS ARE EMERGING THAT RAISE SERIOUS CONCERNS.
- WORLD ENERGY SITUATION FOR THE FUTURE INCLUDES OPPORTUNITIES AND RISKS.
- CHALLENGE FOR POLICYMAKERS - FIND PROPER BALANCE BETWEEN FREE AND COMPETITIVE MARKETS AND COST EFFECTIVE ACTION.

ELECTRICITY'S FUTURE IN THE U.S.

- LIKELY THAT SUBSTANTIAL NEW GENERATING CAPACITY WILL BE NEEDED NATIONWIDE DURING THE 1990'S.

RENEWABLE ENERGY

- THE GREATEST ADVANTAGE OF RENEWABLES - BASED ON TECHNOLOGY- RATHER THAN ON INSECURE RESOURCES.
- THE RESOURCES THAT UNDERLIE THEM ARE INDIGENOUS.
- RENEWABLE ENERGY TECHNOLOGIES PROVIDE "TECHNICAL OPTIMISM" FOR GLOBAL AND NATIONAL ENERGY SECURITY IN THE MORE DISTANT FUTURE.

**GEOSCIENCE RESEARCH FOR ENERGY SECURITY
ENERGY RESEARCH ADVISORY BOARD
FEBRUARY 1987**

- MORE EFFECTIVE UTILIZATION OF THE EARTH'S NATURAL THERMAL ENERGY IS REQUIRED.
- REASONABLE FRACTION OF FEDERAL ENERGY RESEARCH SHOULD BE DIRECTED TOWARD LONG-TERM RENEWABLE RESOURCES.
- ERAB RECOMMENDS A SHIFT... TO MORE BASIC GEOTHERMAL, GEOSCIENCES RESEARCH.

FUTURE REPORTS

NATIONAL ACADEMY OF SCIENCES STUDY

- FUNDED BY THE GEOTHERMAL TECHNOLOGY DIVISION.
- WILL RECOMMEND OPTIMUM MECHANISMS FOR COOPERATIVE R&D RESEARCH.

ENVIRONMENTAL PROTECTION AGENCY

- AN EPA STUDY OF THE WASTES GENERATED BY THE EXPLORATION, DEVELOPMENT, AND PRODUCTION OF GEOTHERMAL ENERGY.
- EPA IS REQUIRED TO RECOMMEND TO CONGRESS WHETHER THESE WASTES SHOULD BE HANDLED AS HAZARDOUS WASTES.

HYDROTHERMAL ENERGY

- **STEAM AND WATER TRAPPED IN POROUS OR FRACTURED ROCK (90 TO 360°C)**
- **TODAY'S SOURCE OF GEOTHERMAL ENERGY**
- **RELATIVELY WIDESPREAD IN THE U.S.**
- **TECHNOLOGICALLY CONSTRAINED TO HIGHEST TEMPERATURE RESOURCES**

**"GEOTHERMAL IS SECOND ONLY TO HYDRO AS THE
CHEAPEST SOURCE OF ENERGY IN THE PG&E SYSTEM."**

**BARTON W. SHACKELFORD
PRESIDENT, PACIFIC GAS AND ELECTRIC COMPANY
OCTOBER 23, 1985**

GEOPRESSURED ENERGY

- **THREE FORMS - THERMAL, CHEMICAL, HYDRAULIC**
- **BRINES CONTAIN DISSOLVED METHANE**
- **HIGH PRESSURE, MODERATE TEMPERATURE BRINES**
- **GREATEST CONCENTRATION ALONG GULF COAST (TEXAS AND LOUISIANA)**

HOT DRY ROCK

- **WATER-FREE HOT ROCK**
- **MAN-MADE FRACTURES**
- **DEPTHS OF 13,000 - 20,000 FEET
(POWER PRODUCTION)**
- **POWER AND DIRECT USE POTENTIAL**

MAGMA

- **MOLTEN OR PARTIALLY MOLTEN ROCK
(850-1200°C)**
- **ACCESSIBLE DEPTHS ESTIMATED AT
10,000 TO 30,000 FEET**
- **VOLCANIC REGIONS (WESTERN STATES,
HAWAII, ALASKA)**

GEO THERMAL ENERGY

GEO THERMAL IS A LARGE POTENTIAL SOURCE OF ENERGY

(ESTIMATED TOTAL $\approx 1.2 \times 10^6$ Q)

GEOHERMAL RESOURCES ARE WIDESPREAD

GEOHERMAL TECHNOLOGY DEVELOPMENT STATUS

**RESEARCH INITIATIVES OF THE DOE
GEOTHERMAL R&D PROGRAM ARE MATCHED TO:**

- **PHYSICAL CHARACTERISTICS OF THE FOUR TYPES OF GEOTHERMAL RESOURCES**
- **MAJOR TECHNICAL BARRIERS AFFECTING UTILIZATION OF THE RESOURCE TYPES**
- **CRITICAL INDUSTRY NEEDS FOR ECONOMIC EXPLOITATION OF NEAR AND MID-TERM HYDROTHERMAL POTENTIAL**

MAJOR TECHNICAL BARRIERS

HYDROTHERMAL

- **UNCERTAINTIES IN LOCATING AND CHARACTERIZING RESERVOIRS**
- **UNUSUALLY HIGH DRILLING COSTS**
- **INJECTION TECHNOLOGY FOR ECONOMIC DISPOSAL OF SPENT BRINES**
- **CORROSION PREVENTION AND MATERIALS DURABILITY**
- **ENVIRONMENTAL ISSUES: SUBSIDENCE, H₂S EMISSIONS, WASTE DISPOSAL**
- **LACK OF EFFICIENT COMPONENTS: DOWNHOLE PUMPS, HEAT EXCHANGERS, INSTRUMENTS**

MAJOR TECHNICAL BARRIERS

GEOPRESSURED

- **UNCERTAINTIES IN PREDICTING RESERVOIR SIZE AND LONGEVITY**
- **COMPLEX FLOW HYDRODYNAMICS**
- **TECHNOLOGY FOR EFFICIENT ELECTRIC POWER GENERATION**

MAJOR TECHNICAL BARRIERS

HOT DRY ROCK

- **PREDICTION OF RESERVOIR LIFETIME**
- **CONTROL OF WATER LOSS**
- **CONTROL OF CIRCULATION IMPEDANCE**

MAJOR TECHNICAL BARRIERS

MAGMA

- **LOCATION AND CHARACTERIZATION OF MAGMA CHAMBERS**
- **EFFICIENT ENERGY EXTRACTION TECHNOLOGY**
- **HIGH TEMPERATURE MATERIALS AND INSTRUMENTATION**

OBJECTIVES OF THE DOE GEOTHERMAL PROGRAM

- **ADVANCE THE STATE-OF-THE-ART IN HYDROTHERMAL TECHNOLOGY WHICH WILL ENABLE SECOND GENERATION FLASH AND BINARY SYSTEMS TO BE AT LEAST 20% MORE EFFICIENT AND EFFECTIVE.**
- **TO ESTABLISH THE TECHNOLOGY BASE WHICH WILL ALLOW INDUSTRY TO MAKE PRUDENT AND TIMELY INVESTMENT DECISIONS WITH RESPECT TO THE DEVELOPMENT AND UTILIZATION OF ADVANCED GEOTHERMAL RESOURCES.**

DOE STRATEGY

- **REMOVE TECHNOLOGY BARRIERS**
- **RESPOND TO INDUSTRY INPUT**
- **GENERIC HIGH-RISK, HIGH-PAYOFF RESEARCH**
- **TECHNOLOGY TRANSFER**
- **BALANCE BETWEEN SHORT, MID, AND LONG TERM NEEDS / RESOURCES**

SUMMARY OF PROGRESS IN FY 1986

- COMPLETED EE-3A WELL AT FENTON HILL HOT DRY ROCK SITE, CONSTRUCTED INTERIM HEAT RECOVERY SYSTEM AND CONDUCTED PRELIMINARY CLOSED LOOP TEST OF THE CONNECTED PHASE II RESERVOIR.
- CONDUCTED RESERVOIR TESTING AT GLADYS McCALL SITE. TESTED IMPROVED SCALE CONTROL METHOD, AND BEGAN ASSEMBLY OF ELECTRIC POWER RESEARCH EXPERIMENT AT PLEASANT BAYOU SITE.
- DRILLED AND CORED 2 MILE DEEP SALTON SEA SCIENTIFIC WELL, OBTAINED CORRINGS, FLUID SAMPLES AND GEOPHYSICAL WELL LOGS, AND CONDUCTED LIMITED FLOW TESTS.
- PERFORMED DETAILED SEISMIC STUDIES AT THE MOST PROMISING MAGMA SITE.

SUMMARY OF PROGRESS IN FY 1986 (CONTINUED)

- CONDUCTED LONG-TERM TESTS ON THE MOST PROMISING MATERIALS AND EQUIPMENT SUITABLE FOR USE IN A MAGMA ENVIRONMENT.
- MODIFIED CONDENSOR ATTITUDE TO TEST CONDENSATION IN THE HORIZONTAL POSITION, TESTED SUPERCRITICAL CYCLES WITH INTEGRAL CONDENSATION.
- PERFORMED LABORATORY SCALE FIELD TESTS OF HIGH ENERGY GAS FRACTURING AIMED AT INCREASING PERMEABILITY IN GEOTHERMAL PRODUCTION AND INJECTION WELLS.
- FABRICATED AND LABORATORY TESTED PROTOTYPE RADAR MAPPING TOOL; FIELD TESTED LOST CIRCULATION ZONE MAPPING TOOLS; AND PERFORMED LABORATORY TESTING AND COMPUTER MODELING OF HYBRID DRILL BIT.

PLANNED ACTIVITIES DURING FY 1987

RESERVOIR TECHNOLOGY RESEARCH

- RESERVOIR DETECTION AND MAPPING TECHNOLOGY.
- DEVELOP MODELS FOR FRACTURED RESERVOIRS.
- DEVELOP A COMPUTER MODEL FOR INJECTED FLUID FLOW.
- EVALUATION OF GEOPHYSICAL METHODS FOR CALDERA RESERVOIR INVESTIGATIONS.
- CONDUCT RESOURCE STUDIES AND SYNTHESIZE DATA FROM SSSDP.

HARD ROCK PENETRATION RESEARCH

- DEVELOP COMPUTER MODELS TO UNDERSTAND THE LOST FLOW.
- DESIGN AND TEST NEW LOST-CIRCULATION MATERIALS.
- ANALYSIS OF MECHANICS IN CUTTER/FORMATION INTERACTION.
- DESIGN AN ADVANCED GEOTHERMAL DRILLING SYSTEM.

HEAT CYCLE RESEARCH

- TEST TWO-PHASE TURBINE EXPANSIONS.
- ANALYZE DATA FROM HEAT EXCHANGER TEST PROGRAM.

PLANNED ACTIVITIES (CONTINUED) DURING FY 1987

GEOPRESSURED RESEARCH

- FLOW TESTING AND SUPPORT ACTIVITIES.
- COMPLETE INSTALLATION OF EPRI HYBRID POWER SYSTEM EXPERIMENT.

HOT DRY ROCK RESEARCH

- DESIGN THE SURFACE SYSTEM FOR THE LONG TERM FLOW TEST (LTFT).
- INITIATE PURCHASE OF SURFACE EQUIPMENT AND PUMPS.
- WORK OVER OPERATIONS AT FENTON HILL.

MAGMA RESEARCH

- DESIGN AND TEST MATERIALS, EQUIPMENT, AND INSTRUMENTS FOR MAGMA ENVIRONMENT.
- DETERMINE THE DEPTH AND SIZE OF MAGMA BODIES.

EXAMPLES OF MAJOR R&D PROGRAM PAYOFFS TO DATE

- **MAGNETOTELLURIC AND PASSIVE SEISMIC EXPLORATION TECHNIQUES (REMOTE REFERENCE AND INFELD PROCESSOR, RESPECTIVELY)**
- **HIGH-TEMPERATURE ELECTRONICS AND SENSORS FOR WELL LOGGING**
- **IMPROVED DRILL BITS; BEARINGS; SEALS, AND LUBRICANTS FOR ROLLER CONE BITS; WATER JET ASSISTED DRILLING; DESIGN AND USE OF POLYCRYSTALLINE DIAMOND CUTTERS ON DRAG BITS**
- **IMPROVED WATER AND MUD-DRIVEN TURBODRILLS FOR DIRECTIONAL DRILLING DERIVED FROM THE HOT DRY ROCK PROGRAM**
- **HIGH-TEMPERATURE ELASTOMERS AND POLYMER CONCRETES**
- **WELLHEAD-SIZE FLASH, TOTAL FLOW, ROTARY SEPARATOR, AND DIRECT CONTACT HEAT EXCHANGER BINARY ELECTRIC GENERATION SYSTEMS**
- **PRECIPITATING AND CLARIFYING TECHNIQUES AND SCALE INHIBITING CHEMICALS TO HANDLE HIGH SALINITY CORROSIVE BRINES**
- **CAVITATING WATER-JET CLEANING FOR PIPES AND HEAT EXCHANGERS**
- **A METHOD FOR DETERMINING FRACTURE ORIENTATION FROM OBSERVATION OF TIDAL PRESSURE FLUCTUATIONS IN A SINGLE WELLBORE**
- **RESERVOIR ENGINEERING AND GEOPHYSICAL TOOLS AND INSTRUMENTATION**

TECHNOLOGY TRANSFER

- **TRANSFER OF GTD R&D PLANS AND TECHNICAL REPORTS VIA DTIC, NTIS, CARRIERS**
- **PARTICIPATION IN GEOTHERMAL RESOURCES COUNCIL AND ELECTRIC POWER RESEARCH INSTITUTE AND INFORMATION DISSEMINATION**
- **COLLABORATION WITH OREGON INSTITUTE OF TECHNOLOGY ON DISSEMINATING DIRECT USE INFORMATION**
- **TECHNICAL WORKSHOPS AND CONFERENCES AT UNIVERSITIES AND NATIONAL LABORATORIES**
- **JOINT FUNDING WITH GEOTHERMAL DRILLING ORGANIZATION (GDO) OF DRILLING TECHNOLOGY RESEARCH**
- **FORMING A GDO-LIKE HYDROTHERMAL RESEARCH ORGANIZATION FOR RESERVOIR AND POWER PLANT RESEARCH**
- **GTD CONFERENCE ON TECHNOLOGY TRANSFER MECHANISMS, 1984**

TECHNOLOGY EXPECTATIONS

- **GEOHERMAL STEAM ELECTRIC PLANTS ARE CURRENT, AND AN ECONOMICALLY FAVORABLE TECHNOLOGY.**
- **NEAR-TERM GOALS WILL INCLUDE ECONOMIC IMPROVEMENTS IN HOT WATER TECHNOLOGIES.**
- **BINARY CYCLE PLANTS SHOULD BECOME COMMERCIALY VIABLE WITHIN THE NEXT 5 YEARS.**
- **GEOPRESSURED TECHNOLOGY SHOULD BE VIABLE IN THE 1990'S; HOT DRY ROCK AND MAGMA AFTER THE YEAR 2000.**

TECHNOLOGY EXPECTATIONS (CONTINUED)

- **HYDROTHERMAL POWER IS POISED FOR STRONG NEAR- TO MID-TERM GROWTH.**
- **GEOPRESSURED, HOT DRY ROCK, AND MAGMA TECHNOLOGIES WILL PROVIDE ACCESS TO LARGER, WIDESPREAD RESOURCES IN THE MID- TO LONG-TERM.**

HYDROTHERMAL POWER IS POISED FOR STRONG MID-TERM GROWTH

ACTUAL OR PROJECTED POWER ON LINE

SOURCE: 1985 EPRI SURVEY; INTERPRETED BY GTD

TRENDS IMPACTING THE PROGRAM

- **REDUCED GROWTH IN CONSUMPTION OF ELECTRICITY**
- **UTILITY RELUCTANCE TO FINANCE NEW PLANTS**
- **DECLINE IN AVOIDED COSTS**
- **ACCEPTANCE OF MODULAR PLANTS**
- **CHANGING FUNDING LEVELS**

**"GEOTHERMAL IS STILL A FLEDGLING INDUSTRY FACED WITH
A VARIETY OF TECHNICAL AND INSTITUTIONAL PROBLEMS WHICH
ARE UNIQUE TO GEOTHERMAL. AS A RESULT, ONLY A FEW OF THE
NATION'S GEOTHERMAL RESOURCES CAN PRESENTLY BE DEVELOPED
AND PRODUCED IN COMPETITION WITH ESTABLISHED ENERGY
TECHNOLOGIES."**

**CAREL OTTE
PRESIDENT
GEOTHERMAL DIVISION, UNOCAL CORPORATION
SPEAKING ABOUT HYDROTHERMAL LIQUIDS EXPLOITATION**

"UNDER THE PRESIDENT'S LEADERSHIP, THE NATION HAS MADE GREAT PROGRESS IN BUILDING A STRONGER FOUNDATION OF ENERGY SECURITY IN RESPONSE TO THE ENERGY CRISIS OF THE 1970'S. HOWEVER, DESPITE MANY GAINS, AMERICA IS AT ANOTHER EQUALLY CRITICAL JUNCTURE IN THE STATE OF ITS ENERGY SECURITY."

**JOHN S. HERRINGTON
SECRETARY OF ENERGY**

ATTACHMENT IV

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ORMESA GEOTHERMAL ELECTRIC POWER PROJECT AT EAST MESA, CA

**L.Y. Bronicki, President and Technical Director
ORMAT Inc., Sparks, NV**

Abstract

This paper presents a view of ORMESA Geothermal Power Plant Project located in the East Mesa section of the Imperial Valley of Southern California. ORMESA is a privately funded project supported under the Loan Guaranty Program of the Geothermal Development Act, Public Law 93-410.

The power plant is a cluster of modular, subcritical Rankine Cycle systems with ORMAT ENERGY CONVERTERS (OEC) as the electricity generating core element. ORMESA is under contract with SCE to deliver 24 MW via Imperial Irrigation District lines to SCE's grid. ORMESA is in the final stages of completion. These facilities include production wells, brine collection systems, cascaded clusters of OECs, energy depleted brine collection systems, injection wells, power plant control centers and auxiliary service systems. References are made to ORMESA II, to be a completely privately financed venture.

Discussed in the present report are: the geothermal field production development, power plant construction, ORMESA's approach to modularization and standardization of components, and an overview of the OECs and power plant controls.

1. Introduction

The Imperial Valley, and particularly the region of East Mesa, has been extensively surveyed and tested for its geothermal anomalies and its potential as a source of thermal energy. The 1973 oil embargo crisis and the subsequent reaction of the Federal Government gave rise to renewed interest geothermal energy and in the area. It was at this time, 1974, that the U.S. Congress passed Public Law 93-410, the Geothermal Development Act, which included the Loan Guaranty Program encouraging private investment.

While power plants have been operating successfully using high-temperature steam at the resource area, there was little or no experience derived from the larger hot water resources. This lack of experience in hot brines provided potential investors in geothermal projects with no basis on which to determine the levels of risk involved. To offset this inability to assess normal commercial risks, Loan Guaranty Program of the Geothermal Development Act provided a mechanism for shifting a substantial portion of the risk assumption from the investor to the Federal Government. In effect, the U.S. Government pledged to indemnify the investor in the event of a project's failure. This indemnification, it should be stressed, does not extend directly to holders of equity positions such as Lease Financing.

ORMAT's approach to power plant development for geothermal applications has a different starting point than almost all other electrical power plant engineering companies. While others have concentrated on large turbogenerating equipment which are downsized for geothermal application, ORMAT has specialized in developing small units, often for remote and unattended installations. Reliability requirements for unattended operation are stringent, and ORMAT's reputation in this regard is high. The small scale application approach explains ORMAT's ability to use the power plant design. The power plant and its modules incorporate half a dozen ORMAT patents.

With the development of OECs, ORMAT concentrated on low enthalpy heat source utilization for the production of electricity. Low temperature geothermal brine is such a heat source. More than 3500 small OEC installations, fired by fossil fuel, have been operating for years, completely unattended, where they supply continuous power in remote locations for telecommunications and pipeline service. On the Trans-Alaska Pipeline, where 106 OECs have accumulated well over 10,000,000 hours of continuous operation since 1976, they generate electric power for valves, pumps, instruments and for telecommunications. Field data from these OECs has yielded statistically valid claims of unusually high reliability, most favorable on-line factors, and provide as-promised performance within schedule and budget commitments. These

claims have also been verified in geothermal installations in Wabuska, NV and Steamboat Springs, NV.

ORMESA is managed by ORMAT as a turnkey project for converting low enthalpy geothermal energy into electric energy. ORMESA is on-line with commissioning to start in June 1987. ORMESA is arranged in an innovative three-level cascade. All OECs were shipped as factory tested modules. ORMESA is on schedule, within budget, and is exhibiting the expected performance.

Figure 1 indicates the location of the East Mesa KGRA in southern California and the project site.

2. Geothermal Resource

The East Mesa KGRA has been the site of much geothermal activity during the last three decades. Satellite surveys first identified magnetic anomalies. The first two deep wells drilled near the East Mesa geothermal field were drilled as wildcat oil wells. The first was drilled to 9,017 feet in 1960, and to 10,550 feet in 1966. Later, the U.S. Bureau of Reclamation and private developers drilled in excess of twenty wells, confirming the existence of a large, pervasive geothermal reservoir with substantial heat reserves. The depth of the reserve is estimated to be 3,000 feet - 7,000 feet at temperatures of 300 - 350 degrees F.

In the Imperial Valley of Southern California, 6 geothermal power plants are presently operational. Their combined generating power is 171 MW. Of these, 2 plants with a combined generating power of 32 MW are in the area located in the East Mesa KGRA.

3. ORMESA

ORMESA has initially started "in-service" status late December 1986, five months since the financial closing of the EPC contract. All qualification and performance tests to date have met performance expectations and have functioned as planned. During the last report period, ORMESA has generated an average 5 MW/day net for sale.

SCE is contractually obligated to purchase all of ORMESA and ORMESA II power generation for 30 years. The contract stipulates terms for three forms of payment. These are tabulated in Table I. In order to make ORMESA and ORMESA II viable commercial undertakings, these forms of payment determine the technical requirements for quality and reliability. In practical terms these put a finite dollar value on reliability and quality.

REGIONAL LOCATION MAP

FIG 1

TABLE 1: UTILITY PAYMENT SCHEDULE

Payment	Terms	ORMESA I	ORMESA II
Energy	all production year 1-10 adjusted fixed rate year 11-30 avoided cost rate	kW-hr	kW-hr
Capacity	firm capacity	24 MW	15 MW
	period min. performance factor	80%	80%
	As-available capacity rate (>)	24 MW	15 MW
Peak Month Bonus	average performance factor	85%	85%
Max Bonus	average performance factor	92%	92%

3.1. ORMESA Structuring

ORMESA and ORMESA II projects were conceived and implemented by ORMAT as private ventures. Drawing on their extensive experience with low enthalpy energy, they provided the engineering and design studies and demonstrated the commercial viability of the projects. ORMAT developed the financial structuring and venture investments and provides the overall project management.

The detail design, engineering, procurement and construction of the ORMESA facility was performed by AMCC, a major EPC firm. The EPC firm constructed the facility under a fixed-price contract for the projected number and location of wells. The performance of the EPC firm was secured by performance and payment bonds. The timely completion and overall performance of the facility was warranted by the EPC firm.

Assisted by a nationally recognized consulting firm in geothermal engineering, ORMESA has developed and supervised the welldrilling program to ensure that adequate production and reinjection wells are available to produce the project's required fluid brine output.

The operation and maintenance of the field are being performed by a drilling constructor under the direction of ORMESA's Field Manager.

3.2. Status

As of March 1987, ORMESA is on schedule and within budget. With 64% of the \$86,000,000 budget committed or expended, all OECs are installed, their automatic functioning has been tested and verified. The same is true for the majority of the supporting subsystems such as cooling towers and water supply, fire detection and control, sand separation, etc.

The project budget is shown in Figure 2 identifying major groupings of construction, field development and financial pre-closing cost elements. These pre-closing costs include, but are not limited to, lease acquisition, existing well procurement, geothermal and engineering studies and evaluations, legal fees, license fees, loan servicing and administrative costs.

The progressive completion status by major trades, electrical, mechanical and civil, are shown in Figure 3.

4. Geothermal Field Development

In recent well tests of existing wells, 5 production wells and 2 injection wells showed a flow of 4200 gpm and a wellhead temperature of 319 degrees F.

Because of earlier development in the East Mesa KGRA, reservoir behavior is fairly predictable. It is estimated that all of the resources controlled by ORMAT are capable of supporting approximately 75 MW of electric power generation with ORMAT's systems. Table 2 is a tabulation of ORMESA wells in place, under construction or planned. Figure 4 shows the existing well locations on the ORMESA site.

TABLE 2: ORMESA PRODUCTION AND INJECTION WELLS

No. of Production Wells	11
No. of Injection Wells	5
Average Production Well Depth, ft	7,000
Average Injection Well Depth, ft	6,000
Nominal Total Flow lbs/hour	4,600,000

ORMESA BUDGET STATUS

FIG 2

FIG 3

ORMESA PROJECT AREAS

Geothermal energy is extracted from the field by pumping the fluid to the surface. The ingathered hot fluid flows through a sand separator to minimize erosion damage and sand packing in the system. The brine then flows through the power plant's 3 level cascade, transferring its heat to the OEC's motive fluid. The energy depleted fluid flows to the field's injection pumps where it is reinjected into the field at strategically selected sites and depths. The injected brine must be maintained above 127 degrees F to retain its chemical and mineral elements in solution. The cold fluid flow passes through the geothermal aquifer, is heated and extracted by the production pumps and lifted to the surface to repeat its cycle.

However, with time, gradual cooling of the water is expected, such cooling being typically about 1 degree to 2 degrees F per year. In ORMESA's operating plan, this temperature decline is compensated for by increasing the total production rate or from additional wells. One additional well is expected to be required every five years.

The resource risk is the possibility that not enough geothermal fluid with the required heat content will flow from the production wells to the OECs to allow ORMESA to generate sufficient electricity to fulfill their SCE contract at a viable payment rate. Although there are strong indications that there is a natural recharge of the resource, this risk is addressed in the construction phase by budgeting funds for the drilling of more wells than are expected to be required.

4.1. Well Drilling Decision Model

Even today, with our advanced state of technology, spotting a well site remains in the realm of an art. To drill now or to delay drilling until more data is developed is a common problem encountered by managers of geothermal projects. ORMAT has modeled this decision making process. The model illustrates the time factor and its relationship to budget for the planning stage, and is intended to influence the decision making at the construction site. It does not provide black/white, success/failure answers, but a choice of an excellent, an average, or a poor chance for a successful well. Figure 5 shows the modeled decision tree. For example, the cost of drilling a well is \$320,000 and interest paid for a month's delay is assumed at \$400,000. The probability of a successful or unsuccessful well is shown in percentages and is based on geothermal/geological data. The decision required is to drill now or delay drilling by a month to acquire additional information. The decisionmaker's choices are:

- A. Drill now, resulting in:
 - i. successful well with a probability of 60% and at a cost of \$320,000;
 - ii. successful well after an unsuccessful well and a one month delay with a probability of 36% and at a cost of \$1,040,000;
 - iii. two unsuccessful wells preceeding a successful well with a probability of 4% and at a cost of \$1,760,000.
- B. Do not drill now, resulting in:
 - i. successful well after one month delay with a probability of 80% and at a cost of \$720,000;
 - ii. an unsuccessful well preceeding a successful well after a two month delay with a probability of 20% and at a cost of \$1,440,000.

Computing the expected cost of A and B yields $EA < EB$. By an error analysis of the assumed probabilities the result's sensitivity is tested. The indicated selected choice is A, drill now.

DECISION MODEL

FIG 5

5. Power Plant

5.1. Plant Description

ORMESA's power plant consists of 26 OECs, a redundant cooling system, motive fluid storage and charging system, sand separators, fire protection and control system, transformer station and a utility substation. All of these are controlled manually or fully automatically. Figure 6 is a photograph of the ORMESA power plant. A schematic layout of the power plant is shown in Figure 7, and the brine's flow path is described as follows:

The hot brine flow enters the power plant through a sand separator and then enters the cascade of OECs. The brine enters the Level I OECs in parallel flow. It passes through Level I vaporizers where a portion of the brine's heat is transferred to the OEC's motive fluid. From there the now partially depleted energy is distributed to the Level II OEC preheater-vaporizers and then similarly through Level III, giving up the remaining energy to Level III OEC's motive fluid.

In brief, the geothermal fluid is forced through four levels of energy conversion (including preheaters). The OECs in Level II and Level III receive cooler geothermal fluids, but at greater flow rates, which compensates for the lower temperatures. As a result, each of the OEC levels generates approximately the same amount of energy. Upon leaving the Level III modules, the geothermal fluid is split again to pass through each OEC pre-heater to pre-heat the organic fluid before finally being gathered and flow to the injection wells which then return the fluid to the heat source.

The facility's parasitic loads are itemized in Table 3:

TABLE 3: NOMINAL PARASITIC LOADS

A. Internal to Power Plant	
Parasitic Loads	
OECs	
OEC (Feed and Oil Pumps) kW	1,125
Cooling System	
Cooling Tower Fans kW	675
Circulating Water Pumps kW	1,560
Geothermal Water	
Reinjection Pumps kW	1,190
Electrical Losses	
OEC module Transformers kW	340
Main Transformers kW	90
Miscellaneous kW	200
TOTAL kW	5,180
B. Powered by Imperial Irrigation District (IID)	
Sweet Water Make-up Pumps kW	100
Production Pumps kW	4,720
TOTAL kW	4,820

The plant's gross generated power is tabulated in Table 4:

TABLE 4: GROSS GENERATED POWER (at generator terminals)

	ORMESA		
	Level I	Level II	Level III
No. operating OECs	16	8	2
Nominal MW/OEC	1.175	1.105	0.940
Total level nominal MW	18.80	8.84	1.88
TOTAL PLANT NOMINAL MW	29.52		

The OEC generated electricity, transformed to 13.6 kV, is transmitted to the plant transformer where it is stepped up to 91 kV and transmitted to the utility's substation as grid synchronized electricity.

In the control center, data transmitted from the process data acquisition system is monitored and process flows are regulated in a manual or automatic operating mode. In either mode, the control center responds to signals from the plant and the utility. It is also able to start-up or shut-down, in either mode, any OEC, production and injection pump and subsystem.

The fire detection and control systems are in accordance with the Fire Code.

The use of fluids at low pressures and temperatures reduces the overall plant stress level, permitting common usage design practices. Also, the geothermal fluid does not come into contact with the precision turbine blades and therefore cannot cause corrosive/erosive damage or fouling.

Since there are no gaseous or liquid effluents, there is no environmental danger. Even in the case of accidental burning of the hydrocarbon motive fluid, only mildly toxic products of combustion are released.

5.2. Modularization

Clustered, modularized OEC concept have inherently multifaceted advantages which are realized through planning and by design. These include reduction of investment risk, plant turn-down capability, the flexibility to redistribute load, flexibility to accommodate changes in the geothermal flow and energy, reduced program cost and getting-on-line advantages. These and others without detrimental effects but enhancement of quality and reliability.

The clustered OEC concept means that ORMESA is not subjected to the "one out, all out" penalty of the single turbine. If, for instance, one of the 16 OECs of the first level of the cascade fails, the others, because they are running under-rated, will get more fluid flow and will, to some extent, compensate. Thus, if, with 26 turbines running, the output is 30 MW, 25 running are designed to give 29.5 MW; 24 running, 28.7 MW; 23 running, 27.8 MW; and 22 running, 26.8 MW. Each loss is less than the 1.2 MW contributed by the turbine which is out.

The ORMESA modular subcritical OECs, arranged in a cascade, can accommodate anticipated variations in pressure and temperature which would otherwise seriously impair the performance of a single unit binary system.

Modular design and planning enhance fast-track projects in that they minimize on-site assembly and installation time. ORMESA and other prior projects have demonstrated that on-site installation time, through achievement of in-service status in 9 months is a realistic project objective even though the site is located in remote and adverse terrain.

Modular designs go hand-in-hand with the cost saving features of standardization. Standardization reduces the cost of engineering, tooling, production and inventory. These cost reductions are achieved without sacrificing quality or reliability.

5.3. OEC Description

Each OEC is a self-contained, free-standing power plant module containing a heat exchanger which includes a vaporizer and a pre-heater, a turbine-generator, a water cooled condenser, a cycle feed pump, and associated controls. Figure 8 is a photograph of an ORMESA Level I OEC.

The geothermal fluid is pumped into tubes within the heat exchanger while simultaneously, isopentane, the organic motive fluid, passes through the shell of the heat exchanger. As the fluids flow through their respective paths, heat is exchanged from the geothermal fluid to the isopentane which vaporizes. This vapor then passes across the turbine where it expands, driving the turbine generator which produces electrical power. After driving the turbine, the isopentane vapor passes into the condenser where water from the cooling system is used to cool and condense the vapor back to liquid form. The cooled isopentane liquid then flows through a pre-heater where it is heated in preparation for the commencement of a new cycle through the OEC. Figure 9 shows an OEC schematic of the brine and motive fluid paths.

OEC subassemblies arrive at the construction site in shipping containers; two each for Level I, and three each for Level II and III: the heat exchanger assembly, the turbomachinery assembly, the electrical control assembly and interconnecting pipes with valves and instrument sensors. To facilitate transportation and off-loading, containers are limited to 45 tons and loads are kept within 40 x 8 x 8 foot envelopes.

Isopentane, the OEC's organic motive fluid, was selected for its favorable thermodynamic properties. Its boiling point at atmospheric pressure is 75 degrees F and dew point is 90 degrees F. The flammability of the fluid makes appropriate system design features and operating procedures mandatory. Appropriate automatic fire detection and control systems in compliance with the Fire Code are also provided.

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ATTACHMENT V

JOINT DOE/DOD GEOTHERMAL ACTIVITIES

Phillip Michael Wright
University of Utah Research Institute

GEOHERMAL DEVELOPMENT

DOD INTERESTS

- *Lowering Energy Costs*
- *Energy Security*

DOE INTERESTS

- *Developing New Technology for*
 - *Lowering Costs of Development*
 - *Increasing Resource Base*

Geothermal Power Generation Costs

Worldwide Geothermal Electricity Generation

DECEMBER 1986

(AFTER DIPIPO, 1986)

<u>Country</u>	<i>Generating Capacity, MW</i>	
	<u>Operational</u>	<u>Under Const. or Planned</u>
KENYA	45.0	60
EL SALVADOR	95.0	75
NICARAGUA	35.0	35
MEXICO	645.0	645
UNITED STATES	2006.3	1320
CHINA	14.6	—
TURKEY	20.6	—
GREECE	2.0	120
AZORES	3.0	10
USSR	11.0	230
ICELAND	39.0	—
GUADELOUPE	4.2	—
ITALY	504.2	655
INDONESIA	32.3	965
JAPAN	215.1	108
NEW ZEALAND	167.2	116
PHILIPPINES	<u>894.0</u>	<u>1303</u>
	4733.5 MW	5642 MW

GEOHERMAL POWER PLANTS IN THE WORLD

Worldwide Geothermal Direct Use

(AFTER GUDMUNDSSON, 1985)

Country	Power (MW)	Energy (GWh)	Load (%)
China	393	1945	56
France	300	788	30
Hungary	1001	2615	30
Iceland	889	5517	71
Italy	288	1365	54
Japan	2686	6805	29
New Zealand	215	1484	79
Romania	251	987	45
Soviet Union	402	1056	30
Turkey	166	423	29
United States	339	390	13
Other	142	582	47
total	7072	23957	39*

* Based on total thermal power and energy

Background

- 1974 - Present: NWC, China Lake studies at Coso Hot Springs, Adak and Fallon Naval Air Station
- 1980-82 Gruy-Federal, Inc. study of 76 DOD Installations thru DOE funding (colocation study)
- 1981 Sandia National Laboratories: report "Geothermal Resource Verification for Air Force Bases" (by Energy Resources Exploration, Inc.)
- 1982-85 CRREL geothermal study at US Army Installations (colocation study)
- 1982 Federal Buildings Program - DOE
- More than 80 DOD installations considered in DOD-Geothermal Resource colocation studies

Results of Colocation Studies

Air Force Installations

High to Moderate Potential

☆ *Ascension AAF, S.A.*

• *Lajes Field, Azores*

• *Lackland AFB, TX*

• *Williams AFB, AZ*

• *Norton AFB, CA*

• *Hill AFB, UT*

Lower Potential

• *Holloman AFB, NM*

• *Mountain Home AFB, ID*

• *Kelly AFB, TX*

• *Kingsley Field, OR*

• *Minot AFB, NB*

• *Ellsworth AFB, SD*

• *Vandenberg AFB, CA*

Results of Colocation Studies

Navy Installations

High to Moderate Potential

☆ Coso Hot Springs, CA

- Adak, AK
- Fallon Naval Air Station, NV
- Twenty-Nine Palms, CA

Space Heating

☆ Keflavik Naval Station, Iceland

- Norfolk Naval Station, VA

Results of Colocation Studies

Army Installations

High to Moderate Potential

- *Hawthorne AAP, NV*
- *Sierra Army Depot, CA*
- *Ft Bliss, TX*
- *White Sands Missile Range, NM*

Lower Potential

- *Ft. MacArthur, Los Angeles, CA*
- *Deiense Depot Ogden, UT*
- *Ft. Irwin, Barstow, CA*
- *Umatilla Army Depot, Hermiston, OR*
- *Ft. Sam Houston, San Antonio, TX*
- *Yakima Firing Center, Yakima, WA*

- ★ Air Force
- ★ Army
- ★ Navy

0 300 mi.
SCALE

- Temperature above 90°C (194°F)
- ▨ } Temperature below 90°C (194°F)
- Geopressed Resources

ECONOMIC STUDIES

Norton AFB Geothermal Heating System (180°F Geothermal Fluid)

<u>Item</u>	<u>Costs (1981 Dollars)</u>
Resource exploration & evaluation	\$271,500
Plant capital:	
Wells & Field Piping	\$5,115,000
Plant Equipment	2,254,000
Transmission System	1,430,000
Peaking Station	628,000
Contractor Mark-Up Design & Construction Management	452,000
Contingency	<u>846,000</u>
Subtotal	10,725,000
Piping Distribution System	11,000,000
Retrofit at User Site	<u>3,003,500</u>
Total	25,000,000

ECONOMIC STUDIES

Norton AFB Geothermal Heating System (180°F Geothermal Fluid)

COSTS (\$K)

Present system	Annual (1981)	20 Yr.
Fuel costs	\$1,791	\$64,096
Operations & Maintenance	448	8,956
Totals:	\$2,239	\$73,052

Geothermal System (with natural gas fired peaking station)

Plant Capital	-	\$25,000
Operations & Maintenance	643	12,860
Peaking Fuels	92	2,516
Totals:	735	40,376
Cost Savings	-	\$32,676

$\$25M \times 0.10_{CRF} = \$2.5M/yr$ $\therefore$ Not economic.

UURI

Military Geothermal Projects

(to April 1986)

COSO HOT SPRINGS, CA - China Lake Naval Weapons Test Center

- *geologic mapping, geophysical surveys*
- *well geology-DOE well site, 1977*
- *STATUS - production wells drilled by California Energy*
 - 75 MW planned

HILL AFB, UT

- *geologic mapping, geochemical surveys, geophysical surveys*
- *test well siting and drilling*
- *STATUS - inactive - no thermal water found*

WILLIAMS AFB, AZ

- *review of existing resource data*
- *review of proposal to USAF RFP*
- *STATUS - inactive - recommended USAF drop project*
 - DOD/DOE data to private developers

M-X/RES, NV and UT

- *lead contractor for M-X/RES geothermal assessment*
- *program plan and presentation*
- *STATUS - inactive - program cancelled*

LACKLAND AFB, TX

- *site and drill production well; 42°C (108°F), 450 gal/min*
- *STATUS - inactive pending long term flow test, economic evaluation*

ASCENSION ISLAND

- *geologic mapping, geochemical surveys, geophysical surveys*
- *thermal gradient drilling, 7 holes*
- *drill and test Ascension #1 : >400°F at 8000 ft; CO₂*
- *STATUS - plan to deepen Ascension #1, increase steam flow*

EXPLANATION

x Basalt Vents

⊗ Recently Active Vents

○ Trachyte Vents

—x—x— Fissure Vents

--- Dikes

— Faults

Cricket Valley

Major Structural Zones

Approx. Extent of
Cricket Valley
Sediments

Georgetown

Sisters Peak

Two Boats

Devil's
Cauldron

Weather Post

Airfield

Green Mtn.
Trachyte Vent

White
Hill

NASA

Mountain
Red Hill

Ascension Isl.

THERMAL GRADIENT HOLE LOCATION

0 1 2 3 4 5000
Scale in Feet

ASCENSION GEOTHERMAL PROJECT

Ascension Geothermal Project

Ascension #1 Siting Considerations

- ◆ **High Temperature in hole LDTGH**
- ◆ **Favorable Fluid Geothermometers**
- ◆ **Low Electrical Resistivity**
- ◆ **Within Rift Zone**
- ◆ **Close to U.S. Base**

CONCEPTUAL MODEL

Geothermal Development Ascension Island

PROJECT ECONOMICS

2MW(e)

Capital cost	0	9,803
Operating costs		
Labor	---	same ---
Maintenance	\$306K	\$200K
Fuel (1)	\$2,391K	\$239K

Total savings (1982 \$) \$2,258K

Simple Payback 4.1 years

7% discount payback

Base case	4.9 years
@ 1.42 fuel costs	6.2 years
@ 1.42 fuel costs + \$1M contingency	6.9 years

(1) $\$1.42 + \$0.36 \text{ diversion cost} = \1.78

CALIFORNIA

0 40 80
MILES

• Redding

San Francisco

Fresno •

Independence

• Bakersfield

Santa Barbara

Los Angeles

• San Bernardino

**COSO
HOT SPRINGS
KGRA**

NON-CALCAREOUS ALTERATION, UNDIFFERENTIATED
 Includes clay-opal-alunite alteration, weak argillitic alteration, stockwork opal veinlets & siliceous sinter

CALCITIC STOCKWORKS AND CALCAREOUS SINTER

Coso Hot Springs, CA

Location: *Naval Weapons Center, China Lake, CA*

Third Party Developers: *California Energy Co., Inc.*

Los Angeles Dept. of Water and Power

Power Purchaser: *Southern California Edison*

Drill Results: *8 production wells since 1981*

Additional development drilling planned

Power Development:

	<u>On Line</u>	<u>Power Plant</u>	<u>MW</u>	<u>Status</u>
<i>Unit 1 (Cal Energy)</i>	<i>1987</i>	<i>Double Flash</i>	<i>25.0</i>	<i>under construction</i>
<i>Unit 2-3</i>	<i>n.a.</i>	<i>Double Flash</i>	<i>2x25.0</i>	<i>advanced planning</i>

ATTACHMENT VI

National Parks and Preserves:

- 1) Mount Rainier
- 2) Lassen Volcanic
- 3) Yellowstone
- 4) Bering Land Bridge
- 5) Gates of the Arctic
- 6) Yukon - Charley Rivers
- 7) Katmai
- 8) Aniakchak
- 9) Wrangell - St. Elias
- 10) Glacier Bay
- 11) Denali
- 12) Lake Clark
- 13) Hot Springs
- 14) Sequoia
- 15) Hawaii Volcanoes
- 16) Lake Mead
- 17) Big Bend
- 18) Olympic
- 19) Grand Teton
- 20) John D. Rockefeller, Jr. Memorial
- 21) Haleakala
- 22) Crater Lake

REPORT OF THE STAFF COMMITTEE

Mr. Ralph E. Burr, Chairman of the Staff Committee, will present the Committee's report. The central responsibility of the Staff Committee is the coordination of the several functions of the IGCC: the on-going analyses of interagency activities in both technical and institutional areas and the preparation of oral and written reports to the Council and to the President and Congress. The Staff Committee represents the Council between the annual meetings and oversees the preparation of the meeting agendas and supporting materials.

The Staff Committee reviewed the Twelfth Annual Report and the FY-1988 Federal Geothermal Program Plan and recommended that they be submitted to the Council for approval at the annual meeting on April 28, 1988.

The major activities of the Staff Committee will be the supervision of the preparation by the BPWG of the Thirteenth Annual Report covering FY-1988 and its accompanying Federal Geothermal Program Plan for FY-1989.

REPORT OF THE BUDGET AND PLANNING WORKING GROUP

Mr. Ralph E. Burr, Chairman of the Budget and Planning Working Group (BPWG) will present the Group's report. The BPWG's principal responsibility has been the preparation of the Council's annual reports and program plans. The Eleventh Annual Report, covering FY-1986, was approved by the Council at its last meeting in April 1987. It was put in final form and sent to the President and Congress in May 1987.

The Federal Geothermal Program Plan for FY-1987 was also accepted by the Council in April 1987. It is an internal document and is not generally distributed outside the IGCC member agencies. Its purpose is to pull together in one document the members' programs and activities that impact on geothermal energy development.

The BPWG has been working on the Twelfth Annual Report covering FY-1987, as well as on the Program Plan for FY-1988. Both documents are ready for Council approval at this meeting.

**THE TWELFTH ANNUAL INTERAGENCY GEOTHERMAL
COORDINATING COUNCIL REPORT
FOR
FISCAL YEAR 1987**

Prepared by the:

**Budget and Planning Working Group
of the
Interagency Geothermal Coordinating Council**

February 10, 1988

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1.0 INTRODUCTION

Geothermal energy is the natural heat of the earth, and can be tapped as a clean, safe, and economical alternative source of energy. Three types of geothermal resources (hydrothermal, geopressed, and hot dry rock) are expected to be commercially exploited by the year 2000. A fourth type, magma, may be economic in the next century. Only hydrothermal resources, which are underground accumulations of hot water or steam, are technically and economically feasible for exploitation at this time. The highest quality hydrothermal resources are being tapped now, and much more of this energy resource is recoverable with current or near-current technology. Therefore, those resources could make a significant contribution, both to increasing domestic energy supplies and to reducing the United States' dependence on imported oil. Moreover, they can be used for various purposes: electric power production, residential and commercial space heating and cooling, industrial process heat, and agricultural process applications.

According to the Department of Energy's Energy Security report (March 1987), geothermal energy could more than double its U.S. output by 1995. The geothermal industry currently produces more than 2,000 MWe of baseload electric energy (equivalent to two nuclear power plants) at prices competitive with coal and nuclear power. Additionally the industry produced more than 2 trillion BTU's of heat energy for direct use last year. Based on a 1986 Electric Power Research Institute (EPRI) survey of industry plans, the U.S. hydrothermal electric power capacity may reach 4,700 MWe by 1995 (EPRI Survey of Utility Industry Estimated Capacity, 1986; GRC Bulletin, Sept./Oct. 1986). Thus, geothermal will play an increasingly important role in the U.S. energy future.

The Federal government has been actively involved in the development of geothermal energy since 1970, when the Geothermal Steam Act was passed. It has been engaged in the leasing of Federal lands for geothermal exploration and development, and conducts numerous research, development, and demonstration programs to investigate the use of geothermal energy. This report summarizes the accomplishments of the Federal government during fiscal year 1987, and describes Federal geothermal energy programs. Table 1 (pp. 2-5) presents a chronological history of significant geothermal energy developments.

The objective of the Federal geothermal program is twofold: 1) to provide the hydrothermal industry with near-term support to improve the feasibility and economics of geothermal development for reservoirs of lower quality; and 2) to undertake long-term, high-risk research to develop a technology base for the advanced forms of geothermal energy. This strategy will permit industry to make informed investment decisions in response to the demands of the energy market. Private industry's leading role is the direct planning, financing, and constructing of demonstration and commercial geothermal energy systems.

The efficient and timely development of geothermal resources depends on the coordinated efforts of Federal, state, and local governments; industry, consumer, and environmental groups; and private citizens. Federal responsibilities and programs are divided among a number of agencies whose activities are coordinated through the Interagency Geothermal Coordinating Council (IGCC), which was established in 1974 by the Geothermal Energy Research, Development, and Demonstration Act, Public Law 93-410. Specifically the intent of the law is ". . . to coordinate those Federal plans, activities,

and policies which are related to or impact on geothermal energy, including auxiliary activities of agencies not represented in the Council membership." The IGCC also serves as a forum for interagency program coordination and information exchange. The Council, through the Chairman, may make recommendations to the appropriate agencies and the President with regard to alternative policies or action considered necessary or desirable to expedite the development and utilization of geothermal energy resources. Member agencies include the Departments of Agriculture, Commerce, Defense, Energy, Housing and Urban Development, Interior, and Treasury and the Environmental Protection Agency. The Federal Geothermal Program budget of the member agencies is presented in Table 2.

TABLE 1
SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES

1884	District heating implemented in Boise, Idaho
1900	Hot water provided in homes in Klamath Falls, Oregon
1916	Power generation at The Geysers resort
1927	First exploratory geothermal wells drilled in Imperial Valley, California by Pioneer Development Company
1959	Small pilot plant operated near Niland, California on Sinclair No. 1 well
1960	Commercial electricity generated from dry steam at The Geysers, California
1970	Geothermal Steam Act passed (Public Law 91-581)
1973	NSF became lead agency for Federal Geothermal Programs USGS, AEC, NSF prepared the first Federal Geothermal Program Plan
1974	Geothermal Energy RD&D Act (Public Law 93-410) passed which included the establishment of the Geothermal Loan Guaranty Program (GLGP)
1975	ERDA formed; Division of Geothermal Energy (DGE) formed primarily from NSF and AEC staff to manage an RD&D program USGS released first national geothermal resource estimates and inventory
1977	Issued the first loan guaranty to Republic Geothermal, Inc. for field development at East Mesa, California DOE formed; DGE continued to manage the RD&D program Bureau of Reclamation successfully completed desalting tests to produce fresh water from geothermal brines
1978	Energy Tax Act (Public Law 95-618) passed Public Utility Regulatory Policies Act (Public Law 95-617) enacted. EPA issued pollution control guidelines for geothermal energy development Successful hot dry rock experiment conducted in New Mexico First geothermal crop-drying plant built in Nevada

TABLE 1
SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES (Continued)

-
1979	USGS released updated national geothermal resource estimates and inventory Streamlining task force recommended measures to IGCC to speed Federal leasing U.S. Navy awarded a contract to develop 75 MWe at the Coso KGRA on the Naval Weapons Center, China Lake, California First geothermal electricity produced from Federal lands, at The Geysers, California World's first experimental binary-cycle plant (10 MWe) built by industry at East Mesa, California
1980	FERC issued regulations (18 CFR 292) establishing hydrothermal geothermal resources as renewable resources and geothermal facilities as qualifying facilities World's largest single geothermal power unit (132 MWe) generated electricity at The Geysers, California 10 MWe flash-steam plant built by industry at Brawley, California First electric power from a hot dry rock resource produced at Fenton Hill, New Mexico First geothermal ethanol plant began production at La Grande, Oregon, under private funding First five DOE-sponsored field demonstrations of direct heat applications became operational First deep geothermal reservoir confirmation well drilled in Atlantic Coastal Plain near Crisfield, Maryland Crude Oil Windfall Profits Tax Act (Public Law 96-223) passed, providing tax credit increase for geothermal equipment Energy Security Act (Public Law 96-294), containing Title VI, "The Geothermal Energy Act of 1979," passed
1981	First U.S. geothermal electric generation plant outside the 48 contiguous states brought on-line in the Puna resource area in Hawaii

TABLE 1

SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES (Continued)

-
- 1981 The Insurance Company of North America began offering insurance against the financial risk of reservoir failure
- The practical demonstration of generating electricity from moderate-temperature geothermal fluids was accomplished at Raft River, Idaho
- A mobile well-head generator with a net output of 1.6 MWe was installed at Roosevelt Hot Springs, Utah
- USGS research drilling at Newberry Volcano, Oregon, indicated for the first time that temperatures (265°C at 3,057 ft) sufficient for electrical production existed in the Cascade Range
- FERC issued amendments to its regulations for qualifying small power production facilities incorporating the provisions of the Energy Security Act relating to non-utility geothermal facilities
- 1982 A 10 MWe flash plant utilizing hypersaline brine began operation at the Salton Sea KGRA, California
- An 80 MWe geothermal electric power plant to be constructed by Occidental Geothermal, Inc. in Lake County, California, and a 49 MWe geothermal electric power plant to be constructed by Republic Geothermal, Inc. and the Parsons Corporation in the Imperial Valley, California, were certified by the FERC as qualifying facilities. Magma Power Company and Magma Development Corporation issued a public notice of self-qualification for an existing 11 MWe geothermal power plant located in East Mesa, California
- In an effort by DOI to accelerate the geothermal leasing program, a record 16 competitive lease sales were held in which 578,656 acres were offered
- USGS completed the first quantitative national assessment of low-temperature (<90°C) geothermal resources of the United States
- 1983 Federal leasing regulations were rewritten, resulting in the deletion of burdensome, counterproductive requirements
- 1984 The first commercial electrical power from Federal lands outside California was generated, with 20 MWe brought on-line by Phillips Geothermal in the Roosevelt Hot Springs KGRA in Utah
- 1985 Lease acreage limit increased by DOI from 20,480 to 51,200 acres per state

TABLE 1
SIGNIFICANT EVENTS IN THE DEVELOPMENT
OF GEOTHERMAL ENERGY IN THE UNITED STATES (Continued)

1986	<p>The Salton Sea Scientific well was drilled and cored to 10,564 ft; cuttings, fluid samples and geophysical well logs were obtained, and preliminary flow tests conducted</p> <p>Congress acted to preclude geothermal leasing where, in the judgment of the Secretary of the Interior, development would result in significant adverse effects to significant thermal features in national parks.</p>
1987	<p>DOE cost-shared with industry the drilling of three deep thermal gradient test wells within the Cascades volcanic area of the Pacific Northwest -- which demonstrate the utility of this technique in identifying underlying hydrothermal features such as those beneath the Cascades.</p>

TABLE 2
FEDERAL FUNDING FOR GEOTHERMAL ENERGY (\$1000) (a)

ORGANIZATION UNIT	Actual 1979	Actual 1980	Actual 1981	Actual 1982	Actual 1983	Actual 1984	Actual 1985	Actual 1986	Actual 1987	Estimated 1988	Requested 1989
Department of Agriculture U.S. Forest Service	780	750	700	600	500	525	946	1,081	966	980	980
Department of Defense											
Navy	300	230	930	848	863	1,100	1,260	1,380	621	440	465
Air Force	0	200	1,010	182	0	0	0	0	0	0	0
DOD Total	300	430	1,940	1,030	863	1,100	1,260	1,380	621	440	465
Department of Energy											
Conservation & Renewable Energy(b)	152,990	149,870	142,521	43,713	79,939	32,615	33,511	25,200	20,630	15,935	16,465
Office of Energy Research (b)	2,100	3,102	3,305	2,650	2,500	2,400	2,600	2,800	2,930	3,000	3,000
Environment	2,820	1,950	723	0	0	0	0	0	0	0	0
GLGP (Program Direction)	0	181	193	134	120	101	121	72	72	72	72
DOE Total	157,910	155,103	146,742	47,497	82,559	35,116	36,232	28,072	23,632	19,007	19,537
Department of Interior											
National Park Service	(c)	(c)	(c)	100	50	250	250	250	225	350	1,000
Fish & Wildlife Service	200	200	70	100	50	0	0	0	0	0	0
Bureau of Land Mngt.	3,340	3,410	3,548	4,055	3,861	3,197	3,227	2,639	2,475	2,200	2,500
Bureau of Reclamation	550	910	60	60	30	0	0	0	0	0	0
Bureau of Mines	1,050	800	400	384	300	0	0	0	0	0	0
USGS, Geothermal Research Program	12,043	10,047	7,889	7,953	7,090	7,215	7,314	5,601	5,841	5,472	5,510
DOI Total	17,183	15,367	11,069	12,652	11,381	10,662	10,791	8,771	8,541	8,022	9,010
Environmental Protection Agency	920	850	1,550	(d)	(d)	(d)	(d)	(d)	(d)	(d)	(d)
TOTAL FEDERAL GEOTHERMAL PROGRAM BUDGET	177,093	172,500	162,001	60,779	95,303	47,403	49,229	39,557	33,760	28,449	29,992

- (a) Budget authority rounded to nearest thousand.
 (b) Best estimate based on the portion of BES research related to geothermal activities. The estimate represents the applicable portions of a number of research tasks.
 (c) Not available.
 (d) While the EPA budget since 1982 has not targeted resources specifically for geothermal, other R&D at EPA (e.g., disposal of liquid effluents) or programmatic activities (e.g., permitting assistance to states) may be applicable to geothermal energy.

2.0 LEASING

The goal of the Federal geothermal leasing program is to make Federal lands available to industry for exploration and development. Leasing is administered by the Bureau of Land Management, with the consent of the Forest Service where National Forest System lands are involved.

The Department of the Interior and Related Agencies Appropriations Act for FY 1987 (Public Law 99-591) was passed by Congress and signed into law October 30, 1986. Section 115 of this Act requires the Secretary of the Interior to collect and publish for public comment in the Federal Register a proposed list of significant thermal features within 22 specified units of the National Park System by February 1987. This list was published as part II in the Federal Register dated February 13, 1987. The Act specifies the criteria to be applied in determining the significance of thermal features in the specified units of the National Park System:

- (1) size, extent, and uniqueness;
- (2) scientific and geologic significance;
- (3) the extent to which such features remain in a natural, undisturbed condition; and
- (4) significance of thermal features to the authorized purposes for which the unit was created.

Based on public comments received on the proposed list, the Act authorized the Secretary of the Interior to make additions to or deletions from the proposed list and to transmit the final list to the House Interior and Insular Affairs Committee and Senate Energy and Natural Resources Committee. The Act further directed the Secretary of the Interior not to issue any geothermal leases pursuant to the Geothermal Steam Act of 1970 (30 U.S.C. 1001) until after the final list of significant thermal features in units of the National Park System was transmitted to Congress.

The final report listing significant thermal features within units of the National Park System, accompanied by copies of all the public comments received on the proposed list, was transmitted to the Congress on June 30, 1987. The final report was published as part III in the Federal Register dated August 3, 1987. With the transmittal to Congress of the list of significant thermal features, the moratorium on geothermal leasing imposed by the Act was lifted. The provisions of the Act also direct the Secretary of the Interior to maintain a monitoring program for each significant thermal feature on the final list transmitted to Congress.

The Department listed thermal features within the following thirteen (13) park units:

Mount Rainier National Park (Washington);
Yellowstone National Park (Wyoming, Montana, Idaho);
John D. Rockefeller, Jr. Memorial Parkway (Wyoming);
Bering Land Bridge National Preserve (Alaska);

Gates of the Arctic National Park and Preserve (Alaska);
Katmai National Park (Alaska);
Aniakchak National Monument and Preserve (Alaska);
Wrangell-St. Elias National Park and Preserve (Alaska);
Lake Clark National Park and Preserve (Alaska);
Hot Springs National Park (Arkansas);
Lassen Volcanic National Park (California);
Hawaii Volcanoes National Park (Hawaii); and
Haleakala National Park (Hawaii).

At the time the final report was transmitted to Congress, there was insufficient information on the possible thermal features (i.e., hydrothermal vents) at the bottom of Crater Lake within Crater Lake National Park. Thus, Crater Lake National Park was not included on the final list. A determination for Crater Lake National Park will be deferred until studies and additional reviews have been completed. Studies will be conducted on Crater Lake so that the Department may make an informed decision in FY 1988 on whether Crater Lake National Park should be added to the list. Concurrent with the studies conducted at Crater Lake to determine the significance of the hydrothermal features, no geothermal leases will be issued surrounding Crater Lake National Park under the discretion vested in the Secretary by the Congress under section 3 of the Geothermal Steam Act of 1970.

For those units in which significant thermal features are listed, future geothermal leasing will depend on whether proposals to explore for, develop, produce, or use geothermal resources surrounding the listed features are "likely to result in significant adverse, adverse, or no effects" to the thermal features listed as significant within the identified units of the National Park System. Any application for a geothermal lease received after June 1987 must be reviewed by the Secretary of the Interior, and the Secretary of Agriculture if the lease application is filed on National Forest lands, to determine the effects of proposed operations on listed features. An Interagency Agreement (IA) among the Bureau of Land Management, National Park Service, U.S. Geological Survey, and U.S. Forest Service is being negotiated to clarify the roles and responsibilities of each Bureau in making such determinations. All determinations as to the potential effect that future geothermal leasing will likely have on listed features must be published in the Federal Register for public comment and review.

No future geothermal lease can be issued in areas proposed for exploration, development or use of geothermal resources if such proposals are determined as reasonably likely to result in a significant adverse effect to any of the listed thermal features within units of the National Park System. In addition, the areas within such proposed lease applications that are likely to result in significant adverse impacts to listed features must be withdrawn from future leasing under the Geothermal Steam Act.

The Department may consider leasing areas covered by future geothermal development proposals that are reasonably likely to result in adverse effects to any of the listed thermal features within units of the National Park System. If future leases are issued in such areas, they must include stipulations designed to protect the listed thermal features during the conduct of approved activities. If, however, the Secretary determines that an ongoing geothermal operation is having a significant adverse effect on any of the listed thermal

features, all activity on the lease must be suspended either temporarily or permanently until the significant adverse effect is eliminated.

The provisions of the Act are designed to protect significant thermal features within units of the National Park System from the potential adverse impacts from future use and development of geothermal resources and will remain in effect until Congress specifically directs otherwise.

2.1 Competitive Leasing

The Bureau of Land Management (BLM) conducts competitive geothermal lease sales for land located in Known Geothermal Resource Areas (KGRA's). During FY 1988, no competitive leases were issued due to a moratorium placed on leasing by the Department of the Interior and Related Agencies Appropriations Act for FY 1987. After the moratorium was lifted on June 30, 1987, a geothermal sale was held in Nevada on September 24, 1987. A total of \$287,216 high bids was received for 10 leases, but leases have not yet been issued.

2.2 Non-competitive Leasing

Non-competitive leases are issued to the first qualified applicant by BLM for land not located within a KGRA. As a consequence of the leasing prohibition imposed by section 115 of the FY 1987 Appropriations Act, during FY 1987, only 5,561 acres were leased through this process.

2.3 Utilization

At the end of FY 1987, 725 MWe were being produced from Federal leases at The Geysers, 20 MWe from East Mesa (California), 20 MWe from Roosevelt Hot Springs (Utah), 2.5 MWe at Cove Fort (Utah), 16 MWe from Beowawe (Nevada), and 10 MWe from Desert Peak (Nevada) for a total of 793.5 MWe.

3.0 HYDROTHERMAL RESOURCE IDENTIFICATION, ASSESSMENT, AND EXPLORATION

The United States Department of Energy and the United States Geological Survey have several programs designed to evaluate the geothermal energy potential in the U.S. These programs are complementary in nature, focusing on different aspects of this goal. USGS activities emphasize geothermal resource inventory and assessment work; DOE activities focus on the technologies for more detailed study of specific resource areas. The main objectives of the USGS programs are to: (1) characterize the geological, hydrological, geochemical, and geophysical nature of the various types of geothermal resources; (2) estimate the location, distribution, and energy content of both the presently identified and the undiscovered geothermal resources of the U.S.; (3) develop resource assessment technology; (4) conduct regional resource assessments and national resource inventories; and (5) contribute to the confirmation of selected specific geothermal reservoirs. The programs also address geoenvironmental effects and issues dealing with the longevity of geothermal systems.

Major accomplishments of the U.S. Geological Survey's Geothermal Research Program in FY 1987 were:

- Completion of interrelated research projects on the geology, geophysics, and geochemistry of Newberry caldera, Oregon, and its hydrothermal system.
- Discovery, using high-resolution seismic-imaging techniques, of a large body of low-velocity material beneath Medicine Lake Highlands, California, possible magma or partially-molten rock that could be the heat source for an overlying geothermal system.
- Continuation of a major effort to sample and chemically analyze thermal and mineral springs in the Cascades (mainly in the Metolius and Deschutes River basins, Oregon) in search of waters that might have components from deep geothermal reservoirs that are hidden by overlying cool ground waters.
- Magnetotelluric soundings and telluric profiles around the Breitenbursh Hot Springs area, Oregon, for interpretation of tectonic structures and possible flow of hot ground water.
- Development of a new tectonic interpretation of the Cascades Range and its relation with westward-migrating volcanism in the Basin and Range province; areas of overlap between the two provinces may hold geothermal resources that are not associated with large stratovolcanoes.
- Acquisition of important geochemical data from new wells at Long Valley caldera, California. The new data will help in constructing an improved model of the region's hydrothermal system. The data are consistent with previous models of water being heated in the west part of the caldera and flowing east. (A previous interpretation of helium isotope ratios at Long Valley had suggested that magma was present beneath the east part of the caldera.)

- Characterization of the hydrothermal system of Norris, Shoshone, and Upper and Lower Geyser Basins in Yellowstone National Park through sampling and chemical analysis of thermal fluids.
- Reconnaissance geologic investigations and studies of hydrothermal alteration of Katmai, Alaska, to support site selection for a multi-agency (NSF-DOE-USGS) investigations of the magma body beneath Katmai volcano.
- Refinement of aeromagnetic methods to estimate the depth of the Curie-temperature isotherm (the depth at which rocks are hot enough to lose their magnetization). The new methods have been applied in the Basin and Range province of Nevada, to evaluate both known and suspected geothermal areas.
- Analysis of borehole physical and chemical data from the joint NSF-DOE-USGS Salton Sea (California) Scientific Drilling Program well. The Salton Sea data reveal a correlation between several borehole geophysical measurements and the degree of core alteration. The relation should permit rapid estimation of the alteration and, consequently, the conditions within the Salton Sea hydrothermal system.
- Fundamental research on thermodynamic properties, electronic structure, microstructures, reaction kinetics, and phase equilibria of minerals for use as geothermometers and geobarometers.
- Technical assistance to several foreign countries (Mexico, Costa Rica, Honduras, Panama, Kenya, and the Azores) on studies of geothermal fields.

Major accomplishments of DOE include cooperation with and occasional funding of some of the above USGS efforts, in addition to specific reservoir studies and reservoir engineering tasks discussed in Section 4.2. DOE is cost-sharing with industry the drilling of deep thermal gradient test wells within the Cascades volcanic region of the Pacific Northwest in order to pioneer a new exploration technology. Two wells were completed near Newberry caldera, Oregon, to depths of 4,000 ft and 4,500 ft, and another borehole was drilled to a 5,000 ft depth near Breitenbush Hot Springs. The USGS performed and will continue to perform downhole studies in these research wells.

4.0 GEOTHERMAL GEOSCIENCES RESEARCH

Geothermal geosciences technologies were initially adapted from petroleum and mining industry exploration methods, and the more recent technologies applied to liquid-dominated reservoirs were also based originally on methods used in historically established dry steam fields (i.e., Larderello, Italy and The Geysers, California). Their application to hot water reservoirs has met with only limited success. In order to ensure prudent development/investment decisions, better methods for characterizing hot water reservoirs and predicting their behavior under production/injection conditions are needed.

Private sector geothermal development begins with exploration to find and confirm the existence of a reservoir with economically exploitable temperature, depth, and volume. This phase of development starts with surface assessments by geophysicists, geologists, and geochemists. Most of the known hydrothermal reservoirs were discovered from surface manifestations, such as hot springs and hydrothermally altered rock outcrops. Exploration increasingly relies on surface geophysical measurements of subsurface properties, using methods such as electrical and magnetic techniques to evolve a model of the subsurface.

The accuracy and efficiency of exploration depend on adequate instrumentation, accurate subsurface mapping, good strategies for selecting appropriate measurements, and good data interpretation. Effective exploration strategies and interpretations depend on geothermal exploration experience and extensive analysis of the data bases from industry and government.

Subsurface assessments are then confirmed by exploratory drilling and production testing to establish reservoir properties. Field development, the next step after an exploitable resource is confirmed, utilizes the geosciences to optimize reservoir management. Conceptual geological models define the geometry and physical properties of the reservoir; geochemical models analyze changes in reservoir fluids and rocks; and numerical simulation predicts long-term reservoir behavior. The model parameters are confirmed and refined by drilling and well testing, and, in turn, are used as tools for siting wells to produce the resource for utilization and injection wells for disposal of the spent brines.

Reservoir definition is critical to obtaining financing for facilities that will require a 20-30 year supply of energy. Application of the geosciences in conjunction with exploratory drilling and production testing have been very successful in hydrothermal areas such as the Imperial Valley, California, and Cerro Prieto in Mexico.

Non-hydrothermal types of geothermal energy have special technical geoscience requirements. For example, although the technologies for handling geopressured brines are much more akin to oil and gas technologies than those used in hydrothermal applications, the forces that drive fluids from geopressured brine reservoirs are much different and more complex than those in conventional oil and gas reservoirs. Thus, it is necessary to develop an appropriate technology for forecasting geopressured geothermal reservoir performance. Due to the absence of fluids in hot dry rock formations, a variety of the geoscience tools used in characterizing subsurface hydrothermal characteristics--such as geothermometers, electrical geophysical techniques, and geochemistry--are not applicable. Current geophysical sensing systems can

be used for measurements in the magma environment although that environment is very complex, making the unambiguous interpretation of geophysical sensing very difficult.

In order to determine and improve the scientific, engineering and economic feasibility of using geothermal energy from the different resource types, the Department of Energy sponsors geothermal research projects whose potential payoffs are either too uncertain or lie too far in the future for industry to be willing to undertake without Federal cooperation and support. Notable FY 1987 achievements of the DOE/Geothermal Technology Division (GTD) program designed to define and address the special geoscience information and technology needs of geothermal energy are highlighted in Sections 4.1-4.4 below.

4.1 Hydrothermal Reservoir Research

The objective is to expand the economically exploitable hydrothermal resource available for private sector development by improving the overall performance and increasing the reliability of reservoir analysis and energy extraction systems. Reservoir technology research is designed to improve the techniques for characterizing reservoirs and mapping fractures. Several engineering techniques are analyzed and refined to determine reservoir parameters, map reservoir boundaries and fractures, identify reservoir processes and characterize boundary conditions. Reservoir modeling techniques are improved to incorporate actual geothermal fluid properties in current computer codes from studies of producing fields. Other research activities include developing and characterizing geothermal tracers and field testing advanced instruments. Research activities will continue to characterize the hydrothermal reservoirs associated with the young volcanic fields of the Cascades Range. A geothermal well was drilled into a very hot reservoir at the Salton Sea in California as part of the Salton Sea Scientific Drilling Project. The well, with a depth of over 10,000 feet, provided valuable data for evaluating the true extent of the Nation's geothermal assets. Although the original studies are essentially completed, the well remains a possible site for brine injection tests. Hydrothermal Industrialization (State Assistance) provides an opportunity for individual states to cooperatively assist in funding for hydrothermal resource assessments.

FY 1987 achievements include:

- Constructed test facilities and prepared for a long-term (20-day) flow test at the Salton Sea Scientific Drilling Project site.
- Completed design of downhole resistivity and audio magnetotelluric instrumentation for correlation with fractures in permeable zones.
- Completed interpretation of regional fracture patterns and geophysical measurements on well cores from the Coso area.
- Completed computer simulation of flow, chemical transport, and heat transfer in a typical porous reservoir containing major vertical fractures.

- The Geothermal Technology Organization entered into agreement for cooperative reservoir-related research with an industry group. This research opportunity is open to all segments of the geothermal industry.
- Completed the development and characterization of selected geothermal tracers for hydrothermal injection research.

4.2 Geopressured Reservoir Research

This research is measuring the behavior of geopressured geothermal reservoirs beneath the coastal areas of Texas and Louisiana in order to (1) refine preliminary USGS definitions of the quantity and character (temperature, methane content, chemistry) of this resource, and (2) provide a scientific and engineering basis for industry estimates of the economic feasibility of utilizing the thermal, chemical (methane), and mechanical energy contained in the basins.

FY 1987 achievements include:

- Began site preparations at the Pleasant Bayou well for flow tests which will ultimately supply brine for cooperative power generation experiments.
- Flow tested the Gladys McCall well to characterize the resource and to evaluate scale control technologies.
- Continued to monitor water quality, microseismicity, and subsidence at well sites.

4.3 Hot Dry Rock Reservoir Research

The objective is to determine the technical and economic feasibility of extracting geothermal heat from hot dry rock (HDR) resources. The technical strategy is to perform experiments at Fenton Hill, New Mexico, where an earlier HDR energy extraction loop was tested, but in a much deeper and hotter portion of the reservoir rock. A large heat exchange system has been created by fracturing the subterranean rock with over five million gallons of water. Two wells--one for injecting and the other for heat recovery--are approximately 13,000 and 12,300 feet deep respectively. The rock temperature is about 238°C (460°F). Tests will be conducted to study the extraction of heat from the system, a key step in the development of a technology for mining heat from fractured, deep, hot, rock masses.

FY 1987 achievements include:

- Development work was completed on the prototype Borehole Acoustic Televiewer (BAT).
- Clean-out, repair work and sidetracking of the EE-2 wellbore was initiated in late FY 1987.

- Reservoir microseismic studies expanded on the 3-dimensional mapping techniques, and geochemical studies were also expanded.

4.4 Magma Energy Extraction Research

The objective is to identify potential accessible magma reservoirs and determine the engineering and economic feasibility of extracting heat from them. Scientific feasibility has been demonstrated for extracting energy from magma bodies. Experimental work at the Kilauea Iki Lava Lake in Hawaii has proven that heat-extracting wells can be bored into shallow molten rock which has been degassed. Designs for magma energy extraction equipment are being developed, and materials that can withstand the magma environment--temperatures of 982°C (1800°F) and above--are being identified for potential use in well casing and downhole equipment.

FY 1987 achievements include:

- Evaluated geochemistry of water-glass heat exchanger using water/magma experiments.
- Completed preliminary magma degassing hazards evaluation.
- Assessed the nucleation of gas bubbles in a simulated magma body.
- Determined the controlling factors for crack initiation in high-temperature glasses.

4.5 Basic Geosciences Research

Other Federal agencies, including the Office of Energy Research of the Department of Energy, and the United States Geological Survey, Bureau of Mines, and Bureau of Reclamation within the Department of the Interior, have undertaken R&D activities in the geosciences area. However, neither the Bureau of Mines' program to extract minerals from geothermal fluids nor the Bureau of Reclamation's program to produce fresh water from saline geothermal fluids is active. The activities of the Office of Energy Research are centered on the conduct of basic research and development to study the geology, geophysics, geochemistry, and dynamics of thermal regions in earth of long-term relevance to geothermal resources. Research and development in these areas should assist in resource recognition and evaluation activities.

5.0 GEOTHERMAL CONVERSION RESEARCH

Geothermal conversion technologies are derived from conventional space heating and cooling, process heat, and steam turbine/electric generator technologies. Choice of application and system design are very dependent on the produced cost and physical characteristics of the geofluid.

Direct uses of geothermal fluids are the simplest applications. These include space heating and cooling, agricultural and aquacultural heating, and industrial process heating. Where the fluids are relatively pure, they can be used directly to raise fish, warm soil (stimulating crop growth), and extend the growing season. In most cases, the fluids are pumped through heat exchangers to heat air or liquids. These systems are constructed from conventional off-the-shelf components, with materials compatibility and overall costs being the major design issues. More complex systems, such as absorption refrigerators, can cool air or liquids.

Electric power generating systems must be matched to geothermal reservoir characteristics, and are based on the following approaches:

Steam power plants produce energy from vapor-dominated reservoirs. The steam is cleaned to remove solids and liquids, then fed into turbines that drive generators. The turbine exhaust usually is condensed and cooled in wet cooling towers for use as make-up cooling water, or is injected into the reservoir. This technology is well developed. Typical plants range from 35 to 120 MWe capacity.

Flash steam power plants produce energy from liquid-dominated reservoirs that are hot enough--typically above 200°C (392°F)--to flash a large proportion of the liquid to steam. Downhole production pumps keep the fluid from flashing in the production wellbores and to prevent the deposition of scale that could reduce brine flow. Flash tanks separate the liquid and steam, and the steam drives one- or two-stage expansion turbines. These systems evolve substantial waste liquid, which is either used for cooling water or pumped back into the reservoir. This technology is economical at many locations, and is being developed in sizes of 10 to 55 MWe as industry gains confidence in it.

Binary cycle power plants are appropriate for liquid-dominated reservoirs too cool for efficient flash steam production, but which contain enough heat to evaporate an organic working fluid in the 105° to 200°C (221° to 392°F) temperature range. Binary plants usually require downhole production pumps to keep the hot brine from flashing in the wellbores. The working fluid is evaporated in a primary heat exchanger, expanded through a turbine, and condensed in a secondary heat exchanger. Current technology keeps the hot water and working fluid separate in conventional heat exchangers. Advanced technology might mix the two fluids in "direct contact" heat exchangers to reduce costs with brines that produce large quantities of scale. Binary plants are beginning to see commercial power, in sizes from 0.3 MWe to 45 MWe.

Hybrid power plants may be developed to supplement geothermal heat with biomass or fossil fuels. Reservoirs too cool to generate electricity economically from the hot water alone can play an efficient "fuel-saving role" in hybrid plants.

Other aspects of conversion technology deal with the chemical constituents of geothermal fluids. These chemicals can cause scaling, corrosion, or mechanical erosion of well and surface plant components, and require special materials and mechanical or chemical treatments. Some may have considerable value as mineral sources.

Because they are very deep, geopressured geothermal wells are costly. But the combination of energy types (methane, hot brine) increases the value of the wellhead flow, which is directed into large tanks. Methane is drawn off at the top; hot brine falls to the bottom, from where it can be conveyed to local direct heat applications or to systems for converting geothermal heat to electric power. The methane can be injected into pipelines for commercial sale, or used onsite as a fuel for conventional electric power generators.

The application technologies for hot dry rock by and large would be the same as those for hydrothermal systems. Magma energy application technologies include the potential for electric power production and the possibility of using the chemical reactivity and/or high temperatures of the magma to evolve hydrogen from water, or to create synthesis gas from water/biomass mixtures.

Notable FY 1987 achievements of the DOE program in these energy recovery and conversion areas are highlighted in the following subsections.

5.1 Hard Rock Penetration

Well drilling is the fundamental technology for exploration and reservoir confirmation, and for geofluid production and reinjection. The cost of a geothermal well is up to four times higher than that of an oil or gas well of similar depth because of geothermal's higher temperatures, harder rock, and more corrosive fluids. Wells and fluid gathering systems typically comprise about one-third to one-half of the capital cost of a geothermal electric system. R&D is aimed at substantially reducing these costs through innovative drilling and well completion efforts, and increasing the safety and reducing the environmental impacts during construction of production systems. The program has strong industrial interaction and extensive technology transfer of technologies.

Notable FY 1987 achievements include:

- Completed single cutter tests under confining pressure for polycrystalline diamond cutter bits.
- Completed fabrication, testing and evaluation of insulated drill pipe for high-temperature wells.
- Completed field testing of radar fracture mapping tool.

5.2 Heat Cycle Technology

This research focuses on significant near-term improvements in energy conversion systems for hydrothermal electric power. Advanced pilot scale heat cycles are undergoing field test. Laboratory evaluations concentrate on improved heat exchangers and condensers.

Notable FY 1987 achievements include:

- Completed the fabrication of the two-dimensional nozzle (to be used in the investigation of hydrocarbon condensation behavior).
- Completed tests with several working fluids in two configurations of an apparatus designed to verify mathematical predictions of enhanced performance.
- Completed the high-temperature elastomer project in which materials suitable for temperature resistant seals were developed.
- Began testing of instruments used to monitor pH and CO₂ on-line brine chemistry in power plants. Conducted manual tests of particle-sizing instruments at Heber.
- Completed final report for the high-temperature elastomer seals project. Results include compositions of modified Y-267 elastomer formulations for high-temperature rotary sealing applications, description of test methods and test data.

5.3 Geopressured Conversion Research

The objective of geopressured conversion research is to determine the efficiency of electric energy production from geopressured resources and to determine the engineering and economic feasibility of direct uses of geopressured brines. The Pleasant Bayou well is ready for tests of electric power production with a system combining methane and thermal energy. This will be the first well system to generate electricity from geopressured brines.

Notable FY 1987 achievement:

- Detail design for the electric power generation experiment, to be conducted in cooperation with the Electric Power Research Institute, was completed at the Pleasant Bayou well site.

5.4 Hot Dry Rock Conversion Research

The objective is to measure the effectiveness and economics of thermal energy extraction from hot dry rock reservoirs. Long-range planning for a heat extraction experiment began.

Notable FY 1987 achievement:

- Began procurement and installation of surface equipment for the Phase II surface system.

6.0 ENVIRONMENT

The Federal geothermal environment program focuses on characterization of the environmental impacts from the development of geothermal energy sources and the development and evaluation of control methods to mitigate or eliminate environmental concerns, including health. The coordination among the private sector, the research community, and Federal and State government agencies on environmental matters has historically been provided by the IGCC's Environmental Controls Panel. The Environmental Controls Panel successfully completed its effort in FY 1981 to refocus and integrate Federal environmental research programs, with EPA, DOE, and DOI being the principal participants in the environmental program. Along with other IGCC specialized panels, the Environmental Controls Panel is inactive. It can be reactivated as appropriate to respond to specific concerns. The environmental program has included: acquisition of baseline data, monitoring, and research related to air quality, surface and ground water quality, hydrological alternations, ecology, solid residuals, subsidence and seismicity, health effects, and socioeconomic problems, and development and evaluation of environmental control technologies. The work since FY 1981 has concentrated on developing improved control methods and measuring actual impacts in the field.

FY 1987 achievements include:

- The hydrologic connection between geothermal targets outside of Lassen Volcanic National Park and the major geothermal system centered under the fumarolic areas within the park were evaluated. These evaluations support park protection-related goals of the National Park Service. The characterization of geothermal resources in and around Yellowstone National Park was furthered based on information gained from studies at Lassen Volcanic National Park. Work to begin defining the thermal system at Crater Lake National Park was begun.

7.0 TECHNOLOGY TRANSFER

Technology transfer is an integral part of all geothermal R&D activities. Technology transfer of the products of Federal R&D is directed toward both technology producers (manufacturers and service firms) and technology consumers (geothermal field developers, drillers, electric utilities, etc.). The program emphasizes technology transfer approaches that encourage and allow market forces to obtain and utilize the technical information provided by the government. Earlier activities that employed direct financial incentives to promote the adoption of specific technologies have been discontinued. The Annual DOE Geothermal Program Reviews and other meetings enhance the dissemination of information and coordination of R&D efforts that are important components of technology transfer. In particular, the Geothermal Drilling Organization with more than 20 industry members, provides an efficient forum for both planning and disseminating relevant technology development.

The Geothermal Energy Research, Development and Demonstration Act of 1974 provided for the establishment of the Geothermal Loan Guaranty Program (GLGP) and of the Geothermal Resources Development Fund. The objectives of the GLGP are to encourage the public and private sectors to accelerate the utilization of geothermal resources by minimizing lenders' financial risk; develop a financial service infrastructure to ultimately provide financing of geothermal projects without Federal assistance; and promote competition and encourage new entrance of firms into the geothermal marketplace. The GLGP has largely fulfilled its purpose, with nine guarantees and commitments issued since its inception, and FY 1988 activities will concentrate on program direction to monitor loans presently outstanding. One default was paid off in 1986 for the Westmorland project. The Department of Energy took possession of the collateral, and in 1987, sold it at auction. In March 1982, a Federal Register notice announced no further applications for new projects would be accepted, but all pending applications would be processed (47 FR 8555, March 1, 1982). The status of the Geothermal Resources Development Fund is described in Table 3.

Financial and economic incentives for private sector development are also provided by other Federal agencies. The Departments of Commerce and Housing and Urban Development offer financing opportunities for geothermal development in their grant programs. Communities may choose to utilize their HUD Community Development Block Grant (CDBG) funds for this purpose, and may request Urban Development Action Grants (UDAG's) provided that private sector leveraging and other requirements are met.

TABLE 3
GEOTHERMAL RESOURCES DEVELOPMENT FUND (1) AND GUARANTY AUTHORITY

		FY 1987	
		<u>FUND(\$)</u>	<u>AUTHORITY(\$)</u>
a) Program Direction		\$ 72,000	
b) Carried over from FY 86	12,500,761		
c) Guaranty fees collected	<u>463,065</u>		
d) Total available		12,963,826	
e) Paid on defaults	0		
f) Administrative expenses (2)	<u>1,453,956</u>		
g) Total Obligations		<u>1,453,956</u>	
h) Balance at end of FY 86 (b through g)		11,509,870	
i) Guaranty authority			\$500,000,000
j) Authority committed to date (8 projects)			285,398,000
k) Authority available			214,602,000
l) Total paid off on defaults			33,500,000
m) Guaranteed loans fully repaid by borrower			48,500,000

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- (1) This financial information is included in the Eleventh Annual Report to satisfy the requirements of Pub. L. 93-410, Section 204.
- (2) Contractor, consultant, and personnel costs necessary to assist in evaluating technological, geophysical, financial, marketing, management, and legal data submitted with guaranty applications and to assist in monitoring guaranteed projects.

8.0 FEDERAL USE OF GEOTHERMAL ENERGY

Where economically appropriate, the Federal government has been involved in the utilization of geothermal resources. In particular, the Department of Defense has been active in the development and use of geothermal energy at several military installations.

On July 15, 1987, at Naval Weapons Center, China Lake, California, Navy Geothermal Plant Number One, Unit Number One, began delivering power to the public utility grid. Unit One is rated at 25-megawatts capacity. NWC's peak power demand is 20 megawatts. Negotiations are underway for an additional 135 megawatts at planned Units Two through Six.

The Naval Weapons Center released three technical publications during 1987. These reports described geothermal exploration and potential at the following sites: Marine Corps Air Ground Combat Center, Twenty-nine Palms, California; Naval Air Station, Fallon, Nevada; and the Coso Field at NWC, China Lake, California.

9.0 PRIVATE SECTOR USE OF GEOTHERMAL ENERGY

Geothermal energy has been used for space and district heating in the United States since the late 1800's. Current uses include agriculture and aquacultural applications, space/district heating, and industrial applications. Currently, direct utilization of geothermal energy is less than 0.1 quads/year. Most of the direct-utilization of geothermal energy is concentrated in California, Idaho, Nevada, New Mexico, Oregon, and South Dakota. Direct-utilization is expected to grow significantly over the next few years, with expansion projected in industrial applications and district heating systems.

The commercial production of electricity from geothermal energy first occurred in the United States in 1960 at The Geysers in California. Since that time, numerous facilities have been constructed. Since March 1980, when qualification of small power and cogeneration facilities under 18 CFR 292 began, through the end of FY 1987, the Federal Energy Regulatory Commission has certified or received notices of qualifying status for 2,037 MWe of non-utility geothermal electric generating capacity.

During FY 1987, the following prospective geothermal electric generating facilities were certified by the Commission to be qualifying facilities, or filed notices of qualifying status:

<u>Applicant Name</u> <u>(Docket No.)</u>	<u>Location</u>	<u>Capacity (MWe)</u>
*Tad's Enterprises Inc. (QF84-318-001)	NV	+0.730
*Ormesa Geothermal II (QF86-681-001)	CA	+1.555
Trans-Pacific Geothermal Corp. (QF86-563-000)	NV	10.0
Trans-Pacific Geothermal Corp. (QF87-243-000)	CA	5.0
Chevron U.S.A. Inc., et al. (QF87-263-000)	NV	2.4
Yankee Caithness, Joint Venture (QF87-383-000)	NV	25.0
Far West Construction Fund Ltd. (QF87-397-000)	NV	7.4
U.S. Energy Corp. (QF87-409-000)	NV	6.5
Earth Energy, Inc. (QF87-511-000)	CA	10.0
Empire Geothermal (QF87-512-000)	NV	10.0
Anadarko Petroleum Corp. (QF87-514-000)	NV	14.0
Kilowatt Company, L.P. (QF87-586-000)	CA	20.0
Freeport McMoran Resource Ptnrs. (QF87-587-000)	CA	27.0
		<hr/> 139.585

Note: An asterisk (*) preceeding the Applicant's name indicates amended filing. Therefore, the capacity shown represents either an increase (+), or decrease (-) in capacity.

**FEDERAL GEOTHERMAL PROGRAM PLAN
FOR
FISCAL YEAR 1988**

Prepared by the:

**Budget and Planning Working Group
of the
Interagency Geothermal Coordinating Council**

January 27, 1988

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1.0 INTRODUCTION

The Federal government has been actively involved in the development of geothermal energy since 1970, when the Geothermal Steam Act (Public Law 91-581) was passed. Federal responsibilities and programs are divided among a number of agencies whose activities are coordinated through the Interagency Geothermal Coordinating Council (IGCC), which was established in 1974 by the Geothermal Energy Research, Development and Demonstration Act (Public Law 93-410). The IGCC is comprised of the Departments of Energy, Commerce, Defense, Interior, Housing and Urban Development, Treasury, and Agriculture, and the Environmental Protection Agency. The following sections delineate the FY 1988 geothermal activities that are being undertaken by the member agencies.

2.0 PROGRAM PLANS FOR FY 1988

2.1 Department of Energy (DOE)

The long-term goal of the Program is to define the scientific, engineering, and economic feasibilities of finding, producing and applying the different geothermal energy types. The Program's R&D activities will provide energy options that private industry can develop in response to market forces.

The energy option that offers near-term technology development within the Geothermal Program continues to be hydrothermal energy. The hydrothermal energy resource base remains the most technically and economically feasible to exploit of all the geothermal energy types. Many of the hydrothermal energy development projects result from adapting today's oil and gas recovery technologies in the geoscience, engineering and energy conversion fields. Many (but not all) technical advances can then be modified to fit the distinct geological, chemical and temperature characteristics of the advanced geothermal energy types--geopressured, hot dry rock and magma. This is to be accomplished by undertaking high-risk, high-payoff research and development and related activities in the major areas of geosciences research and energy conversion research. In addition, selected state assistance projects are being supported.

2.1.1 Geosciences Research

Major FY 1988 activities in geosciences research are highlighted below.

- Reservoir Definition Geological, geochemical, geophysical, and reservoir engineering techniques used to determine reservoir parameters for mapping boundaries and fractures will be refined throughout FY 1988. By incorporating actual geothermal fluid properties in current computer codes, reservoir modeling techniques should improve.
- Brine Injection Work will continue with tracers and the modeling of fluid migration to understand the behavior of injected fluid. Analyses of the migration of injected fluids will be performed and injection fronts will be tracked. From this work, chemical and thermal breakthroughs to production wells will be predicted. The

Salton Sea Scientific Drilling Program Well is being investigated as a possible site for further brine injection experiments.

- Exploration Technology The purpose of this research is to increase knowledge of applicable exploration techniques and the depth required to penetrate the overlying cold ground water systems that mask and suppress young volcanic hydrothermal systems. In FY 1988 the results of the cost-shared work done in the Cascades will be made available through a workshop and publication of the final results.
- Geopressured Reservoir The objectives of FY 1988 activities are to provide a model predicting geopressured reservoir performance based on long-term flow testing and show the economics of the total geopressured recovery system. Flow tests are scheduled at the Pleasant Bayou well to characterize these resources. The Pleasant Bayou site is being prepared for production and for the testing of a hybrid pilot plant with the Electric Power Research Institute. A detailed geologic investigation of the Gladys McCall geology will help to determine the reservoir's geometry and fluid sources. Production and geochemical data from tests will be analyzed, and water quality, microseismicity, and subsidence monitored.
- Hot Dry Rock Reservoir Final repair of wellbore EE-2 will be accomplished by sidetracking the well around a badly damaged section. This will be followed by final assembly and check out of the closed loop system in preparation for start of the Long Term Flow Test (LTFT). The twelve-month closed loop flow test will start toward the end of FY 1988.
- Magma Energy Extraction Preparation for drilling a deep geophysical observation well will be initiated at Long Valley, California. Preparation includes drill site evaluation and long-term magma/metal compatibility studies. The actual drilling may start as early as September 1988.

2.1.2 Conversion Research

Major FY 1988 activities in energy conversion research are highlighted below. (Energy utilization aspects of geopressured and hot dry rock resources are incorporated into the highlights of relevant geosciences research areas.)

- Hard Rock Penetration The primary activities in FY 1988 are research on two-phase (solid/liquid) drilling fluids for plugging fractures, measurement of performance of candidate materials in the Lost Circulation Test Facility, and systems analysis of coring technology. Other R&D efforts will include: testing insulated drill pipe for high-temperature drilling, development of a radar fracture mapping tool, and construction of a laboratory model for acoustical data telemetry. Joint-venture R&D efforts with industry will include: lost circulation testing in the field, a drill string dynamics user group, wellbore diagnostics, high-temperature elastomer development, testing of drill pipe protectors and rotating head seals, and evaluation of a downhole air turbine for drilling.

- Conversion Technology The principal activities of the Heat Cycle Research Program in FY 1988 will be reconfiguration and possibly relocation of the Heat Cycle Research Facility, and analysis of data from past experiments aimed at validating heat exchanger rating codes for geothermal applications. The Materials Development Program will focus on high-temperature well cements and lost circulation control materials. Investigation of non-metallic heat exchanger tube linings will be a joint effort of the two programs.

2.1.3 Hydrothermal Industrialization

In FY 1988, DOE will continue its National Geothermal Information Service and Technical Assistance Program, whereby states and the public can obtain technical information on geothermal resources and engineering assistance for direct-use applications. This activity has served to sensitize the states to the potential benefits of hydrothermal exploration. By this time, the states are well aware of this potential and the need for special outreach activities has been satisfied. Informal coordination will be continued on an ad hoc basis as needed.

2.1.4 Geothermal Loan Guaranty Program (GLGP)

The Geothermal Energy Research, Development and Demonstration Act of 1974 provided for the establishment of the GLGP and of the Geothermal Resource Development Fund. The objectives of the GLGP are to encourage the public and private sectors to accelerate the utilization of geothermal resources by minimizing lenders' financial risk; develop a financial service infrastructure to ultimately provide financing of geothermal projects without Federal assistance; and promote competition and encourage new entrance of firms into the geothermal marketplace. The GLGP has largely fulfilled its purpose, with nine guarantees and commitments issued since its inception, and FY 1988 activities will concentrate on program direction to monitor loans presently outstanding. In March 1982, a Federal Register notice announced no further applications for new projects would be accepted, but all pending applications would be processed (10 CFR 790, March 1, 1982, Vol. 47, No. 40, p. 8555).

2.2 Department of the Treasury

The Department of the Treasury does not allocate funds directly to geothermal activities. Departmental participation in this program is handled within the normal staff expenses. Treasury's geothermal-related function is as a lender, under the guaranteed loan program, through the Federal Financing Bank. No lending activity under the Geothermal Resources Development Fund is scheduled for FY 1988.

2.3 Department of Housing and Urban Development (HUD)

The success of community and economic development efforts is influenced by the availability and cost of energy. Therefore, the Department of Housing and Urban Development (HUD) is providing funds that may be used, at the discretion of the recipients, to assist communities in energy-related matters, including geothermal. This is pursuant to recent Congressional authorization for HUD to

provide funding for energy production and conservation projects under the Community Development Block Grant (CDBG) program.

Also pursuant to such authorization, HUD provides support to community energy projects which have private capital at risk under the Urban Development Action Grant (UDAG) Program. HUD field offices (Community Planning and Development Divisions) may be contacted by localities that wish to make use of the UDAG program to finance energy conservation and alternative energy supply projects, including geothermal.

2.4 Department of Commerce (DOC)

The Economic Development Administration (EDA) was established within the Department of Commerce for the purpose of stimulating business activity in economically depressed areas. The Public Works and Development Facilities Program has awarded project grants for up to 80% of the cost of constructing facilities needed for long-term economic growth. The Business Development Assistance Program has provided loan guarantees to businesses establishing or expanding plants. EDA loan guarantees are intended to stimulate or facilitate business development, and as such, EDA is not specifically a proponent of geothermal development. Although projects involving the utilization of hydrothermal energy may be funded by EDA, they would not receive preferential consideration because of their geothermal utilization. The President's FY 1988 Budget indicates that such earmarking is no longer appropriate and proposes elimination of the EDA except for monitoring of previous obligations.

2.5 Environmental Protection Agency (EPA)

EPA's principal role in geothermal development is to assess environmental parameters and to assist responsible parties to control significant pollution problems. The Agency, which provides guidance, standards, and pollution-control regulations, has no specific geothermal regulations in force. However, any installation must meet EPA (or state, where delegated) permitting requirements which determine acceptable discharge levels of pollutants in the atmosphere, in and to receiving waters, in drinking water aquifers, and on land.

In FY 1988, EPA plans to continue to monitor the progress of geothermal developers. At this time, no regulatory actions are planned which would uniquely impact the geothermal industry.

2.6 Department of Agriculture (DOA) - U.S. Forest Service (FS)

The Forest Service is responsible for consenting to the issuance of leases by the Bureau of Land Management (BLM) for National Forest System lands and for providing terms and conditions for adequate protection of those lands. In accordance with the general aim of giving priority to mineral leasing activities, the Forest Service, in conjunction with BLM, will continue its priority consideration of geothermal leasing proposals, except where directed by Congress not to process lease applications in wilderness, Congressionally-mandated wilderness study areas and the RARE II study recommended wilderness and further planning areas. The Forest Service reviews exploration and

development operating plan proposals involving National Forest System lands to provide terms and conditions for adequate protection of these lands. The Forest Service also permits preliminary exploration to obtain indications of geothermal resource potential prior to leasing.

In accordance with part 2(e) of section 115 of the 1987 Appropriations Act, "The Secretary of Agriculture shall consider the effects on significant thermal features of those units of the National Park System in determining whether to consent to leasing under Geothermal Steam Act of 1970, as amended, on National Forests and other lands administered by the Department of Agriculture available for leasing under the Geothermal Steam Act of 1970, as amended, including public withdrawn and acquired lands."

2.7 Department of the Interior (DOI)

2.7.1 Bureau of Land Management (BLM)

2.7.1.1 Leasing Activity

The Department of the Interior and Related Agencies Appropriations Act for FY 1987 placed a moratorium on all new geothermal leasing until a "Report on Significant Thermal Features within Units of the National Park System" was transmitted to Congress on June 30, 1987. As a result, no geothermal leases were issued except for three noncompetitive leases in Nevada for 5,561 acres. A geothermal lease sale was held in Nevada on September 24, 1987, in which 40,671.5 acres were offered. Total high bids were \$287,216 for 10 leases covering 20,474.64 acres in Dixie Valley and Rye Patch, Nevada. A geologic analysis has been completed for the Glass Mountain KGRA in California. It is expected that approximately 40,000 acres will be offered for sale in the second quarter of FY 1988.

2.7.1.2 Exploration and Development Proposals

Present electrical generation from Federal leases totals approximately 793.2 MW, mostly from The Geysers. East Mesa in California, Beowawe and Desert Peak in Nevada, and Roosevelt Hot Springs and Cove Fort in Utah also contribute. A small nonelectrical plant in Animos Valley in New Mexico supplies heat for a greenhouse. Ormesa placed a 30 MW plant on line in East Mesa in early 1987 and has a 20 MW plant under construction. Six plans of utilization have been submitted in California. Three at East Mesa include two plants proposed by GEO Co. for 37 MW each and one plant proposed by Ormesa for 10 MW. Three proposals for China Lake Naval Weapons Center in California were exempted from the National Wildlife Federation lawsuit by the court in January 1987: California Energy Co. for two plants of 45 MW each and the Los Angeles Department of Water and Power for a 10 MW pilot plant. Environmental documents were prepared for a 10 MW plant to be constructed at Mammoth Lakes, California, by Pacific Lighting and Energy Systems. A protest received from the Sierra Club will delay further activity until at least early 1988. In Nevada, there are two plants in production: one, a 10 MW at Desert Peak; and the other, a 16 MW plant at Beowawe. Four plants are currently under construction in Nevada: 3.6 MW at Soda Lake, 15 MW at Steamboat Hot Springs, 65 MW at Dixie Valley, and 4.8 MW at San Emidio. Also two new proposals have been made: one for a 4.8 MW

facility at Brady Hot Springs, Nevada, and one for 15 MW at Fish Lake Valley, Nevada.

2.7.2 United States Geological Survey (USGS)

The goal of the U.S. Geological Survey (USGS) Geothermal Research Program is to understand the nature, distribution, and magnitude of geothermal resources of the United States, as a basis for determining the proper role of geothermal energy as one of the alternative energy sources in national energy policy. The long-term objectives of the Program are (1) to characterize the geological, geochemical, geophysical, and hydrological nature of the various types of geothermal systems; (2) to assess quantitatively the Nation's geothermal resources, periodically updating the assessments as new information becomes available and as assessment methodologies are refined; and (3) to evaluate the possibility and nature of environmental effects, including increased seismicity, ground subsidence, and hydrologic changes, that may be induced by the withdrawal of fluids from, or injection of fluids into, a geothermal system. These objectives include estimates of the distribution and energy content of the deeper, undiscovered hydrothermal resources and development of methodologies and techniques for assessing thermal energy stored in magma and hot dry rock.

Current plans for future research emphasize (1) fundamental scientific investigations of the deep magmatic and thermal regions of the Earth's crust to develop complete physical and chemical models of processes during formation of geothermal resources, and (2) multi-disciplinary studies to define the characteristic parameters of all types of geothermal energy sources associated with young volcanic areas. Investigations of processes help to identify the various types of geothermal resource, to describe the flow of magmatic heat within geothermal resource areas, and to understand the recharge of hot water systems with cooler fluids from surrounding areas. This research leads to techniques for the estimation of the amount of thermal energy in individual geothermal systems and within broader geothermal regions, and of the distribution of this energy in molten rock, in hot dry rock, and in zones of hot circulating water. The characterization studies consist of site-specific studies of individual geothermal systems, as well as regional geological and geophysical studies to establish a framework for determining where geothermal resources are likely to occur. This research leads to specific and regional models of geothermal systems, estimates of the nature, location, and energy content of geothermal resources of the United States, and an evaluation of the recoverability of thermal energy from hydrothermal resources. All of these studies will be supplemented by data from cooperative deep drilling projects of the Federal continental scientific drilling program of the National Science Foundation, Department of Energy and the USGS.

Because of the higher thermal energy potential of the deeper crust, emphasis is being given to young igneous centers where magma, hot dry rock, and hydrothermal convection resources occur in the same location. The Geological Survey estimated in its 1978 nationwide geothermal resource assessment that the amount of thermal energy stored in magma, hot dry rock, and hydrothermal convection zones to a depth of 6 miles might be as much as 100 times the energy stored in shallower (less than 2 miles) hydrothermal convection zones alone. Although the technology of extraction of some of this deep geothermal energy is not yet economically competitive with other energy sources, the potential

impact of such a large amount of energy is immense. Of particular interest to industry are the centers of recent volcanism in the Cascades, due in large part to discovery of a high-temperature hydrothermal system in a USGS research well at Newberry Volcano in Oregon.

In FY 1988, a multi-disciplinary study of the Cascade Range will continue to be a major part of the USGS Geothermal Research Program, with efforts focusing on an integration of the resulting data. A project to assess Cascades geothermal potential will be established, with the near-term goals to evaluate the regional geologic and tectonic setting in which geothermal systems of the Cascades occur and to evaluate the degree to which subterranean flow to cold water masks deep hot geothermal systems.

Other FY 1988 plans include:

- Cooperative investigations with the Department of Energy to evaluate the geothermal energy potential of selected Central American countries.
- Monitoring of flow rate, temperature, and chemical composition of springs in the Lassen geothermal area in northern California to establish baseline measurements and natural variations against which the effects of future geothermal development may be assessed.
- Cooperation with the Department of Energy and the National Science Foundation in direct sampling of the deep parts of hydrothermal convection systems and magmatic systems by deep drilling.
- Geologic field mapping of Medicine Lake, Lassen Peak and vicinity, Crater Lake, Mt. Adams, Kilauea, and Mauna Loa volcanic areas, for assessment of Cascades and Hawaiian geothermal resources.
- Compilation of a geologic map of the Cascades in California, Oregon, and Washington, together with potassium/argon age determinations, to recognize and interpret regional changes in volcanism and their implications for geothermal systems.
- Geophysical and geochemical studies of the Katmai volcanic complex, Alaska, in support of continuing geological mapping and alteration studies for the planned multi-agency deep-drilling project.
- Revision of a conceptual model for the Long Valley, California, geothermal system, incorporating data from new (and newly accessible) drill-hole data.
- Isotopic studies to corroborate and refine non-isotopic interpretations of geothermal fluids.
- Establishment of a new seismic network for western Oregon, required for understanding of volcano-tectonic relations that can create areas of high-heat flow and geothermal potential.
- Improvement of computer models of transient electromagnetic soundings for imaging geologic structures related to hydrothermal systems.

- Development of a multichannel electrical resistivity system--a refinement of single-channel resistivity surveys that are a foundation of traditional geothermal exploration.
- Regional magnetic, gravity, and geoelectrical studies of the Cascades Range, and chemical studies of its thermal springs, to test the hypothesis that cold surface waters mask deep geothermal resources in the Pacific Northwest.
- Selection of appropriate methods to evaluate possible effects of geothermal development on thermal features in National Parks, including Lassen Volcanic, Crater Lake, and Yellowstone National Parks.
- Refinement of geophysical techniques to detect, delineate, and characterize subsurface magma bodies using advanced active and passive seismic techniques and integration of the results using newly developed tomographic models.

The geothermal research activities of the USGS are closely coordinated with those of the U.S. Department of Energy (DOE). Some activities of the USGS program contribute to certain objectives of the geothermal energy program of DOE which, accordingly, has provided the USGS with some supplemental funds to increase the timeliness of such activities.

2.7.3 Fish and Wildlife Service (FWS)

Although the Fish and Wildlife Service (Service) does not have line item funds for geothermal activities in FY 1988, the Service plans to continue its role in the fish and wildlife aspects of the Federal Geothermal Program in cooperation with the lead agencies and to further the Department's geothermal leasing program in keeping with the Service's objective of supporting the sensible and orderly development of energy and mineral resources.

Several field stations in the west have been actively following the Federal Geothermal Program in order to achieve early identification of endangered species and critical fish and wildlife habitat issues. Plans are to continue this modest activity in FY 1988. The Service believes that early coordination with BLM, USGS, and FS is essential to expedite the Federal Geothermal Program. To make the best use of limited resources and avoid unnecessary delay on projects involving important fish and wildlife considerations, it is imperative that the Service be informed of upcoming actions and areas of potential conflict on a continuing, timely basis.

2.7.4 Bureau of Mines

Nearly a decade of continuous involvement by the Bureau of Mines in research involving geothermal resources recovery, e.g., geothermal brine minerals recovery and materials applications, ended in FY 1983. Concluding efforts concerned minerals processing technologies to recover lithium from geothermal brines. Additionally, research was conducted to recover tungsten from the brines of Searles Lake, California. Final research results were published in FY 1984.

2.7.5 Bureau of Reclamation

The Bureau of Reclamation has funded several projects studying the utilization of geothermal fluids to augment the limited water resources of the western United States. Three desalting plants were built and testing was conducted. Although the desalting process proved feasible, the reservoir that was utilized for the testing was assessed as insufficient for full-scale production and the tests were terminated. Studies of geophysical testing of approximately 10 sites were completed in Arizona, Nevada, and California. The Bureau of Reclamation is currently not active in geothermal studies.

2.7.6 National Park Service (NPS)

The Department of the Interior and Related Agencies Appropriations Act for FY 1987 (Public Law 99-591) was passed by Congress and signed into law October 30, 1986. Section 115 of this Act requires the Secretary of the Interior to publish a list of significant thermal features.

The final report listing significant thermal features within units of the National Park System, accompanied by copies of all the public comments received on the proposed list, was transmitted to the Congress on June 30, 1987. The final report was published as part III in the Federal Register dated August 3, 1987. With the transmittal to Congress of the list of significant thermal features, the moratorium on geothermal leasing imposed by the Act was lifted. The provisions of the Act also directs the Secretary of the Interior to maintain a monitoring program for each significant thermal feature on the final list transmitted to Congress.

The Department listed thermal features within the following thirteen (13) park units:

Mount Rainier National Park (Washington);
Yellowstone National Park (Wyoming, Montana, Idaho);
John D. Rockefeller, Jr. Memorial Parkway (Wyoming);
Bering Land Bridge National Preserve (Alaska);
Gates of the Arctic National Park and Preserve (Alaska);
Katmai National Park (Alaska);
Aniakchak National Monument and Preserve (Alaska);
Wrangell-St. Elias National Park and Preserve (Alaska);
Lake Clark National Park and Preserve (Alaska);
Hot Springs National Park (Arkansas);
Lassen Volcanic National Park (California);
Hawaii Volcanoes National Park (Hawaii); and,
Haleakala National Park (Hawaii).

At the time the final report was transmitted to Congress, there was insufficient information on the possible thermal features (i.e., hydrothermal vents) at the bottom of Crater Lake within Crater Lake National Park. Thus, Crater Lake National Park was not included on the final list. A determination for Crater Lake National Park will be deferred until studies and additional reviews have been completed. Studies will be conducted on Crater Lake so that the Department may make an informed decision in FY 1988 on whether Crater Lake National Park should be added to the list. Concurrent with the studies conducted at Crater Lake to determine the significance of the hydrothermal

features, no geothermal leases will be issued surrounding Crater Lake National Park under the discretion vested in the Secretary by the Congress under section 3 of the Geothermal Steam Act of 1970.

Studies to Determine the Significance of Crater Lake National Park, as required by Public Law 99-591:

The preliminary field report covering studies conducted during fiscal year 1987 on the hydrothermal processes in Crater Lake, Crater Lake National Park, was submitted to the Secretary of the Interior in October 1987. The data strongly support the presence of hydrothermal input to the bottom of Crater Lake. The exact nature of the discharge is uncertain and requires further study. Using a remote camera, the researchers observed many locations with hydrothermal precipitates and diffuse flow at two sites. Their observations are compatible with dispersed flow through sediments from a number of vent sites. A small, manned submersible will be used in the summer of 1988 to facilitate a more thorough mapping of the thermal features of the lake and sample the venting fluids. Such work is necessary to understand the role that hydrothermal activity has on the chemistry, biology, and physics of Crater Lake.

Monitoring Program for Significant Thermal Features in Units of the National Park System:

Responding to the requirements of section 115 of Public Law 99-591, NPS will implement a program of geothermal monitoring and baseline resource identification to better understand the active thermal features under its custody. This program will be designed to compile data (scientific evidence) needed to assure that thermal features in the identified parks are not adversely affected by the exploration, development, or utilization of the lands subject to geothermal lease application. The program also will be designed to insure minimal delay and/or costs to geothermal lease applicants.

Under this monitoring program, three categories of activities are planned:

- (1) A program of description, study and regularly repeated observational measurements of geothermal features in NPS areas (spring description, location, temperature, flow, etc.) and a program to complete geological maps at appropriate scales for all areas with geothermal features;
- (2) Geophysical, geochemical, hydrological and geothermal studies to provide improved subsurface understanding between areas where leasing and preservation conflicts are known to exist; and,
- (3) An observation well monitoring program and program of analysis for those areas where geothermal development has proceeded and geology between the developed area and park features is incompletely understood and/or there is potential that the hydrothermal systems may be linked. This program will be part of the mitigation requirements of the developer. Data will be provided to NPS and other responsible Federal agencies.

2.8 Department of the Navy

The Navy's planned R&D efforts in FY 1988 include additional geological studies on the China Lake, California, Coso reservoir and the initiation of geoscientific studies at Indian Wells Valley, California. Also, technical publications will report findings of drilling studies at Pickel Meadows, California.

2.9 Federal Energy Regulatory Commission (FERC)

The Federal Energy Regulatory Commission does not allocate funds explicitly for geothermal programs. The Commission's participation occurs through the issuance and administration of rules establishing certain geothermal facilities, generating electric power, as qualifying facilities eligible for the benefits afforded by the Public Utility Regulatory Policies Act (PURPA) to electricity producers using renewable energy sources. The benefits include a requirement for power purchase by electric utilities at full avoided cost, and exemption from Federal and state rate or financial regulation. The Commission also administers the special geothermal power benefits authorized by the Energy Security Act of 1980 (Public Law 96-294) for both utility and non-utility owned geothermal projects. Wholesale rates for sale of electricity by one utility to another are determined by the Commission. Where these involve issues of geothermal power costs, the geothermal facility returns are affected by the Commission's decisions.

Presentation on:

Department of Energy's Geothermal
Research and Development Program

John E. Mock
Director
Geothermal Technology Division
U.S. Department of Energy

Presentation on:

Department of Defense Geothermal Activities

**Carl F. Austin
Head of Geothermal Program Office
U.S. Naval Weapons Center
China Lake, California**

Presentation on:

Status of the U.S. Geothermal Industry

**David N. Anderson
Executive Director
Geothermal Resources Council
Davis, California**

Presentation on:

The Committee on Renewable Energy Commerce and Trade

**Robert H. Annan
Director, Photovoltaics Technologies Division
Department of Energy**

NEW BUSINESS

Miss Donna R. Fitzpatrick, Chairman, Interagency Geothermal Coordinating Council will open the floor to any new business.

PLANS FOR NEXT MEETING

The next meeting of the full Council of the IGCC is tentatively scheduled for April, 1989.