GEOTHERMAL ELECTRIC POWER, THE STATE OF THE WORLD — 1985

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INTRODUCTION

The purpose of this rapporteur's report is to summarize the most important aspects of the set of technical papers from the various countries around the world in which geothermal energy is now being used to generate electricity, or which are expected to do so in the near future.

We shall avoid repeating data which can best be studied within the context of each individual paper, but rather will focus on the trends that emerge from a comprehensive view of the data in their totality. This data will be incorporated with this author's own past studies to form a long-term growth pattern in geothermal power that may provide a clue as to the future growth possibilities in the field on a worldwide basis.

Since there is no individual paper on the United States in the electric power section, we will go into more detail for the United States than for the other countries. No formal survey was conducted of field developers, utilities, etc., but rather the author has drawn from his continuing study and information gained from selected individuals and organizations.

For the purpose of presentation, the countries of the globe have been grouped into geographical clusters. Within each cluster, brief summaries of the activities of each country are described in alphabetical order. In most cases the summary is drawn from the individual country papers; in some cases, the author has relied on his own resources.

AFRICA

Djibouti Republic

Surface thermal manifestations have been discovered at ten areas in the Djibouti Republic: Lake Asal, Allol-Sakalol, N. Goubbet, Gaggade Area, Hanle, Lake Abbe, Arta, Dorra, Gadjoura, and Obock. Geochemical studies have been done at all sites, and geological and geographical studies have been carried out at most. Only at Lake Asal and Hanle have exploratory wells been drilled. The maximum temperature found in well Asal-1 was 258° C, the flow rate was 37.5 kg/s, and the salinity was 128,000 ppm. It has been estimated that about 300 MWe might be obtained from the Lake Asal prospect.

Reference:

"Geothermal Prospects in the Djibouti Republic," A.M. Houmed, *Proc. 6th N.Z. Geoth. Workshop*, U. Auckland, 1984, p. 227-231.

Ethiopia

There are nine hydrothermal areas that have been identified so far in Ethiopia. The Lake District, 300 km south of Addis Ababa, has three such areas: Wondo Genet, Lake Abaya, and Lake Langano. In the last area, four wells have been drilled: LA-1 and -2 were not productive; LA-3 and -4 are both productive. Reservoir temperature is high, in excess of 290° C, but permeability is low. The estimated power potential of the two producers is 2 to 3 MW. A total of nine wells is scheduled for the area.

References:

"The Geological Environment of the Ethiopian Hydrothermal Areas," G. Demissie, *Proc. N.Z. Geoth. Workshop*, U. Auckland, 1980, p. 167-170.

"Minimum Age of the Aluto Geothermal System (Ethiopia) from Fossil Temperatures Beneath a Deep Lateral Outflow," M.P. Hochstein, G. Caldwell, and K. Kifle, *Proc. 5th N.Z. Geoth. Workshop*, U. Auckland, 1983, p. 209-212.

Kenya

The first geothermal power plant on the African continent is located at the Olkaria field in the East African Rift Zone. The plant is owned by the Kenya Power and Lighting Company, which plans to expand the plant in the near future. The facility is currently rated at 45 MW (three 15 MW units). The first unit was inaugurated in August 1981, the second in December 1982, and the third in March 1985. The operation has been excellent; a capacity factor of 0.88 was achieved for the first two units through 1983. By 1990 KP&L plans to have 120 MW installed at Olkaria. See Table 1.

The Olkaria field is believed capable of supporting much more than the existing 45 MW. The reservoir temperature ranges from 245 to 300°C, the depth of the reservoir is about 1000 m, and more than 25 wells have been drilled to date. The power potential of each well is only 1.0 to 2.5 MW because of low permeability; the average flow rate per well is about 4.4 kg/s of essentially dry steam at a wellhead pressure of 600 kPa.

The present power plant and well field lies in the eastern sector of the field and covers an area of about 2 km^2. Several exploration wells drilled to the west and northwest of the present plant have been successful and may eventually lead to a much larger area of exploitation, perhaps as much as 25 km^2. The three units at Olkaria supply about 21 percent of Kenya's electric power, and the ultimate geothermal power potential of the country has been estimated at 1400 MW for 25 years.

References:

"First Geothermal Power Plant in Africa," Mitsubishi Heavy Industries, Ltd., Tokyo, Japan.

"Nations Moving to Exploit Vast Rift Valley Geothermal Resource," B.M. Murphy, *Renewable Energy*, May 1983.

Mr. P. Getecha, Technical Manager, Kenya Power and Lighting Co., Ltd., Nairobi, Kenya. Personal communication.

Tanzania

There appears to be good potential for geothermal energy in Tanzania, but little activity is evident at present. In the Songive River Valley, in the Mbeya region, average reservoir temperatures are in the range of 140 to 200°C; the maximum temperature is about 220°C. In the Musoma area, a 35 m well encountered fluid at a temperature of 98°C. Other areas cited are Ngorongora and Kisaki Tangalala.

References:

"Reconnaissance of Geothermal Resources in Tanzania," G.M. Kifua, *Proc. N.Z. Geoth. Workshop*, U. Auckland, 1980, p. 175-179.

Response to GRC Questionnaire, J.S. Makundi ; This Volume.

Other Countries

The following other countries in Africa have identified geothermal resources that eventually may be exploited: Burundi, Malawi, Rwandi, Uganda, and Zaire.

CENTRAL AMERICA

Costa Rica

An outstanding prospect is under development at the Miravalles geothermal field in the Guanacaste province of Costa Rica. Five wells have been completed, all successfully, and the estimated power potential is 23 MW for a single-flash plant or 32 MW for a double-flash plant. The fluid temperature in the reservoir is about 240°C and some calciting of the wells has been observed. The Instituto Costarricense de Electricidad (ICE) expects to begin construction of a 50 MW (est.) plant in the near future, to be on-line by 1990.

References:

"Costa Rica: Country Update Report," M.F. Corrales; This Volume.

El Salvador

El Salvador was the first country in Central America to operate a geothermal power plant. Ahuachapan Unit 1 was put into service in June 1975; it was followed one year later by Unit 2. In 1980 the Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL) installed a third unit at Ahuachapan. See Table 2.

Units 1 and 2 are single-flash plants that receive steam from individual wellhead separators; Unit 3 is a double-flash plant that receives steam from wells and flash tanks in which the separated liquid from the wellhead separators is flashed to generate low-pressure steam. The units are rated at 30, 30 and 35 MW, respectively.

Waste liquid has been disposed of different ways. One is by disposal to the Pacific Ocean via a 75 km covered concrete canal with 16 siphons along the way to traverse the rugged countryside; the other is by reinjection at the periphery of the field. For a short time at the beginning of plant operations in 1975, the waste was discharged into the nearby Rio Paz until the canal was completed. From time to time, the amounts of fluid being sent to the canal and to the injection wells have been varied in an attempt to optimize the production of the field. This has not been altogether successful since the reservoir pressure has declined dramatically. From 1975 to 1984, the reservoir fluid pressure has dropped from 3334 to 2118 kPA, during which time 167.4×10^9 kg of fluid were produced and 37.6×10^9 kg were reinjected. Reinjection has generally produced positive results as regards reservoir engineering; fluid pressures were kept reasonably stable during injection although two wells were badly sited for reinjection purposes. The onset of operation of the third unit appears to have destabilized the balance in the reservoir and precipitated the steep decline in pressure and temperature. The temperature drop is associated with the pressure drop as would be expected for a two-phase, liquid-vapor condition, plus an additional amount in the case of those wells located near reinjection wells. Reinjection was stopped at the beginning of 1983; it has been recommended that it be reinitiated on a more efficient and planned schedule.

References

"Ahuachapan Field Management." A. Vides Ramos: Unpublished report.

"The Geothermal Power Station at Ahuachapan, El Salvador," R. DiPippo. *Geoth. Energy Mag.*, Vol. 6, Oct. 1978, p. 11-22.

"Ahuachapan Geothermal Power Plant, El Salvador," R. DiPippo, *Proc. Fourth Annual Geoth. Conf. and Workshop*, EPRI Rep. No. TC-80-907, 1980, p. 7.7-7.12.

Guatemala

A 15 MW single-flash plant is scheduled to be built at Zunil. A half dozen wells exist at the site, four of which are considered good producers (3.55 MW average power potential). Financing for the next phase of the project is being arranged and construction could begin in 1985. In addition to the currently drilled part of Zunil, other promising geothermal areas in Guatemala include: Zunil Stages II and III, Amatitlan, and Moyuta. At least nine other areas have been identified but await further exploration and definition.

Reference:

Sem. Latinoamericano sobre Exploracion Geotermica, OLADE, Sept. 1983, p. 73-99.

Honduras

Although there are about 16 known geothermal areas in Honduras, five have been designated as principal ones: San Ignacio, Platanares, Azacualpa, El Olingo, and Sambra Creek. There is no plan at this time to develop any into an electric generating facility.

Reference:

Sem. Latinoamericano sobre Exploracion Geotermica, OLADE, Sept. 1983, p. 105-110.

Nicaragua

Nicaragua has been operating Momotombo Unit 1, a 35 MW single-flash plant, since 1983. The plant is located on the southern flank of the volcano Momotombo on the shore of Lake Managua. More than 25 wells have been drilled; the reservoir temperature is about 232°C and a typical well produces roughly 15.7 kg/s of total flow at 181°C with a total solids content of about 6800 ppm. The estimated total electric power potential of Momotombo is 100 MW. Another area, Masaya-Nandaime, has an estimated reservoir temperature greater than 200°C and appears promising. All in all, Nicaragua may hold more than 1000 MW of potential geothermal power. See Table 3.

Reference:

Sem. Latinoamericano sobre Exploracion Geotermica, OLADE, Sept. 1983, p. 115-128.

Panama

Seven geothermal areas have been identified in Panama. Six of these (El Valle, Calobre, Huacas de Quije, Los Santos, Aguas Calientes, and Coiba) are in the very early stages of exploration; one, Baru-Colorado, has progressed to the prefeasibility stage. Within Baru-Colorado, six wells have been drilled near the site of surface thermal manifestations known as Cerro Pando. The total drilled depth is 2620 m. No estimates of power potential are available at this time.

References:

Sem. Latinoamericano sobre Exploracion Geotermica, OLADE, Sept. 1983, p. 129-134.

Response to GRC Questionnaire, A.H. Ramirez, This Volume.

NORTH AMERICA

Canada

The southern flank of Meager Mountain in British Columbia has been drilled and tested during the last decade. Of the three deep wells completed, only one is a producer albeit a very weak one (3.3 kg/s). Reservoir temperature is in the 230°C range, but the formation has very low permeability. The two nonproductive wells registered bottomhole temperatures of 250 to 260°C. Furthermore, the wells are difficult to drill (directional drilling to total depths of 3000 to 3500 m), and the site is remote, best reached via helicopter. Although a few other areas have been identified as having the possibility of geothermal potential, there are no plans to develop any of them to the power production stage.

References:

"Geothermal Energy in Canada:," A.M. Jessop; This Volume.

"Meager Creek Geothermal Project: Testing and Monitoring During 1983-84," J.J. Stauder and S.A.S. Croft, *Proc. Eighth EPRI Geoth. Conf. and Workshop*, EPRI Rep. No. AP-3686, 1984, p. 3.37-3.38.

Mexico

A vigorous and effective geothermal development program has propelled Mexico into third place among the world's countries that generate electricity from geothermal energy. See Table 4. The main fields under active exploitation and development include: Cerro Prieto (four separate areas), Los Azufres, and Los Humeros. Other fields, such as La Primavera, may eventually reach the production stage. By the close of 1985, Mexico will have 645 MW of geothermal power on line, generating 5 percent of the nation's electricity requirements. By the end of the decade, the installed capacity may be as high as 2440 MW. It is interesting to note that both Southern California Edison and San Diego Gas and Electric Company have signed long-term power purchase agreements with the Comision Federal de Electricidad (CFE) for large blocks of power from the Cerro Prieto plants.

Reference:

"Present and Planned Utilization of Geothermal Resources in Mexico," Comision Federal de Electricidad, This Volume.

United States

The United States is the world's largest producer of electricity from geothermal energy. As of 1985 the U.S. will have 2022.11 MW installed in a total of 56 power units located in five states—California, Hawaii, Nevada, Oregon, and Utah. The vast majority of the activity resides in California, but during the past year a number of projects have gotten underway in Nevada.

California. We will arbitrarily divide the state into three regions for our purpose: The Geysers, the Imperial Valley, and the rest of the state.

*1. **The Geysers.*** Table 5 summarizes the status of plants at the world's largest geothermal field. All plants in operation and in planning are of the dry steam type, with the exception of the small binary plant being designed to harness the so-called "Wild Well" (Thermal No. 4). Most of the plants are owned and operated by Pacific Gas and Electric Company (PG&E), but others include: Northern California Power Agency (NCPA), Sacramento Municipal Utility District (SMUD), California Dept. of Water Resources (DWR), Santa Fe International Corp., Modesto Irrigation District (MID), and Central California Power Agency (CCPA).

*2. **Imperial Valley.*** By the end of 1985, there will be six power plants in operation in the Imperial Valley. See Table 6. The plants will have a total installed capacity of 161.0 MW and will include plants of the binary, single-flash, and double-flash types. Some of them will utilize complex chemical treatment systems to handle and stabilize the extremely aggressive brines in the Brawley, Niland, and Salton Sea areas.

A decade ago some estimates of the geothermal power potential of the Imperial Valley ran as high as 9000 MW.

From our present vantage point, it seems clear that such a value is unrealistically high, but great progress has been made in solving the corrosion and scaling problems that stymied development of the hypersaline, high-temperature fluids near the Salton Sea where the greatest potential resides. The adoption and adaptation of flash-crystallizer and reactor-clarifer technology is moving these plants out of the realm of pilot plants towards the point where they may be considered commercial.

At North Brawley, a 10 MW single-flash plant has been running since 1980. Union operates the well field and the brine handling equipment; Southern California Edison (SCE) operates the power plant. The brine handling technique relies on maintaining the dissolved solids in solution and has not been entirely successful from an operating viewpoint. The overall capacity factor is about 35 percent.

Considerably better performance has been achieved at the 10 MW Salton Sea Geothermal Electric Project (Union, SCE, Southern Pacific Land Company, and Mono Power Company). The brine processing includes both flash crystallizers and reactor-clarifiers to remove the solids from the geofluid in a controlled manner. The plant has a lifetime on-line factor of about 85 percent and a capacity factor of about 75 percent.

This same technology, on which Magma Power Company holds patents, will be used at the Vulcan Power Plant scheduled to start operating late in 1985. The plant will produce 34.5 MW of saleable power, which will be purchased by SCE. The power system is a double-flash type with separate high- and low-pressure turbines each with its own generator; the power ratio between the HP and LP machines is about 3:1. The turbines are being supplied by Mitsubishi Heavy Industries, Ltd.

The Ralph M. Parsons Company is constructing a double-flash plant at Niland, the Niland Geothermal Energy Program (NGEP). The first phase will produce 38.6 MW of net power, and should be completed in mid-1986. Clean, high-pressure steam will be generated using a condenser/reboiler arrangement that removes the large amount of noncondensable gases (9 percent by weight of steam). Additional HP steam will be flashed from the liquid portion of the geofluid separated at each wellhead. A low-pressure flash vessel will generate LP steam for use in the lower stages of the turbine, which will be supplied by Fuji Electric Company. The two turbines will have separate condensers. The design specifications for phase 1 call for steam inlet conditions of 167.7°C, 689.5 kPa (HP) and 117.5°C, 124.1 kPa (LP); exhaust pressures of 5.42 kPa (HP) and 7.72 kPa (LP). After at least 1 year of operation, 31.4 MW may be added to the plant through additional wells and some modification to the turbine. The HP steam pressure and temperature will remain unchanged, but the LP conditions will be modified to 124.2°C, 155.8 kPa, and the condensers will operate at 6.91 kPa (HP) and 12.29 kPa (LP). Parsons is the owner of the wells, the brine processing equipment, and the power plant; SCE will purchase the power through the Imperial Irrigation District.

This year electricity will begin to flow into the grid from the world's largest binary plant, the Heber Binary Demonstration Plant, a 65 MW (gross), 45 MW (net) power plant that uses a mixture of isobutane and isopentane as its working fluid. A demonstration of success, both on technical and economic grounds, will go a long way toward opening up a large number of low-to-moderate temperature geothermal resources. Binary plants are one of the most nonpolluting types of power plant that can be conceived, a major advantage in environmentally sensitive areas. However, binary plants still require an independent supply of cooling water, a limitation that could either hamper development or force designers to resort to dry (i.e., air) cooling. In most situations, dry cooling is much more expensive than wet cooling towers.

Roughly 1 mile to the east of the Heber binary plant, the Heber Flash Plant of the Heber Geothermal Company will also reach the production stage during 1985. It will be a double-flash plant with a net rating of 49 MW. Since these two plants will draw fluid from the same general reservoir, it will be interesting to see if their operations affect one another. They will also serve to show the relative advantages and (or) disadvantages of a flash versus a binary plant.

At the East Mesa field, the portion originally under lease to Republic Geothermal is about to begin development by ORMESA through the use of small, modular binary units. The plan is to install 26 separate units, each with a gross rating of 1.25 MW, to produce 20 MW of net saleable power. The power units are under construction at the factory at the time of writing, although not all pieces of the agreement are yet in place. It is expected that all equipment for cooling and electrical systems will be on site during 1985, with power coming on line in1986; the plant will be built by Ormat and power will be purchased by SCE. The resource temperature is 160°C.

*3. **Rest of California.*** There are three areas in California outside of The Geysers and the Imperial Valley, where geothermal power development is underway: Coso Hot Springs in the Long Valley caldera, Mammoth area near the Casa Diablo Hot Springs, and Honey Lake near the Wendel-Amedee KGRA. See Table 7.

Conventional flash-steam turbines are being constructed for use at Coso, but at the other two sites, novel systems are being operated or installed. At Mammoth, two companies are involved with small, modular binary plants. One of these plants, the Mammoth-Pacific project, comprises two 3.5 MW, air-cooled, isobutane units, whereas the other, the Chance Ranch project, will involve five 600 kW, skid-mounted, shop-prefabricated units. The contrast between this approach to binary plant design and that adopted for the Heber Demo is striking.

At Honey Lake, a wood-waste-fired steam generator/turbine will be coupled to a bottoming isobutane cycle that will receive some of its heat from geothermal liquid pumped from a well. The plant will be rated at 30 MW (two 15 MW turbogenerators) with the geothermal resource providing about 25 percent of the power. Operation is expected in the first quarter of 1987.

Hawaii. The wellhead unit built to run on one of the world's hottest production wells (358°C) has been in operation since March 1982. The main operating problem has involved finding the best method to dispose of the hydrogen sulfide gas emitted from the noncondensable gas extraction system. The most recent attempt involves the use of a Citrex Process in which one-third of the H_2S is burned to form SO_2, which is then absorbed into a solution of sodium citrate. This SO_2-rich solution is then reacted with the remaining two-thirds of the H_2S to form a sulphur slurry, which is then filtered and dried. The original incinerator/absorber system was efficient (99.9 percent) but expensive. See Table 7.

Nevada. A flurry of activity is underway in Nevada with a number of geothermal projects slated for completion in 1985 or in the near future. See Table 7. A total of about 105 MW is now scheduled to be on line by 1987; 30 percent of this capacity is in binary plants.

The first power generated from geothermal energy in Nevada came from a 600 kW binary unit at Wabuska Hot Springs in 1984. The plant is a skid-mounted unit manufactured by Ormat and has logged over 4000 hours of operation at this writing. The resource temperature is 106° C, the well is about 107 m deep, a 75 kW pump assists production, boosting the flow rate from an artesian flow of about 9 kg/s to 45 kg/s, and cooling water is handled in a spray pond and recirculated to the plant's condensers. The power equipment was delivered to the site in April 1984, preliminary runs were made in July of 1984, and in September the plant was on line. The owner of the plant is Tad's Enterprises of Orinda, CA; power is sold to Sierra Pacific at 5.1 cents/kWh.

Another binary power project is under construction at Brady Hot Springs by Munson Geothermal, Inc., of Reno. MGI holds about 12,480 acres under lease at Brady and plans to install 2.8 MW by the end of 1985 with a follow-on of 5.5 MW through the rehabilitation of the Raft River Dual-Boiling Binary Plant. The 2.8 MW will be achieved by running 6 to 9 modular units from Ormat. Reservoir fluid temperature is about 149° C, and the wells will probably be pumped. Power will be sold to Sierra Pacific.

Binary plants are also being planned for Steamboat Springs and Fish Lake. In the case of the latter resource, the fluid temperature is in the range 188 to 200°C as determined by the discovery well drilled in 1984 and the confirmation well completed in January 1985. Although a binary-type plant has been decided upon, the manufacturer has yet to be selected. A total of 15 MW is expected to be installed by the end of 1986.

At Steamboat Springs, Geothermal Development Assocs. plans to install seven modular Ormat units: four 1200 kW units and three 800 kW units. A net power of about 5.5 MW is expected. Reservoir fluid temperatures are 160° C at 152 m; wells will be pumped to prevent flashing. A 10-year power purchase agreement is in place with Sierra Pacific.

Two 20 MW flash plants are in the planning stage for Dixie Valley (Spring Creek and Dixie Central) by Trans-Pacific Geothermal Company. They may be on line by 1987.

The Beowawe resource will be tapped by a double-flash steam plant. Mitsubishi Heavy Industries, Ltd. has the turbine/generator under construction and expects to have the 17 MW unit on line by the end of 1985. The plant will be owned and operated by Chevron USA Beowawe. Power will be purchased by Southern California Edison through Sierra Pacific.

An innovative 9 MW double-flash plant incorporating a rotary separator turbine is under construction at Desert Peak. The power conversion equipment will be built by Transamerica Delaval Inc.—Biphase Energy Systems. The Biphase double-flash system proved more efficient and cost effective than competitive energy conversion systems. Ground was broken for the plant in January 1985 and the plant should be completed late in 1985.

Oregon. Last year the geothermal project at Hammersly Canyon was expanded with the addition of three 370 kW modular binary plants, bringing the total installed capacity to just over 2 MW. The plants are owned by Wood & Assoc. who sell the power to Pacific Power & Light. See Table 7.

Utah. Two resources in southern Utah are being developed: Roosevelt Hot Springs (Milford) and Cove Fort-Sulphurdale. See Table 7. A 20 MW single-flash plant, Blundell Unit I, came on line in 1984 at Milford. Because of the high temperature of the resource (260° C), the geofluid carries a significant amount of silica (510 ppm) and silica scaling has been a concern during operation. A wellhead unit is under construction at Milford that will use the Biphase rotary separator expander in conjunction with a dual pressure steam turbine to generate a net power of 14.5 MW.

Mother Earth Industries (Cove Creek Geothermal) will have four Ormat binary units in place at its Cove Fort-Sulphurdale prospect by June 1985. Each unit has a gross output of 800 kW and the net power for sale from the first four units will be about 2.7 MW. Power will be purchased by the city of Provo. Phase 2 of the project will involve the installation of two more units, each 1 MW net, by the end of 1985. Phase 3, to be completed in 1986, envisions the addition of a steam turbine in a topping mode to make efficient use of the dry steam being produced by the wells. The energy of the exhaust from the turbine will be harnessed by the binary units from Phases 1 and 2, which will then be operating in a bottoming mode. Altogether the six binary units and one steam turbine should produce about 6.5 MW net.

References:

"Worldwide Geothermal Power Development: 1984 Overview and Update," R. DiPippo, *Geoth. Resources Council BULLETIN*, Vol. 13, No. 9, 1984, p. 3-12.

Geothermal Hot Line, S.F. Hodgson, ed., Calif. Div. of Oil and Gas, Sacramento, Vol. 14, No. 2, 1984

The following individuals provided the author with data through personal communication:

K. Boren, GeoProducts, Inc.
G. Calderon, Interamerican Development Bank
G. Crane, Southern California Edison
W. Dolan, Steam Reserve Corp.
M. Eickhof, Pacific Gas & Electric Co.
C. Giles, The Ben Holt Co.
Z. Krieger, Ormat Systems
K. Kuriyama, Mitsubishi Heavy Industries, Ltd.
J. Moore, California Energy Company
S. Munson, Munson Geothermal, Inc.
H. Ram, Ormat Systems
M. Rands, Imperial County Public Works Department
T. Seesee, Ralph M. Parsons
R. Tenney, Magma Power Company
W. Teplow, Trans-Pacific Geothermal, Inc.
J. Wood, Wood & Associates

SOUTH AMERICA*

*Reference:
Sem. Latinoamericano sobre Exploracion Geotermica, ORLADE, Sept. 1983.

Argentina

Argentina has no geothermal power plants, but two areas are being explored. One is Copahue in the western-central Andes Mountains where one well has been drilled. There is some promise for this field. The other area is Jujuy in the far northern area of the country where Argentina borders on Chile and Bolivia.

Studies at Copahue have shown a reservoir temperature of about 230° C. The existing well produced 4.4 kg/s of saturated steam, enough to drive a 2.5 MW condensing turbine. This field may have a power potential in excess of 50 MW.

Reference:
"Experience in Geothermal Energy," ELC-Electroconsult, Milan, Italy, Oct. 1982.

Bolivia

There are no geothermal power plants in Bolivia, but seven areas bordering on Chile are considered prospects. They are: Sajama, Valle del Rio Empexa, Salar de la Laguna, Volcan Ollague, Quetena, Laguna Colorada, and Laguna Verde. No deep wells have been drilled yet. Reservoir temperatures at some sites may be 240 to 250° C based on shallow wells. By 1990, 30 MW may be installed.

Reference:
Response to GRC Questionnaire, W. Cassis Zamora; This Volume.

Chile

The main geothermal field in Chile is El Tatio in the Antofagasta province in the far north at an elevation of 4300 m above sea level. Of the seven deep wells drilled, two are productive; the proven power capacity of these wells is about 15.5 MW. Reservoir temperature is in the range 225 to 250° C. Demand for power in this remote part of the country depends on the activity at the Chuquicamata copper mine, the largest in Chile.

Reference:
"Experience in Geothermal Energy." ELC Electroconsult, Milan, Italy, Oct. 1982.

Colombia

There are no geothermal power plants in Colombia. Four areas are being assessed: Ruiz Volcano (3 zones), Chiles Volcano, Azufral de Tuquerres, and Paipa. Estimated reservoir temperatures range from 85 to 271° C based on various geothermometers. A 3 MW pilot plant may be installed by 1990.

Reference:
Response to GRC Questionnaire, N. Garcia and B.Salazar; This Volume.

Ecuador

There are no geothermal power plants in Ecuador, but five areas located from Cuenca to Quito and continuing to the Colombian border are being explored. They are: Cuenca-Azogues, Chimborazo, Chalupas, Imbabura-Cayambe, and Tufino-Chiles-Cerro Negro.

Peru

There are no geothermal power plants in Peru. There are numerous areas marked by surface thermal manifestations, the most promising of these being in the southernmost part of the country. The five areas of most interest are: Chivay, Chachani-Laguna Salinas, Calacoa, Tutupaca, and Challapalca.

Venezuela

There are no geothermal power plants in Venezuela. Two areas along the northern coastal section appear to hold some potential. They are the Barcelona-Cumana and the El Pilar-Casanay areas.

ASIA

China

As many as 12 individual power plants of various types are in operation in China. By the end of 1985, the total installed capacity may reach 14,321 kW. The largest units are 3.0 MW in size and are located at Yangbajing in Xizang (3 units) and at Chingshui in Taiwan (1 unit). At least four and possibly five binary units will be operating this year using fluid with temperatures as low as 48° C. Binary cycle working fluids include: ethyl chloride, normal- and iso-butane, and refrigerant-11. Since the vast majority of China's geothermal resources are of low-to-moderate temperatures, it is conceivable that small binary units may be installed at any number of sites. All in all by 1990, 20 to 30 MW may be installed throughout China. See Table 8.

References:
"Geothermal Update Report: Taiwan, Republic of China," W.-T. Cheng; This Volume.

"Preliminary Assessment of Geothermal Resources of China," X. Kuide and others; This Volume.

"Binary Cycles in China," H.-Y. Zhou, *Proc. 5th NZ Geoth. Workshop*, U. Auckland, 1983, p. 275-279.

Professor Cai Yihan, Tianjin University; Personal communication.

India

There are no geothermal power plants in India. There are, however, about 12 areas in the southwestern Himalayas that may hold geothermal potential. These areas in the Duga, Parkti, and Chonathang valleys will probably be low-to-moderate in temperature. A higher temperature resource (>250° C) may lie further up toward Tibet.

The Central Electricity Authority is looking into the possibility of installing an experimental 1 MW unit at Puga Valley in the Ladakh region of the State of Jammu and Kashmir. The liquid-dominated reservoir has a temperature of about 245° C, produces two-phase flow at a dryness fraction of roughly 0.20 at pressures ranging from 370 to 675 kPa, and is located at an elevation of 4500 m above sea level.

Thailand

There are five hot spring areas in the northern part of Thailand near the border with Burma and not far from the city of Chiang Mai. They are: Mae Chan, San Kampaeng, Fang, Mae Taeng, and Mae Cham. The ultimate power potential may be 150 MW for 30 years, but the exploration program must be completed before an accurate assessment can be made. The Fang and San Kampaeng areas have been selected for intense study. Cooperative agreements have been signed with the French for the former area and the Japanese for the latter area to assist in development. At Fang, shallow wells flow with a wellhead temperature of 105°C and sufficient flow rate to operate a micro-binary plant of about 50 kW. A 120 kW binary unit is planned for this field to demonstrate the feasibility of power production. At San Kampaeng, one well (GTE-6) produced a flow of 6 kg/s at a temperature of 106°C from a production zone at 490 m depth. A deep exploration well (1500 to 2000 m) has been sited and was scheduled for drilling late in 1984.

Reference:

"Geothermal Power Development in Thailand," C. Jivacate, *3rd ASEAN Geoth. Energy Sem.*, Bandung, Indonesia, May 1984.

Turkey

Turkey's first geothermal power plant was a 0.5 MW wellhead unit that operated from 1974 to 1981 at the Kizildere field. Presently six wells at that site provide steam for a 20.6 MW single-flash plant. The wells also yield high amounts of carbon dioxide and are prone to calcite scaling. So far, the scaling has been dealt with by maintaining a high back-pressure at the wellhead (about 1570 kPa) and mechanically cleaning the wells every 6 months. The use of downhole chemical scale inhibitors and carbon dioxide injection (EFP System) are being studied. In spite of these difficulties, the plant operates for about 7000 hours per year and produces electricity at a very economical cost (10 US mill/kWh). Geothermally generated electricity is about 89 percent cheaper than electricity from diesel plants, about 73 percent cheaper than oil-fired plants, 49 percent less than lignite-fired plants, and 78 percent less than coal-fired plants. The use of the waste energy in the separated liquid will further enhance the overall utilization of the geothermal resource.

There are two other high-temperature fields: Aydin-Germencik and Canakkale-Tuzla. Both should eventually lead to power plants. It is possible that three other fields may be of the dry-steam type: Nemrut, Tendurek, and Zilan.

All in all by 1990, as much as 130 MW may be on line in Turkey. See Table 9.

Reference:

"Present Status and Future Development of the Denizli-Kizildere Geothermal Field of Turkey," S. Simsek; This Volume.

Union of Soviet Socialist Republics

The main geothermal areas within the USSR include: Kamchatka, the Kurile Islands, Sakhalin Island, northern Caucasus, Dagestan, Armenia, the Crimea, and the Trans-Carpathian range of the Ukraine.

The electric power potential of the Kamchatka region alone is about 2000 MW. When all types of geothermal resource are considered, the total in the USSR may be as much as 150,000 MW. It has been estimated that about 5 percent of the country's electricity in the year 2000 might come from geothermal energy.

Current topics of research interest are hot-dry-rock technology and hybrid geothermal-fossil plants primarily for use on geopressured geothermal resources having dissolved hydrocarbon fuels.

The state of power plant development is shown in Table 10. From this we can see that possibly 241 MW may be on line by the year 1990, i.e., at the end of the next five-year plan.

ATLANTIC

The Azores (Portugal)

A 3 MW single-flash plant has been operating on the island of Sao Miguel since 1979. It has not been able to generate at rated capacity due to a lack of sufficient steam. Efforts are now underway to expand the capacity of the field and to explore other areas of promise on the island. See Table 11.

Reference:

"Geothermal Resources of Sao Miguel Island, Azores, Portugal," W.A. Duffield and L.J.P. Muffler, USGS Open File Rep. 84-287, US Geological Survey, 1984.

Iceland

Geothermal power plants are operating at three sites in Iceland: Namafjall (3 MW), Krafla (30 MW, installed; 28 MW, actual), and Svartsengi (8 MW). The first of these is used in conjunction with a diatomite plant and is a single-flash unit. The Krafla plant is a double-flash unit supplying power to the grid. The last one operates as part of the water-supply system at Sudurnes; some of the power is used at the plant to run pumps and some is distributed to the grid.

It has taken a number of years for the Krafla plant to reach its rated capacity owing to troubles with the steam supply and the wide diversity of geofluid characteristics encountered by the wells. A second 30 MW unit has been acquired but has not yet been installed. See Table 12.

Reference:

Response to GRC Questionnaire, Gudmundur Palmason; This Volume.

CARIBBEAN

Dominica

Two promising geothermal prospects exist at Soufriere and Wotten Waven where some 10 to 15 wells have been drilled. The wells average about 500 m in depth and the results are encouraging. Perhaps as much as 50 to 100 MW may be possible at each site when fully developed.

Dominican Republic

Areas under exploration include: Graben de Enriquillo, Termal de Azua, Yayas de Viajama-Constanza, and San Juan. Geothermometry has not produced a consistent indication of reservoir temperatures, and further work is needed to assess more accurately the potential of these sites.

Reference:

Sem. Latinoamericano sobre Exploracion Geotermica, OLADE, Sept. 1983, p. 141-160.

Guadeloupe (France)

A 4.2 MW double-flash plant has recently been installed at La Bouillante. This is the first geothermal plant to be built in the Caribbean area and may provide a model for future developments among the many islands that have geothermal resources. See Table 13.

Haiti

Several areas are being examined for possible exploitation. These include: Sources Chaudes, Los Pozos, Sources Pauntes, and Jeremie. With the exception of Los Pozos where geothermometry indicates a temperature of 120 to 130° C, these are low temperature prospects at best.

Reference:
Sem. Latinoamericano sobre Exploracion Geotermica, OLADE, Sept. 1983, p. 101-103.

Saint Lucia

A program of geological, geochemical, and geophysical exploration has been carried out at the Soufriere area. From this study, the locations of three deep exploratory wells were recommended: Belfond, Sulphur Springs, and Etangs. Reservoir temperatures appear to be in the 240 to 280° C range, but the nature of the reservoir is not exactly known at this time. Financing for the next phase of the program is being arranged. A preliminary estimate of power potential of the field is 30 MW based on results of studies to date.

Reference:
"Evaluation of the St. Lucia Geothermal Resource—Summary Report," Los Alamos National Laboratory, Rep. No. LALO-84-26, April 1984.

EUROPE

Denmark

The geothermal resources of Denmark appear unsuitable for the generation of electricity by the usual means owing to the rather low temperatures encountered.

Reference:
"Geothermal Activity in Denmark," C.F. Pedersen; This Volume.

Federal Republic of Germany

The only economically feasible way of generating electricity from Germany's low-temperature resources seems to be as part of a total energy utilization system. Project Bruchsal combines an organic Rankine cycle with a heat pump and a series of direct applications. Even so, a gas-fired engine would be needed for power back-up during peak demand. Only 500 kW of electrical power from geothermal sources is expected by 1990.

Reference:
"Present Status (1985) on Utilizing Geothermal Energy in the Federal Republic of Germany," R. Haenel; This Volume.

Greece

By the end of 1985, a 2 MW single-flash pilot plant will be operating on the island of Milos. The plant was built by the Public Power Corporation as hopefully the first of a number of plants to tap the large potential of Milos (120 MW) and other islands lying along the volcanic arc of the Aegean Sea. The condensing turbine/generator unit was built by Mitsubishi Heavy Industries, Ltd., and will be delivered to the site later this year. Full operation is expected in November 1985. See Table 14.

At least five wells have been drilled at the Milos field. Typical characteristics are as follows: temperature in the reservoir is about 300° C; wellhead dryness fraction is about 48 percent; noncondensable gases are about 1 to 2 percent.

Other areas with promise include: Nisyros (1 well, reservoir temperature of 350° C, 86 percent wellhead dryness fraction), Loutraki-Soussake, and Argenos (Lesbos). There are at least nine other sites that are ranked as lower in priority for development. The estimated geothermal power potential for all of Greece ranges from about 375 to 1000 MW.

Reference:
"Milos Geothermal Project (Greece): Exploration, Drilling and Preliminary Production Data," R. Cataldi and others, *Proc. Int. Conf. on Geoth. Energy*, BHRA Fluid Engineering, 1982, Vol. 1, p. 97-111.

Italy

For more than 80 years, electricity has been generated from geothermal energy in Italy by capturing the natural steam at Larderello and the surrounding areas. As of 1985 the installed capacity will reach about 520 MW, nearly all from dry steam plants. The more challenging task of using the liquid-dominated resources is being tackled with success, with a 4.5 MW pilot plant at Latera now in operation. Four standardized 15 MW units are under construction at various sites in the dry steam fields. By the year 1995, Italy expects to have about 900 MW on line from geothermal plants. See Table 15.

Reference:
"Update Report on Geothermal Development in Italy," G.C. Ferrara, F. Luccioli, G.C. Palmerini, and U. Scappini; This Volume.

Romania

The low-temperature geothermal resources of Romania have recently been used to power a small binary power plant. The fluid temperature was 82° C. Plans are to push the technology to the level of 1 MW plants in the near future.

Reference:
M.T. Sarbulescu, IFLGS, Bucharest; Personal communication.

Switzerland

The temperatures of Switzerland's geothermal resources appear too low for the economical generation of electricity.

Reference:
"Overview of Geothermal Activities in Switzerland," J.-C. Griesser and L. Ryback; This Volume.

United Kingdom

There appears to be no prospect for economic power generation from the hydrothermal geothermal resources of the UK. Only through the development of hot-dry-rock (HDR) technology might it be feasible to generate electricity. Economic uncertainty about this technique makes projections of costs very unreliable. Should the technology prove favorable, about 10 percent of the UK's electricity needs might be met by HDR geothermal plants.

Reference:
"Geothermal Resources of the UK: Country Update Report," J.D. Garnish; This Volume.

PACIFIC

Australia

There are many geothermal wells in Australia that provide hot water for bathing, heating, or stock use, but none have been used to generate electricity. Maximum temperature observed has been 110° C; some wells flow at rates of 70 kg/s spontaneously and apparently indefinitely. Such a well might be connected to a simple organic Rankine cycle and easily generate 300 to 500 kW. There is the possibility of high-temperature resources in western Victoria based on active tectonism.

Reference:
"Geothermal Energy in Australia," J.P. Cull; This Volume.

Indonesia

The ultimate geothermal power potential of Indonesia is estimated to be 10,000 MW. Exploration and (or) development are taking place at 18 areas in Sumatera, 29 areas in Java, 16 areas in Sulawesi, and 14 areas in Bali, Lesser Sunda Islands, and Moluccas.

Presently, there are two wellhead units (2.25 MW, total) and one central station (30 MW) in operation. The next plants to be built will be Units 2 and 3 at Kamojang (2 x 55 MW). They are scheduled to begin operation in the middle of 1987 and early 1988, respectively. Power plants are scheduled for the following areas by 1994; Dieng (112 MW by 1990), Darajat (110 MW by 1992), Salak (220 MW by 1993), Lahendong (30 MW by 1993), Cisolok (110 MW by 1994), Banten (110 MW by 1994), and Bedugal (955 MW by 1994). The reservoir at Kamojang produces dry steam; the others are liquid-dominated. See Table 16.

Reference:
"The Status of Geothermal Energy Developments in Indonesia up to the Year 2000," V.T. Radja; This Volume.

Japan

There are nine geothermal power plants in Japan, ranging in size from 0.1 MW at the Kirishima Kokusai Hotel to 55 MW at the double-flash Hatchobaru plant. The plants are located on three of the Japanese islands: Honshu, Kyushu, and Hokkaido. The total rated capacity is 215.1 MW including 22 MW from a dry-steam plant (Matsukawa), 88.1 from six single-flash plants (Otake, Onuma, Onikobe, Kakkonda, Suginoi Hotel, and Kirishima Kokusai Hotel), and 105 MW from two double-flash plants (Hatchobaru and Mori). Expansion of some of the existing plants is being given serious consideration. Step-out drilling is underway, for example, at Hatchobaru in preparation for the construction of another 55 MW unit. See Table 17.

Reference:
Response to GRC Questionnaire, M. Higo; This Volume.

New Zealand

The principal geothermal generating facility in New Zealand is at Wairakei, the site of the world's first commercial geothermal power plant using fluid from a liquid-dominated resource. Only 11 of the original 13 power units (installed from 1959 to 1963) are still in operation. However, the two units (Units 5 and 6) that have been removed from service because of the decline in reservoir pressure and the loss of high-pressure steam are being rehabilitated for use at the Ohaaki power plant now under construction. These two 11.2 MW back-pressure turbines will be matched with two new 46.9 MW machines to give the Ohaaki plant a rated capacity of 116.2 MW. The plant will be a double-flash unit. A study is being made of generating an additional 5 MW at Wairakei by using a bottoming binary cycle powered by the waste hot water that in now discharged to the Waikato River. Altogether 167.2 MW is now on line in New Zealand at two sites; by 1988 there should be 283.4 MW on line. See Table 18. Of the numerous geothermal areas in New Zealand, those with the brightest prospects for power development are: Mokai, Rotokawa, and Tauhara.

Reference:
"Status Report on the Existing and Planned Utilisation of Geothermal Energy in New Zealand," I.A. Thain; This Volume.

Philippines

The aggressive program of geothermal power development begun in the early 1970s is being pursued albeit at a somewhat slower pace than originally anticipated. The results of the program are impressive: 894 MW installed over a span of 8 years (1977 to 1985); another 690 MW proven under the wellhead; four fields being exploited and another ready for power production in 3 years; and 23 more specific areas in various stages of exploration. By the year 1990, the Philippines plans to have 1041.5 MW on line from geothermal sources, enough to supply just under one-quarter of the nation's demand for electricity. See Table 19.

Reference:
"The Philippines' Geothermal Potential and Its Development: An Update," B.S. Tolentino and B.C. Buñing; This Volume.

SUMMARY

Table 20 shows the roster of countries with geothermal power plants installed as of 1985. There are 188 separate power units (turbine-generator sets) in 17 countries with a total capacity of 4,763,981 kW. The country most likely to improve its standing dramatically over the next 5 years is Indonesia. Conceivably Indonesia could surpass Italy, and challenge Mexico as the third largest geothermal power producer by 1990. The list of countries will grow by then and might include the following: Costa Rica, Guatemala, Chile, India, Thailand, Saint Lucia, Romania, and Australia.

Table 21 shows the growth of geothermal power capacity worldwide since 1979. The annual percentage growth rate from 1978 to 1985 is about 16.5 percent. If this rate can be maintained for the next 5 years, one would expect to have over 9400 MW on line worldwide by the end of 1990. Based on the country reports presented in this volume, and assuming favorable economic conditions, such an expectation appears reasonable. It will be noted that 5 years is about the doubling time for a 16 percent growth rate.

Reference:
"Worldwide Geothermal Power Development: 1984 Overview and Update," R. DiPippo, *Geothermal Resources Council BULLETIN*, vol. 13, No. 19, 1984, p. 3-12.

Table 1. Geothermal Power Plants In Kenya

Plant	Year	Type	MW	Status
Olkaria:				
Unit 1	1981	1-Flash	15	Operational
Unit 2	1982	1-Flash	15	Operational
Unit 3	1985	1-Flash	15	Operational
Olkaria Hill	1991-92	Flash	55-60	Planned
Eburru	Future	—	—	Exploration
		Totals:	45	Operational
			105	Operational or planned

Table 2. Geothermal Power Plants In El Salvador

Plant	Year	Type	MW	Status
Ahuachapan:				
Unit 1	1975	1-Flash	30.0	Operational
Unit 2	1976	1-Flash	30.0	Operational
Unit 3	1980	2-Flash	35.0	Operational
Berlin	Future	2-Flash	55.0	On Hold
Chipilapa	Future	Flash	30.0	Planned
		Totals:	95.0	Operational
			125.0	Operational or planned

Table 3. Geothermal Power Plants In Nicaragua

Plant	Year	Type	MW	Status
Momotombo:				
Unit 1	1983	1-Flash	35	Operational
Unit 2	1986	1-Flash	35	Under construction

Table 4. Geothermal Power Plants In Mexico

Plant	Year	Type	MW	Status
Pathe	1959	1-Flash	3.5	De-commissioned
Cerro Prieto I:				
Unit 1-2	1973	1-Flash	2x37.5	Operational
Unit 3-4	1979	1-Flash	2x37.5	Operational
Unit 5	1981	2-Flash	30.0	Operational
Cerro Prieto II:				
Unit 1-2	1984	2-Flash	2x110	Operational
Cerro Prieto III:				
Unit 1	1985	2-Flash	110	Under construction
Unit 2	1985	2-Flash	110	Under Construction
Cerro Prieto IV:				
Unit 1-2	1992	2-Flash	4x55.0	Planned
Los Azufres:				
W.H. Unit 1-2	1982	Dry Steam	2x5.0	Operational
W.H. Unit 3-5	1982	1-Flash	3x5.0	Operational
Unit 1	1986	2-Flash	50	Under Construction
W.H. Unit 6-12	1987	1-Flash	7x5.0	Advanced planning
Unit 2	1988	2-Flash	55	Advanced planning
Unit 3	1989	2-Flash	55	Advanced planning
Unit 4	1990	2-Flash	55	Advanced planning
W.H. Unit 13-22	1993	1-Flash	10x5.0	Advanced planning
Los Humeros:				
W.H. Unit 1-3	1987	1-Flash	3x5.0	Under construction
Unit 1	1990	2-Flash	55	Advanced planning
Unit 2	1991	2-Flash	55	Advanced planning
		Totals:	425	Operational
			710	Operational or u.c.
			1290	Oper., u.c. or planned

Table 5. Geothermal Power Plants at The Geysers, USA

Plant[1]	Year	MW	Status
PG&E Geysers:			
Unit 1	1960	11	Operational
Unit 2	1963	13	Operational
Unit 3	1967	27	Operational
Unit 4	1968	27	Operational
Unit 5-6	1971	2x53	Operational
Unit 7-8	1972	2x53	Operational
Unit 9-10	1973	2x53	Operational
Unit 11	1975	106	Operational
Unit 12	1979	106	Operational
Unit 13	1980	133	Operational
Unit 14	1980	109	Operational
Unit 15	1979	59	Operational
Unit 16	1985	114	Under construction
Unit 17	1982	114	Operational
Unit 18	1983	114	Operational
Unit 19	n.a.	55	Preliminary planning
Unit 20	1985	114	Under construction
Unit 21	1988	140	Advanced planning
Unit 22	n.a.	114	Preliminary planning
Unit 23	n.a.	114	Preliminary planning
Unit 24	n.a.	114	Preliminary planning
Wild Well	1985	1.2	Advanced planning
NCPA 2	1983	110	Operational
SMUDGEO No. 1	1983	72	Operational
Bottlerock	1985	55	Operational
OXY 1	1984	80	Operational
NCPA 3	1985	2x55	Under construction
Modesto GEO	n.a.	110	Preliminary planning
South Geysers	n.a.	55	Advanced planning
SMUDGEO No. 2	1987	55	Preliminary planning
CCPA No. 1	1988	55	Under CEC review
CCPA No. 2	n.a.	55	Preliminary planning
	Totals:	1792	Operational[2]
		2660.2	Oper., u.c., or planned

[1] All units are dry-steam type except Wild Well unit which will be a binary plant.
[2] Includes plants under construction and scheduled for completion in 1985.

Table 6. Geothermal Power Plants in United States (Imperial Valley, CA)

Plant	Year	Type	MW	Status
East Mesa:				
B.C. McCabe No. 1	1979	Binary	12.5	Operational
Magma Unit 2	n.a.	Binary	25.0	Planned
Magma Unit 3	n.a.	Binary	25.0	Planned
ORMESA (Ormat)	1986	Binary	26x0.77	Under construction
Salton Sea:				
Geothermal Electric Project (Union/SCE/SPLC/MPC)	1982	1-Flash	10.0	Operational
Vulcan Power Plant (Magma/SCE)	1985	2-Flash	34.5	Under construction
Niland (NPN Partnership)	n.a.	2-Flash	49.0	Planned
Niland Geothermal Energy Program (Parsons):				
Phase 1	1986	2-Flash	38.6	Under construction
Phase 2	1988	2-Flash	31.4	Planned addition
Heber:				
Binary Demo Plant	1985	Binary	45.0	Under construction
Flash Plant (HGC)	1985	2-Flash	49.0	Under construction
North Brawley	1980	1-Flash	10.0	Operational
Westmorland	1988	Binary	15.0	Planned
South Brawley (CU I)	n.a.	Flash	49.0	Planned
		Totals:	161.0	Operational*
			219.62	Operational or u.c.
			414.02	Oper., u.c., or planned

*Includes plants under construction and scheduled for completion in 1985.

Table 7. Geothermal Power Plants in United States (Non Geysers and Non Imperial Valley)

Plant	Year	Type	MW	Status
California				
Coso:				
Unit 1	1986	1-Flash	25.0	Under construction
Unit 2-3	n.a.	1-Flash	2x25.0	Advanced planning
Mammoth:				
Mammoth-Pacific	1984	Binary	2x3.5	Operational
Chance Ranch (Wood & Associates)	1985	Binary	5x0.6	Under construction
Honey Lake	1987	Hybrid: wood-geothermal	20.0	Under construction
Hawaii				
Puna No. 1	1982	1-Flash	3.0	Operational
Idaho				
Raft River	1982	Binary	5.0	Being moved to Brady H.S., NV
Nevada				
Wabuska Hot Springs	1984	Binary	0.6	Operational
Beowawe	1985	2-Flash	17.0	Under construction
Brady Hot Springs:				
Phase 1	1985	Binary	2.8	Under construction
Phase 2	1986	Binary	5.5	Under construction
Steamboat Springs	1985	Binary	5.5	Planned
Fish Lake	1986	Binary	15.0	Planned
Big Smokey Valley	1986	Flash (?)	10.0	Planned
Desert Peak	1985	Total flow/2-Flash	9.0	Under construction
Spring Creek	1987	2-Flash	20.0	Planned
Dixie Central	1987	Flash	20.0	Planned
Oregon				
Hammersly Canyon:				
Unit 1-3	1983	Binary	3x0.30	Operational
Unit 4-6	1984	Binary	3x0.37	Operational
Utah				
Milford:				
Blundell Unit 1	1984	1-Flash	20.0	Operational
Wellhead No. 1	1986	Total Flow/2-Flash	14.5	Under construction
Cove Fort-Sulphurdale:				
Phase 1	1985	Binary	4x0.675	Operational
Phase 2	1985	Binary	2x1.0	Under construction
Phase 3	1986	Dry steam	2.3	Advanced planning
		Totals:	69.11	Operational*
			134.11	Operational or u.c.
			256.91	Oper., u.c. or planned

* Includes plants under construction and scheduled for completion in 1985

Table 8. Geothermal Power Plants in China

Plant	Location	Province	Year	Type	MW	Status
Dengwu:	Fengshun	Guangdong				
Unit 1			1970	1-Flash	0.086	Operational
Unit 2			1977	Binary	0.20	Operational
Unit 3			n.a.	1-Flash	0.25	Under const.
Huailai	Huailai	Hebei	1971	Binary	0.285	Operational
Wentang	Yichun	Jiangxi	1971	Binary	0.05	Operational
Huitang	Ningxiang	Hunan	1975	1-Flash	0.30	Operational
Chingshui	Yilan	Taiwan	1981	1-Flash	3.0	Operational
Xiongyue	Xiongyue	Liaoning	1978	Binary	0.10	Operational
Yangbajain	Yangbajain	Xizang				
Unit 1			1977	1-Flash	1.0	Operational
Unit 2			1984	2-Flash	3.0	Operational
Unit 3			1981	2-Flash	3.0	Operational
Unit 4			1985	2-Flash	3.0	Under const.
Tuchang	Tuchang	Taiwan	1985	Binary	0.30	Under const.
Tong'an	Tong'an	Fujian	n.a.	Binary	0.30	Uncertain
Zhaoyuan	Zhaoyuan	Shandong	n.a.	Flash	n.a.	Uncertain
Fuzhou	Fuzhou	Fujian	n.a.	Binary	n.a.	Uncertain
				Totals:	**14.321**	**Operational***
					14.871	**Oper. or u.c.**

*Includes plants under construction and scheduled for completion in 1985.

Table 9. Geothermal Power Plants In Turkey

Plant	Year	Type	MW	Status
Kizildere	1974	1-Flash	0.5	Inactive
Kizildere	1984	1-Flash	20.6	Operational

Table 11. Geothermal Power Plants in the Azores

Plant	Year	Type	MW	Status
Pico Vermelho	1979	1-Flash	3.0	Operational

Table 10. Geothermal Power Plants in the U.S.S.R

Plant	Location	Year	Type	MW	Status
Paratunka	Kamchatka	1967	Binary	0.68	Dismantled
Pauzhetskaya	Kamchatka	1967	Flash	11	Operational
Mutnovskaya:	Kamchatka				
Unit 1		1986-90	Flash	50	Under construction
Unit 2		future	Flash	50	Planning stage
Unit 3		future	Flash	50	Planning stage
Unit 4		future	Flash	50	Planning stage
Neftekumsk	Stavropol	1986-90	Hot Rock	10	Under construction
(Un-named)	Dagestan	1986-90	Hot Rock	10	Under construction
(Un-named)	Ukraine	1986-90	Hot Rock	10	Under construction
			Totals:	11	Operational
				91	Oper. or u.c.
				241	Oper., u.c. or planned

Table 12. Geothermal Power Plants in Iceland

Plant	Year	Type	MW	Status
Namafjall	1968	1-Flash	3.0	Operational
Krafla:				
Unit 1	1978	2-Flash	28.0	Operational
Unit 2	Future	2-Flash	30.0	On hold
Svartsengi:				
Unit 1	1978	Flash	1.0	Operational
Unit 2	1979	Flash	1.0	Operational
Unit 3	1980	Flash	6.0	Operational
		Total:	39.0	Operational

Table 13. Geothermal Power Plants in Guadeloupe

Plant	Year	Type	MW	Status
La Bouillante	1984	2-Flash	4.2	Operational

Table 14. Geothermal Power Plants in Greece

Plant	Year	Type	MW	Status
Milos Pilot	1985	1-Flash	2	Under construction

Table 15. Geothermal Power Plants in Italy

Plant	Year	No. Units	MW[1]	Type[2]
Larderello 2	n.a.	4	58.0	C
Larderello 3	1969	5	113.0	C
Gabbro	1969	1	15.0	C
Castelnuovo	n.a.	4	50.0	C
Serrazzano	n.a.	5	47.0	C
Sasso Pisano	n.a.	1	3.5	NC
Sasso Pisano	n.a.	2	15.7	C
Lago	n.a.	3	33.5	C
Monterotondo	n.a.	1	12.5	C
Radicondoli	1979	2	30.0	C
San Martino 1	1980	1	9.0	C
Lagoni Rossi 1	1960	1	3.5	NC
Logoni Rossi 3	1981	1	8.0	C
Molinetto 2	1982	1	8.0	C
Travale 2	1973	1	15.0	NC
Travale 2	1946	1	3.0	C
Piancastagnaio	1969	1	15.0	NC
Bagnore 1	1945	1	3.5	NC
Bagnore 2	1945	1	3.5	NC
La Leccia	1983	1	8.0	C
Latera	1984	1	4.5	NC
San Martino 2	1985	1	15.0	C
Pianacce	1985	1	15.0	C
Bellavista	1985	1	15.0	C
Unspecified	1985	1	15.0	C
		Totals:	459.2	Operational
			519.2	Operational or under const.

[1] Plant totals. [2] All plants are dry-steam type except Latera which is 1-Flash; C = condensing, NC = noncondensing turbine.

Table 16. Geothermal Power Plants in Indonesia

Plant	Year	Type	MW	Status
Kamojang:				
Wellhead Unit	1978	Dry Steam	0.25	Operational
Unit 1	1982	Dry Steam	30.0	Operational
Unit 2	1987	Dry Steam	55	Under construction
Unit 3	1988	Dry Steam	55	Under construction
Unit 4-5	n.a.	Dry Steam	2x55	Preliminary planning
Dieng:				
Wellhead Unit	1980	1-Flash	2.0	Operational
Unit 1	1988-89	Flash	55	Advanced planning
Unit 2	1989-90	Flash	55	Advanced planning
Darajat:				
Unit 1	1991	Flash	55	Planned
Unit 2	1992	Flash	55	Planned
Salak:				
Unit 1	1988-89	Flash	55	Advanced Planning
Unit 2	1989-90	Flash	55	Advanced Planning
Unit 3	1992	Flash	55	Planned
Unit 4	1993	Flash	55	Planned
Lahendong:				
Unit 1-2	1992-93	Flash	2x15	Planned
Cisolok:				
Unit 1	1993	Flash	55	Planned
Unit 2	1994	Flash	55	Planned
Banten:				
Unit 1	1993	Flash	55	Planned
Unit 2	1994	Flash	55	Planned
Bedugal:				
Unit 1	1990-91	Flash	55	Planned
		Totals:	32.25	Operational
			142.25	Operational or u.c.
			997.25	Operational, u.c. or planned

Table 17. Geothermal Power Plants in Japan

Plant	Year	Type	MW	Status
Matsukawa	1966	Dry Steam	22.0	Operational
Otake	1967	1-Flash	12.5	Operational
Onuma	1973	1-Flash	10.0	Operational
Onikobe	1975	1-Flash	12.5	Operational
Hatchobaru	1977	2-Flash	55.0	Operational
Kakkonda	1978	1-Flash	50.0	Operational
Otake Pilot	1978	Binary	1.0	Dismantled
Nigorikawa Pliot	1978	Binary	1.0	Dismantled
Suginoi Hotel	1981	1-Flash	3.0	Operational
Mori	1982	2-Flash	50.0	Operational
Kirishima Kokusai Hotel	1984	1-Flash	0.1	Operational
Hatchobaru II	n.a.	2-Flash	55.0	Advanced planning
Kakkonda II	n.a.	Flash	50.0	Advanced Planning
Suginoi II	n.a.	1-Flash	3.0	Early Planning
		Totals:	215.1	Operational
			323.1	Operational or planned

Table 18. Geothermal Power Plants in New Zealand

Plant	Year	Type	MW	Status
Wairakei:				
Unit 1	1959	SCSF-IP-NC	11.2	Operational
Unit 2	1958	SCSF-HP-NC	6.5	Dismantled
Unit 3	1959	SCSF-HP-NC	6.5	Dismantled
Unit 4	1959	SCSF-IP-NC	11.2	Operational
Unit 5-6	1962	SCSF-HP-NC	2x11.2	To be installed at Ohaaki
Unit 7-8	1959	SCSF-LP-C	2x11.2	Operational
Unit 9-10	1960	SCSF-LP-C	2x11.2	Operational
Unit 11	1962	2-Flash	30.0	Operational
Unit 12-13	1963	2-Flash	2x30.0	Operational
Kawerau	1961	1-Flash	10.0	Operational
Ohaaki:				
Unit 1	1988	2-Flash	2x11.2 2x46.9	Under construction
		Totals:	167.2	Operational
			283.4	Operational or under construction

Table 19. Geothermal Power Plants in the Philippines

Plant	Year	Type	MW	Status
Tongonan:				
W.H. Unit	1977	1-Flash	3.0	Operational
Unit 1-3	1983	1-Flash	3x37.5	Operational
Unit 4	1989	1-Flash	37.5	Planned
Unit 5-19	n.a.	Flash	15x55.0	Planned
Tiwi:				
Unit 1-2	1979	1-Flash	2x55.0	Operational
Unit 3-4	1980	1-Flash	2x55.0	Operational
Unit 5-6	1982	1-Flash	2x55.0	Operational
Unit 7-10	n.a.	Flash	4x55.0	Planned
Mak-Ban (Makiling-Banahaw):				
Unit 1-2	1979	1-Flash	2x55.0	Operational
Unit 3-4	1980	1-Flash	2x55.0	Operational
Unit 5-6	1984	1-Flash	2x55.0	Operational
Palinpinon:				
W.H. Unit 1-2	1980	1-Flash	2x 1.5	Operational
W.H. Unit 3-4	1984	1-Flash	2x 1.5	Operational
Unit 1-3	1983	1-Flash	3x37.5	Operational
Unit 4-5	n.a.	Flash	2x55.0	Planned
Bac-Man (Bacon-Manito)				
Unit 1	1988	Flash	55.0	Planned
Unit 2	1989	Flash	55.0	Planned
		Totals:	894.0	Operational
			2196.5	Oper., u.c. or planned

Table 20. Geothermal Power Plants On-Line as of 1985

Country	No. Units	Type(s)†	MWe
United States	56	DS,1F,2F,B	2022.11
Philippines	21	1F	894.0
Mexico	16	1F,2F	645.0 *
Italy	43	DS,1F	519.2 *
Japan	9	DS,1F,2F	215.1
New Zealand	10	2F	167.2
El Salvador	3	1F,2F	95.0
Kenya	3	1F	45.0
Iceland	5	1F,2F	39.0
Nicaragua	1	1F	35.0
Indonesia	3	DS,1F	32.25
Turkey	2	1F	20.6
China	12	1F,2F,B	14.321*
Soviet Union	1	F	11.0
France (Guadeloupe)	1	2F	4.2
Portugal (Azores)	1	1F	3.0
Greece (Milos)	1	1F	2.0*
Totals	188		4763.981

† DS = dry steam; 1F, 2F = 1 - and 2-flash steam; B = binary.
* Includes plants under construction and scheduled for completion in 1985

Table 21. Recent Growth in Worldwide Geothermal Plant Capacity

Date	Capacity, MW
Mid 1979	1758.9
Mid 1980	2110.536
Mid 1981	2493.086
Mid 1982	2558.886
Mid 1983	3190.286
Mid 1984	3769.686
End 1985	4763.981