THE STATUS OF WORLD GEOTHERMAL POWER GENERATION 1995-2000

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ABSTRACT
In order to assess the status of international geothermal power generation, the Rapporteur reviewed the Country Update Papers from all nations generating or planning to generate electricity. Salient facts were synthesized, summary descriptions of geothermally-related activities written and appropriate tables and graphs created.

The reviews revealed that: 1) geothermally fueled electric power is being generated in 21 nations as of February 2000, 2) the installed capacity has reached 7,974 MWe (Table 1) which is a 16.7% increase since 1995 (Table 2), 3) the total energy generated is at least 49,261 GWh (with estimates of the data for four nations that presented no information) (Table 3), 4) during the last five years, about 1,165 wells more than 100 meters deep were drilled (Table 4) and 5) at least 13,621 person-years of professional geothermist's time was expended in the nations that reported this statistic (Table 4).

It has been concluded that greater increases in the total international installed geothermal generation capacity were inhibited by the economic crisis that occurred in Southeast Asia, by the low petroleum prices that prevailed during the 5 year period and by serious capacity declines at The Geysers field in California, USA. It is believed that all three of these conditions are currently improving, technology is advancing and international environmental awareness is spreading. Accordingly, it appears likely that over the next 5-10 years, the growth rate of geothermal energy use for power generation will significantly increase.

INTRODUCTION

Geothermal energy development continued to increase between 1995 and 2000 from 6833 MWe to 7974 MWe, but the rate of growth slowed from the 22.5% per 5 years rate enjoyed between 1980 and 1990 to about 16.7%, a figure just slightly below that of the 1990-1995 period.

On the positive side, the Philippines led the world by installing 682 MWe while Indonesia showed the next greatest capacity increase with 280 MWe built. Italy, New Zealand and Iceland geothermal generation growth was very significant at 153, 151 and 120 MWe respectively, and Central American development blossomed with Costa Rica building 87.5 MWe, El Salvador 56 MWe and Guatemala 33 MWe. It is also important to recognize that Ethiopia built its first, 8.52 MWe plant during the last 5 years and that Russia re-entered the geothermal power construction scene by installing 12 MWe in their far eastern Kamchatka region.

Unfortunately, in the USA, geothermal generation decreased by 588 MWe, primarily due to resource quality and quantity declines in The Geysers field.

The slowing rate of growth of international geothermal development can be ascribed to several factors, the most important of which are:

- The very low prices of petroleum products which favored the generation of power using these fossil fuels.
- The economic crisis that occurred in Southeast Asia just as geothermal development was accelerating in the region and
- The previously-mentioned resource declines in The Geysers.

The geothermal work done in Central America, Italy, New Zealand and Iceland is very impressive and the prognoses from fourteen nations suggest that by 2005 growth of almost 43% to about 11,400 MWe might be possible.

The author believes that in the next five years, the Southeast Asian economic situation will improve, oil and gas prices will be higher that they have been for many years and the world will increasingly appreciate the "green" benefits of geothermal energy use. If these trends come to pass, our industry should grow faster than it has for the last 10 years and gather momentum that will feed on itself until geothermal energy becomes a household word and a widely accepted, environmentally friendly technology.

GEOTHERMAL POWER GENERATION STATUS SUMMARIES

Australia

In 1986, a 20 kW experimental power plant was constructed at Mulka cattle station in South Australia and in 1991-1992, a 150 kW binary plant was built at Birdsville, Queensland. Together they produce about 0.9 GWh of energy annually.

At Mulka cattle station, water was taken from hot artesian bores to power a binary/flash steam, 415 volt, two-phase generator, but no commercial development has followed and no new news is available. At Birdsville, the powerplant uses 99^{o}C water from the town's water bore. This well has flowed for 75 years and produces about 30 L/s at a shut in pressure of 1213 kPa from a depth of 1173-1220 meters.

The plant was financed by the Federal Government and the Queensland Electricity Commission and it was designed and built by Enreco Pty. Ltd. Of Alice Springs. The system operated from 1992 to 1994. In 1997, the plant was acquired by Capelec Corporation and power generation, at full 150 kW capacity, was resumed in 1999.

Of significant interest is the increasingly intense effort being given to the development of several Hot Dry Rock projects by Federal and private entities. A license was granted to Pacific Power Corporation who have moved forward at Muswellbrook to the point where drilling began in April 1999. The drilling is planned to proceed in four stages, to take about 4 years and to cost AUD$ 23.8 million (US$ 15.6 million).

China

China has more than 2700 thermal springs and, if thermal wells and mine outflows are counted, more than 3200 thermal features. Reports are that 255 high temperature geothermal systems have been identified and of these, more than 50 have been studied and assessed. To date, most of the geothermal use has been for space heating, agri-business, aquaculture, balneology and medicinal purposes. However, since 1977, a few moderate to high temperature resources have been used to generate power. Geothermal development has reportedly been growing at an annual rate of about 12% over the last 10 years and continuation of this trend is planned. Estimates of the geothermal power potential made in 1995 were 1000 MWe in south Tibet, 570 MWe in west Yunnan, 170 MWe in western Sichuan and up to 100 MWe in the Tatun region of Taiwan. The latest estimates have not been broken down by region but are for 5,800 MWe for 30 years.

The largest power plant complex in China is at Yangbajing in the Tibet Autonomous Region. The total 1999 capacity is 25.18 MWe (gross), 16 MWe (net), generated by nine single flash, double flash and hybrid cycle power plants, fueled by 140-160^{o}C fluids flowing from 18 wells approximately 200 meters deep. It is reported that the cost of the first plant was about $US 40 million when it was built in 1977, that more than $5x10^{8}$ kWh have been generated since 1979 and that by the end of 1993, the annual energy output had exceeded $1x10^{8}$ kWh. The station supplies 41% of the power needed by Lhasa City in summer and 60% of their winter needs. A program of reinjection testing has been carried out in the past 5 years so as to help maintain the resource and control heat pollution caused by the power plant effluent and there are plans to exploit the postulated deep (~1,850 meter) reservoir.

Several other geothermal fields have been explored in Tibet, western Sichuan and western Yunnan and geothermal power plants have been built at seven sites in China in addition to the largest one at Yangbajing: Dengwu U-1 (86 kW), 1970, Dengwu U-2(386 kW),1977; Dengwu U-3, (300 kW), 1982; Huitang (300 kW), 1975; Langjiu (2.0 MWe), 1987; Quingshui (3 MWe), 1981, Tuchang (300 kW), 1985 and Nagqu (1.3 MWe), 1993.

Since 1995, five of these plants have been taken out of service so that in June 1998, five geothermal power plants had China's total capacity of 29.166 MWe and produced an aggregate 100 GWh annually.

In Taiwan, the Tu Chang 300 kW, water cooled power plant came on line in 1987 at a cost of $US 2 million. The plant, owned by Industrial Technology Research Institute, uses a liquid-dominated, 130^{o}C resource flowing from one 500 meter deep well. The produced fluids contain 2% by weight non-condensable gasses most of which is CO_2 that is recovered for commercial sale. Power is sold to Taiwan Power Company who resell it at $US 0.04/kWh.

During the past five years, no new geothermal electric power was put on line, however studies of the Yangbajing deep reservoir and of the western Yunnan Province resources have been conducted.. For the last five years, the emphasis has been on the development of low and medium enthalpy resources and this has progressed rapidly so that there are now more than 1,620 direct use sites in operation. (This topic is discussed in the Direct Use Rapporteur report).

Costa Rica

On 25 March 1994, the first 55 MWe of power from the Miravalles I field was generated by the Instituto Costarricense de Electricidad. Two plants were built; Unit 1 is a 55 MWe single flash condensing plant while 5 MWe more are generated at using a "Boca Pozo" ("well mouth") noncondensing back pressure facility obtained from CFE of Mexico.

The Unit 1 plant, built by Toshiba, runs on 114 kg/s of steam, at 6 bars pressure, provided by eight wells; separated brines are injected into six wells at a rate of 642 kg/s and non-condensable gasses are removed by steam ejectors.

The drilling of production and injection wells for the second 55 MWe phase to the west and south of the main plant was completed in 1997 and power from Miravalles II came on line in 1998. Also during 1998 and 1999, a drilling campaign to obtain steam for the 27.5 MWe Miravalles III plant was completed and work is now on schedule for its commissioning in May 2000.

In addition to the work done and being planned at Miravalles, studies have been conducted at the Tenorio and Rincon de la Vieja prospects with some favorable results. Drilling at Tenorio was delayed due to the ramifications related to formation of a National Park that includes part of the prospective area. Though the first well, drilled to 2,178 meters in 1999 encountered permeabilities and gradients lower than expected, current ICE plans are to drill three more wells. If results are encouraging, a power plant could be built by 2006.

Rincon de la Vieja, now within the boundaries of a newly created National Park, has been estimated to have ~140 MWe potential. Previously conducted pre-feasibility studies have had to be reassessed in light of Park-related regulations. This work was completed in 1999 and identified two areas, Borinquen and Las Pailas, as the most promising. If the results of Environmental Impact Analyses are approved and permits are issued, drilling of five wells in these prospects could begin by the end of 2001.

The 1995 geothermal generation capacity of Costa Rica was 60 MWe and 592 GWh were produced. The geothermal capacity represents 7.77% of the national capacity and the energy produced is 10.21% of the national total. With plants in construction and planned, their capacity by the year 2000 will be 141.5 MWe. By 2003 it should rise to 161.5 MWe and by 2010, production from Tenorio and Rincon de la Vieja should significantly increase the total.

El Salvador

As of 1999, the installed geothermal generation capacity in El Salvador was 115 MWe which is 15.39% of the national capacity. Power generated totaled 800 GWh which is 20% of the national total.

Geothermal exploration began in El Salvador in 1954. The first power was put on line in 1975 when a single flash, 30 MWe plant was built at Ahuachapan. Capacity doubled in 1976 with the addition of a similar second 30 MWe unit and in 1980, a third, this time double flash, 35 MWe unit was added to bring Ahuachapan's total capacity to 95 MWe.

This was done by drilling 32 production wells but without any reinjection capability (disposal was via a canal to the ocean). The result was that steam deliverability and wellhead pressures decreased and power output eventually declined to 45 MWe. Beginning in November 1996 there has been in progress a program that includes: a) the drilling of 10 new production wells south of the production area, b) building of a pipeline for brines to be injected into existing wells at Chipilapa, 7 kilometers from Ahuachapan, c) construction of the whole gathering system and d) refurbishment of power plants. The results of this work have been an increase of power output to 53 MWe and stabilization of reservoir pressures at 1994 levels.

In the 1960s, there was also some exploration of the Berlin field in the eastern part of El Salvador. During these studies six wells were drilled to depths ranging between 1400-2300 meters. Temperatures to 230°C were found, but permeabilities were low and development was halted. In 1980-1982 two wells with commercial characteristics were drilled and in 1992 two 5 MWe back pressure plant were installed.

In July 1999, a new 56 MWe (2 x 28 MWe) condensing power plant was built at a cost of $US 120 million. The reservoir depth is between 1,950 and 2,300 meters and the highest measured temperature is 305°C. Eighteen new production and injection wells were drilled to provide fluids for the plants.

San Vicente and Chinameca are two other geothermal areas with commercial potential in central El Salvador. Geologic, geochemical and geophysical studies have been conducted in both prospects with recorded temperatures to 230°C and good permeabilities indicated. The potentials of each area have been estimated to be 50 MWe and the final bidding process for concessions at both areas is scheduled to begin in December 1999.

The El Salvadorian geothermists plan studies in Coatepeque, Santa Rosa Lima and Obrajuelo Lempa in addition to the continued development and/or expansion of the areas described above.

El Salvador has reformed its electricity industry since legislation was passed in November 1996. All thermal generation assets were sold by CEL to foreign investors and the geothermal generation facilities were spun off into Geotérmica Salvadoreña S.A. de C. V. which is owned by CEL but which will be privatized soon. As a result of this new system, wholesale power prices have stabilized at about $US 0.06/kWh.

There are three major projects planned in El Salvador that will significantly affect future power prices. These are pending grid interconnections between El Salvador and Honduras, the construction of SIEPAC, a planned 230 kV, 1,800 kilometer long trans-Central America power line and the contemplated construction of natural gas pipelines from Mexico through Central America and/or from Colombia to Panama.

Since 1995, 123 to 70 person-years of public utility effort have been expended annually on geothermal activities as well as about 6-9 person-years per year of university and foreign consultant time. During the same time period, El Salvador has spent about $US 3 million on R&D, $US 172 million on field development and equipment and about $US 175 million on electrical utilization.

Ethiopia

Thirty years after the initiation of geothermal exploration, Ethiopia has finally joined the ranks of nations generating geothermally-fueled electric power. This is a great achievement and all involved are to be heartily congratulated.

Geothermal exploration in Ethiopia began in 1969 and to date, 27 prospects having at least 700 MWe potential have been identified. There is reported to be the potential for 170 MWe from seven sites in the Lakes District, 260 MWe from seven sites in the Central Afar, 120 MWe from 5 sites in the Southern Afar and 150 MWe from 5 sites in the Danakil Depression. The three most intensely explored areas are Aluto-Langano and Corbetti in the Lake District and Tendaho in the Central Afar region.

At Aluto, between 1985 and 1986, eight exploratory wells were drilled to a maximum depth of 2,500 meters with temperatures up to 180°C recorded. In 1995, a 1986 feasibility report was reviewed by GENZL of New Zealand who recommended the installation of a 5 MWe condensing power plant.

In 1996, a contract was awarded to Ormat Industries. In 1998 a two unit, 8.52 MWe (gross), 7.28 MWe (net) plant was synchronized to the national grid and in June 1999, the plant was commissioned. The plant capacity equals 1.93% of the full national capacity while the 30.05 GWh generated are 1.85% of the national power generation total.

Ethiopian Electric Power Corporation (EEPCO) plans are to increase generation at Aluto to 30 MWe in the near future and possibly, to use the resources, in a cascaded scheme, to extract soda ash and to process diatomites.

Tendaho has been evaluated via prefeasibility and feasibility stage studies together with the drilling of three deep and three shallow wells. Temperatures to 260°C have been recorded and it is believed that four of the six wells can be productive. EEPCO plans to build a 2.5-3 MWe plant there soon and to eventually expand the installation to the 20 MWe anticipated field capacity.

The Corbetti area is within a 12 km wide caldera that contains fumaroles and steam vents. Six gradient wells have been drilled in this environment to depths ranging from 93 to 178 meters. A maximum temperature of 94.1°C was recorded.

Currently, the Ethiopian Institute of Geological Surveys is: a) Monitoring geochemistry and reservoir parameters at Aluto-Langano and Tendaho, b) Conducting detailed geologic mapping and geophysical studies in the Lakes District and c) Sampling waters and gasses from surface manifestations in the Main Ethiopian Rift and in the Northern and Southern Afar regions.

In the near future, they plan to drill more production wells at Aluto-Langano so as to provide steam for the field expansion and also to generate 2.5 to 3 MWe at Tendaho using the existing wells.

EEPCO plans to increase geothermal capacity to 700 MWe as financing becomes available and to export excess power. Despite an abundance of undeveloped hydropower sites, it would appear that geothermal power will certainly play an increasingly important role in EEPCO's power generation plans in the new millenium.

France

As was the case in 1995, the 4.2 MWe, double flash plant built in 1984 at La Boulliante on the French island of Guadeloupe remains the only geothermal installation completed. Due to scale and corrosion problems, the plant was shut down in 1991, however these problems were corrected, the plant design was simplified and power generation was resumed in 1996. Currently the plant generates 2% of Guadeloupe's electricity.

Recently there has been renewed interest in the use of geothermal energy in the French Caribbean islands and there are therefore plans to increase capacity at La Bouillante to 20 MWe. To this end, an inferior well drilled in 1974 was successfully stimulated by injection of cold water so as to increase its production capability and the drilling of three new wells has been scheduled for 1999 or 2000.

Development of geothermal resources prospected in the past on Martinique and La Reunion islands is also likely and new supplementary geoscientific studies are planned over the next few years so as to identify drilling sites.

Guatemala

The first geothermally fueled electric power to come on line in Guatemala is at the Amatitlan "Caldera" project. At this field, 28 km southeast of Guatemala City, four wells drilled prior to 1995 by West Japan Engineering Consultants (West Jec) encountered temperatures to 300^{o}C at depths to 2058 meters. In 1998, using fluids from two of these wells, Company Ingenieros Civiles Asociados (ICA) installed a 5 MWe back pressure power plant. This unit will be run by ICA for three years and will provide power for the national grid until expansion of the field and the construction of a condensing 25-30 MWe plant is possible.

In addition, in the southeastern part of the Amatitlan caldera, the private firm BLOTECA has drilled four shallow (200 meters deep) wells on a very small industrial land tract. The wells have encountered fluids at temperatures to 200^{o}C and plans are to: 1) use the fluids to dry/cure concrete blocks and 2) fuel a binary generation plant that will sell power to the national grid. BLOTECA is already using fluids from previously drilled slim holes very successfully to cure their blocks and an associated firm, Agroindustria La Laguna, is also using these fluids at a site immediately adjacent to the BLOTECA property, to dry a selection of tropical fruits prior to packaging them for commercial sale.

The second Guatemalan geothermal power plant to come on line has been built at the Zunil I field in the Province of Quetzaltenango. Nine wells have encountered temperatures to 297^{o}C at depths ranging from 1500-2330 meters and a six unit, air cooled, 27.8 MWe (gross), 24 MWe (net) Ormat plant started operations in August 1999. Ormat International, Inc. working under the local name Orzunil, will operate the plant for 25 years, buy steam from INDE and sell power to the national grid. In 1999, four injection wells were drilled at Zunil I in order to have adequate capacity for receipt of all spent power plant fluids.

Only 2 km east of Zunil I, a second field, Zunil II has been discovered. Three slim holes drilled to 757 meters encountered commercial quality resources with well Z-21A producing 35t/h of dry steam. Explorationists believe that the primary, liquid-dominated reservoir at the Zunil II field may have the potential for fueling 40-50 MWe. In addition to the fields summarily described above, the Moyuta, Tecuamburro, Totonicapan and San Marcos fields show commercial potential.

The Guatemalan geothermists drilled 8 wells more than 100 meters deep between 1995-1999. They had 29 MWe on line at the end of 1999. This equals 3.68% of the country's installed capacity while the 215.9 GWh generated is 3.69% of the nation's output. INDE has reduced its staff significantly within the past 5 years and they currently have no funds budgeted for future expansions.

Iceland

Currently, the total installed capacity of geothermal power in Iceland is 170.1 MWe (13.04% of the national installed capacity), generated from fields at Bjarnarflag, Krafla, Svartsengi and Nesjavallir. Installation of 16 MWe more is planned by 2005. The geothermal energy now produced is 1138 GWh annually, or 14.73% of the national energy total.

At Bjarnarflag (Namafjall field), a single flash back pressure turbine, built in 1969, continues to generate 3.2 MWe using steam from a 280^{o}C resource at 9.5 bar and 12.5 kg/s.

At Krafla, a 30 MWe, double flash plant has remained on line since 1977 despite nine volcanic eruptions, innumerable earthquakes and brine contamination, scaling and corrosion caused by volcanic gases infiltrating the geothermal resource. In 1996, 4 wells were drilled and in 1997 a second 30 MWe unit started production. The resource temperature is 210^{o}C, steam separation is at 7.7 and 2.2 bar absolute and the total Krafla power production in 1999 was 60 MWe and 484 GWh.

The third geothermal field at which electricity is produced is Svartsengi where power generation is actually secondary to the pumping of geothermal brines for district heating. Nevertheless, in 1978, three single flash back pressure turbines were built, capable of 6.0, 1.0 and 1.0 MWe respectively. In 1989, three 1.2 MWe Ormat binary units were installed and in 1992 another four 1.2 MWe Ormat plants were commissioned. In 1999, following the drilling of 3 production wells and 1 injection well, a new single flash 30 MWe plant was built, bringing the Svartsengi total to 46.4 MWe.

Finally, at Nesjavallir, two 30 MWe single flash plants, with a working pressure of 12 bars (190^{o}C), were commissioned in October and November 1998. Now under consideration is further expansion of this field by another 30 MWe to an ultimate total of 90 MWe.

Orkustofnun, the National Energy Authority, continued to explore Iceland's geothermal fields and from 1995 to 1999 they drilled 8 wells in high enthalpy fields and 241 wells in low temperature areas. Utilization of professional geothermist's time remained very steady during this time period but expenditures for the building of 120 MWe of new geothermally fueled capacity soared from $US 7 million to $US 90 million.

Indonesia

In 1995 there were 305 MWe of installed capacity. By the end of 1999, there were expected to be a total of 589.5 MWe of capacity installed at six fields. This equals 3.04% of the total national capacity and 5.12% of the nation's energy. There will be 140 MWe at Kamojang, 330 MWe at Salak, 55 MWe at Darajat and 60 MWe at Dieng plus the 4.5 MWe generated at two pilot plants. As of the end of 1999, neither the Dieng nor the Lahendong plants were operating so that the available capacity was 527 MWe.

There are seven fields in various stages of operation and development:

Java Fields

Kamojang: Dry steam fuels 140 MWe; average reservoir temperature is 245°C at 35 bars; 29 wells capable of providing 60 MWe of steam were drilled in 1996-97 but a planned 60 MWe plant has been postponed due to the economic crisis.

Salak: Units 3, 4, 5 and 6 each at 55 MWe, came on line in 1997; total capacity is now 345 MWe and an 80% capacity factor has been maintained; the reservoir is liquid-dominated, neutral-Cl with temperatures from 240°C to 310°C.

Darajat: By 1999, Amoseas of Indonesia, Inc. had drilled 17 wells and built a 70 MWe plant to supplement the 55 MWe already in place; the dry steam resource temperature is about 245°C; the power plant has not come on line due to the economic crisis.

Dieng: Between 1995 and 1998, 25 wells were drilled by Himpurna California Energy (HCE) to fuel a 60 MWe plant; the resource is two-phase at 280-330°C; the plant is not currently in operation due to the economic crisis.

Wayang Windu: Asia Power/Mandala Nusantara drilled 18 wells capable of providing enough steam for 185 MWe; the field and plant were completed and tested in July 1999; the field is liquid-dominated and temperatures range from 250-270°C. The plant is not operating due to the economic crisis.

Sumatra Field

Sibayak: Through July 1999, 10 wells have been drilled; the proven capacity is 25 MWe; in 1995, Pertamina installed a 2.0 MWe backpressure power plant; the reservoir is liquid-dominated with a temperature of 240-275°C.

North Sulawesi Field

Lahendong: Fifteen exploration and development wells have been drilled and can supply steam adequate for 30 MWe; in 1992, a 2.5 MWe plant was installed, but it has never gone into commercial operation; in May 1999, plans were completed for construction of a 20 MWe plant to be in operation by 2001; the resource is liquid-dominated with temperatures of 260-330°C.

Geothermal resources have been confirmed by drilling at Sarulla, Sumatra, Patuha, Java and Karaha, Java. Exploration drilling has been conducted at seven additional geothermal areas in Sumatra, Java, Bali and Flores.

Between 1995 and 1999, 96 exploration wells, 107 thermal gradient holes, 147 production wells and 18 injection wells were drilled. Professional manpower allocated to geothermal escalated from 221 person--years in 1995 to 526 person-years in 1999 and the percentage of the national power demand supplied by geothermal increased from 1.6% in 1995 to 3.4% in 2000.

By the year 2005, Indonesian geothermists anticipate that 15 fields will have been developed so as to produce 1,987 MWe. This will be accomplished through field extensions at Darajat, Dieng and Lahendong and a new project on line at Wayang Windu. The percentage of the national power demand to be filled by geothermal in 2005 is expected to be about 7%. There are also 70 high temperature prospects: 31 in Sumatra, 22 in Java and Bali, 6 on Sulawesi, 8 on Nusatenggara and 3 on Maluku. Estimated reserves at these sites are 20,000 MWe and total reserves are thought to be about 9,900 MWe.

The development of Indonesia's very considerable geothermal resources was brought to a halt by the serious economic downturn in the late 1990's and the ensuing political upheaval. Power sales from geothermal plants were very negatively impacted by this situation and until stability returns to the country, geothermal exploration and development by non-Indonesian entities will be scant.

Italy

Despite liberalization of the electricity market in Italy and the associated reorganization of Enel, during the 1995-1999 period, geothermal electric power generation in Italy increased to 785 MWe, with energy output reaching 4403 GWh in 1999 (1.03% of the national installed capacity produces 1.68% of Italy's total energy production). At Lardarello, Mt. Amiata and Latera, 260 MWe was installed, 105 MWe were under construction in January 2000, while funds have been committed for later construction of 285 MWe. During the 1995-1999 period, 229 MWe was decommissioned.

Specifically, within the Larderello Area, 60 MWe was built at Farinello in 1995, 20 MWe were installed at Nuovo Sasso and at Le Prata in 1996, 20 MWe each at Carboli 1 and 2, Selva 1 and Montiverdi. The Carboli 1 unit was built in 1998, while the other 4 were put on line in 1997. In the Mt. Amiata region, a 20 MWe unit was built at Bagnore 3 in 1998. Finally, at Latera, a water-dominated reservoir was tapped to fuel a 40 MWe double flash plant in 1999.

Since 1995, a total of 33 production and 2 injection wells were drilled. The depths of these wells ranged from 2000-4000. A most notable well was drilled in the Travale-Radicondoli region of Tuscany: it produced about 70 kg/sec of superheated steam and is thought capable of fueling 30-40 MWe alone. Plans are to build 60 MWe of new capacity in the vicinity of this well.

The amount of time worked on geothermal projects by professional geothermists in Italy decreased slightly, probably due to the reorganization of Enel. In 1995-1996, there were 176 person years of effort expended; in 1997-1998 the time decreased to 161 person years and in 1999 it reached 149 person years. Since 1985, $US 280 million was spent on R&D and $US 1,254 million on field development. Of these funds, 99% were obtained from private sources and only 1% were derived from public coffers.

Japan

As of 1 January 1995, the installed geothermal power capacity was 312.3 MWe generated by 12 plants built in 11 fields. This capacity equates to 0.23% of the national installed capacity and the plants generate 0.36% of the nation's energy.

The plants range in size from the 65 MWe Yanaizu-Nishiyama unit to the 100 kWe Kirishima International Hotel back pressure generator in Beppu, Kyushu.

In March 1995, a 30 MWe single flash plant was commissioned at Yamagawa. In the same month, a 50 MWe single flash plant went on line at Sumikawa in Akita prefecture. At this site, multiple wells were drilled from a single pad and warm waste waters are used to melt snow around the plant buildings. In May 1995, the 65 MWe Yanaizu-Nishiyama plant was built. This facility was designed to be as simple as possible and its efficiency is increased by the cascaded use of underflows in a nearby municipal greenhouse complex.

Also in May 1995 the 30 MWe single flash Kakkonda No.2 plant began operations. The wells supplying this field tap a reservoir at about 3,000 meters depth, well below the reservoir used by Kakkonda No. 1. In March 1996, a 30 MWe single flash plant was built at Ogiri in Kagoshima Prefecture. This plant is similar in design to those at Otake, Hatchobaru and Yamagawa.

Takigami, explored since the early 1980's, went on line in November 1996 with 25 MWe generated via a single flash cycle. This plant is in the same region as Otake, Hatchobaru and a couple of small private plants, thus making the area the most prominent geothermal zone in Japan. Finally, in March 1999, a 3.3 MWe dry steam plant was commissioned on the small island of Hatchijojima in Tokyo prefecture. The resource is beneficially used for greenhousing and other direct applications besides provision of power.

With the upgrading of the output of the Uenotai plant from 27.5 to 28.8 MWe, a total of 546.9 MWe of geothermal capacity has been installed via 19 plants in 17 geothermal fields. This capacity is 0.2% of Japan's total installed capacity from all sources but the 3,531.6 GWh generated in FY 1998 is 0.4% of the power generated in Japan for that period. The latter advantage is due in part to the high (80.7%) average utilization factor reported for Japanese geothermal plants during the past five years.

The reported investment by Japanese government agencies from 1995-1999 was $US 467.1 million, a decrease from $US 632 million spent in the 1990-1994 period and from the $US 727.3 million paid from 1985 to 1990. Geothermal energy continues to be considered highly important by the Japanese government, but allocations of professional time spent in four major agencies decreased by 8 to 14% between 1995 and 1999.

Kenya

Since 1995, no new power plants have been built in Kenya. Power produced at the Olkaria East, three-unit, 48 MWe gross (45 MWe net), single flash, Mitsubishi installation built in 1981 decreased about 3 MWe to 31 MWe by 1994. The decrease was said to be due to declines in the steam produced from the connected wells. In order to correct this situation, four make-up wells were connected in 1995 and two more were added in 1996. Currently 24 of 29 wells are contributing steam with three more scheduled to be added by the middle of 2000 to ensure that full capacity can be maintained. The steam from the wells connected to date have enabled the plant output to return to design levels. Plant availability was reported to range from 96.8% in 1981 and 92.8% in 1997. The geothermal capacity is 5.29% of the total national capacity and the energy produced is 8.41% of the full national energy supply.

Reinjection, first with cold water and now with hot fluids has been initiated and has reduced pressure and well-output declines to about 3% per year. The majority of the first wells drilled at Olkaria East were relatively shallow. In 1997, efforts were begun to deepen some wells and as a result, production from well OW-05 has increased from 1 MWe to 4.8 MWe.

In 1997, well OW-714, in Olkaria Northeast, was retested and the potential for this part of the field is now estimated to be about 80 MWe. Some work has begun recently and it is hoped that a plant can be completed by January 2002.

In the Olkaria West part of the field a well begun in 1993 was completed and bids were let in 1996. A private firm signed power purchase agreements with Kenya Power and Light in 1998 and four wells were to be flow-tested in early 1999.

The Olkaria Domes field was explored by three wells to 2,200 meters in 1998 and 1999. Discharge tests are in progress and it appears as if this might be the site of Olkaria IV.

Exploration in the Olkaria Northwest and Southeast areas was conducted in 1996 and 1998 respectively. The results were not encouraging.

The Eburu area, south of Olkaria, was explored and drilled in 1996. A low enthalpy (453 kJ/kg) was found.

At Longonot, immediately southeast of Olkaria, surface exploration delineated a site for the first exploration well scheduled to be drilled in September 1999. If this well is successful, two more are planned. All of this work depends on the availability of funds.

The Kenyan government plans to be generating 576 MWe of geothermally fueled power within the next 18 years. To help achieve this goal, the public utilities in Kenya have allocated professional manpower that increased from 23 person-years in 1995 to 29 person years in 1999 and a total of $US 13.8 million has been spent in research, development and drilling since 1995.

Mexico

Mexico currently has an installed capacity of 755 MWe that is generated at three fields. This capacity is 2.11% of national capacity and the energy generated is 3.16% of the total national energy supply. Cerro Prieto produces 620 MWe, Los Azufres generates 93 MWe and Los Humeros outputs 42 MWe.

At Cerro Prieto, there are 9 units in operation in Phases I, II, and III. Plant factors average 92.4%. There are plans to add four 20 MWe units as part of Phase IV in 2000.

At Los Azufres, there are eight 5 MWe backpressure units, one 50 MWe single flash plant (Tejamaniles). The flash plants cost about $US4 million each and run on resources whose temperatures range from 265 to 360°C. The wells from which these fluids flow are 2,740 to 6,873 feet (835-2,095 m) deep.

There are also two 1.5 MWe binary plants, installed in 1993, that are air-cooled and which use 175°C separated brines, at 141 tonnes/hr, that originate at wells U-11 and U-12. Since 1995, capacity actually decreased by 5 MWe when one backpressure unit was removed and sent to the Amatitlan Caldera field in Guatemala. Plans are to add four 25 MWe plants by 2001 and then to build another 100 MWe so that the estimated field capacity of 250-300 MWe is gradually realized.

The Los Humeros field features seven 5 MWe backpressure plants commissioned between 1990 and 1993. Because these units have been operating at 6 MWe without any problems for several years, the capacity of Los Humeros is now said to be 42 MWe rather than the 35 MWe claimed in 1995. Addition of 50 MWe more is planned by 2002.

The plants, all built by Ansaldo-Makrotek, operate on resources flowing from 7 wells at temperatures of 320-340°C resulting in turbine inlet pressures of 8 bar. The well depths range from 5,250 to 7,300 feet (1,600 to 2,225 m).

At Cerro Prieto, between 1995-1999, 42 wells were drilled: 41 for production and 1 for injection. At Los Azufres, 1 production well and two exploration wells were drilled bringing the number of wells in that field to 72. At Los Humeros, 4 wells and one injection well were drilled into a field that now has 40 wells.

Finally, at Las Tres Virgenes, three production and 2 injection wells were drilled. These will be used in conjunction with two 5 MWe condensing power plants that were started in 1999 and which are slated for commissioning in December 2000. Additional plans are to add a 15 MWe condensing plant by 2002.

The La Primavera field near Guadalajara has a proven capacity of 75 MWe but development is awaiting resolution of some environmental matters. When this happens, probably in mid-2000, CFE plans to install several (unspecified) 5 MWe units. The resource temperature is anticipated to be 356°C and the resource depth about 9,800 feet (2,987 m).

Currently, Mexico's geothermal fields produce about 3.2% of the nation's power. The addition of 325 MWe of geothermal is planned by 2005, this will slightly increase the percentage of geothermal in the nation's energy mix to about 4%.

Mexico's CFE continues to expend a great deal of professional scientist time on geothermal activities with the person-years of effort ranging from 220 in 1995 to 240 in 1997. During the same period, universities have put in 40-45 person-years and private industry has expended 19-35 person-years of effort. All of these figures show that there has been some growth in the staffing of the Mexican geothermal industry since the previous five year reporting period.

New Zealand

Since 1995, there has been an increase of 144 MWe in the geothermally generated power in New Zealand. This is due in part to the restructuring of New Zealand's electricity industry (as summarized below) and the resulting availability of government-drilled wells and one power plant at below-appraised-value prices.

Currently, geothermally generated electric power in New Zealand totals 440 MWe. This capacity equals 5.11% of the total national capacity and the energy generated is 6.08% of the national energy total. The power is produced via 32 units installed at 6 sites. The output ratings range from 1.2 - 55 MWe and the total annual energy produced is 2268 GWh/yr.

Wairakei is still the largest field with 164 MWe of capacity. Ohaaki is next with 114 MWe produced. Then come the Kawerau-Tasman Pulp & Paper plant (10 MWe), Kawerau-Tarawera (6 MWe), Rotokawa (25 MWe), 9 MWe at Ngawha, 55 MWe at McLachlan-Wairaki, and 55 MWe at Mokai. Installation of 15 MWe more of binary power is also planned at Wairaki. Thus, by the year 2005, a total of 455 MWe should be geothermally generated.

At Wairaki, pressures held relatively constant, but steam production continued to decline at about 4% per year. Five new production wells were drilled after 1995 to make up for this decline. The newly produced steam, together with the installation of a small backpressure turbine in place of some pressure reducing valves, resulted in a 4 MWe increase in overall Wairaki capacity. Also, in 1996, 5 deviated injection wells were drilled so that by 1997 2,000 to 2,500 tonnes per hour were being injected with no adverse effects on field production.

In 1996, the 55 MWe McLachlan (Poihipi) was built by Mercury-Geothermal in the southwestern part of the Wairaki field. This plant taps a shallow steam reservoir and is the nation's only non-base load geothermal unit. Construction of a planned 15 MWe bottoming cycle binary plant, slated to be a is on hold.

At Ohaaki, the high pressure steam production continued to decline and plant output decreased from 80 to about 50 MWe. In 1995 three deviated wells were drilled and two of them encountered hot fluid entries at about 2,400 meters depth. Also in 1995, two existing wells were deepened and deviated to try to intercept this same resource. One was successful and the combined drilling programs resulted in the production of new steam able to fuel about 15 MWe. It is hoped that this will extend the plant life well into the next decade.

At Kawerau, a 10 MWe back pressure plant was installed in 1966 and in 1990, two 1.2 MWe plus one 3.5 MWe binary Ormat plants were built. The resource temperature is 342°C but the binary plants also use underflow from the back pressure plant that previously flowed into the Tarawera River.

One injection well was drilled in 1998 so that now about 30% of separated geothermal brines are injected.

At Ngawha, construction of the first plant was begun by Ormat in 1997 and the plant was commissioned in 1998. Reported plans are to install 15 MWe more.

At Mokai, the drilling of 6 exploration wells in 1981-1983 disclosed what, at 326°C, may be the hottest resource in New Zealand. One well alone appears able to support generation of 25 MWe. Resource consents for a 55 MWe plant were obtained in 1997 and an Ormat Combined Cycle plant together with a 20 kilometer transmission line and the drilling on one additional well were begun in late 1998. When the plant is commissioned in December 1999, it will be the first geothermal installation to be wholly owned by a Maori Tribal Trust.

Eight wells drilled in the 1960's and 1980's at Rotokawa, 8 kilometers north of Wairaki, discovered a 330°C resource, at about 2,000 to 2,500 meters, having an estimated potential of at least 200 MWe. Beginning in 1995, the Tahahara Maori tribal trust purchased two wells from the government, drilled one more production well and two more reinjection wells and formed a partnership with Power New Zealand to build a 24 MWe plant. An Ormat Combined Cycle design was selected and a 29 MWe gross, 24 MWe net plant was commissioned in December 1997.

Exploration at Tauhara found a permeable steam cap that is connected to the Wairaki field at depth. Plans for a 15 MWe plant are awaiting approval.

The time spent on domestic and overseas geothermal projects by New Zealand's professional governmental geothermists was about 114 person-years from 1995 and 1999 but decreased from 40 to 8 person-years annually during the period. Time spent by geothermists from public utilities and universities was 17 and 37 person-years respectively, with little variance each year. The use of private industry experts aggregated 309 person-years, with a high of 102 in 1998 and a low of 36 in 1995.

New Zealand's geothermal developments over the last five years have cost an average of $US 1.1 million/MWe, well below the cost elsewhere in the world. Despite this advantage, the rapid development of private power in New Zealand has resulted in a significant over-capacity situation and this, combined with the low price of natural gas, is anticipated to inhibit further geothermal power development for the foreseeable future.

Nicaragua

The first commercial exploitation of Nicaragua's rich resources came in 1983 when a 35 MWe single flash unit was constructed at the base of Momotombo volcano. In 1989, a second, similar plant was built, however there was never any reinjection and since the 1980's the power produced has declined to about 20 MWe. In 1999, Ormat International signed an agreement with Instituto Nicaraguense de Energia (INE) to take over the project and do what is required to resume power generation of 70 MWe.

San Jacinto-Tizate was also recognized as being highly prospective in the 1960's. Between 1993 and 1995, the Nicaraguan-Russian consortium Intergeoterm drilled seven wells 724 to 2,335 meters deep in the area. Measured temperatures ranged from 264 to 289°C and the cumulative capacity of wells SJ-4, 5 and 6 has been estimated to be about 25 MWe.

INE has approved concessions for geothermal exploration and development in three other areas. Trans-Pacific Geothermal has a concession at El Hoyo-Monte Galan where between 1996 and 1997 they identified four prospective zones and have estimated a potential of 150 to 200 MWe.

In December 1999, INE granted a concession at El Najo-Santa Isabel to SAI who reportedly plan to build a 60 MWe plant.

Finally, in 1999, INE granted a concession in the El Casita area to Triton Energy. Their plan, if significant environmental constraints and geologic hazard concerns can be overcome, is to build at least 10 MWe for use at the El Limon mine.

If political and economic conditions in Nicaragua continue to stabilize, it may be possible to have 145 MWe on line by 2005. Towards this end, INE has been allocating about 30 person-years of effort annually and private industry has devoted 3 to 20 person-years of work per year between 1995 and 1998. The installed capacity equals 16.99% of the total national capacity and the reported energy generation would equal 17.22% of the national energy total. In the author's opinion, if the Momotombo plant has been operating near 20 MWe as documented above, the latter figure might be closer to 3.5%.

Philippines

The Philippines are the world's second largest producer of geothermally generated electricity. As of late 1999, there is a total installed capacity of 1,908.98 MWe . The geothermal plants are generating 21.52% of the nation's energy supply from six fields, in which there are 11 areas in production as listed in Table 5.

At Mak-Ban, there exist three plants of 330 MWe, 80 MWe and 15.73 MWe. These plants derive fluids from 73 production wells and reinject via 14 wells.

At Tiwi, power generation has declined due to cold water influx and the severe damage caused by Typhoon "Loleng". As of July 1999, the operator, Philippine Geothermal Incorporated (PGI) was negotiating with National Power Corporation (NPC) regarding the terms of a "Tiwi Rehabilitation Project" aimed at optimization of the performance of the field's existing power plants so as to improve generating efficiency.

At Tongonan, the largest known Philippine field, BOT legislation has enabled very significant expansion during the past 5 years. In addition to the Tongonan I 112.5 MWe plant operated by NPC, the following BOT plants were built:

a) Tongonan II, comprising the 131.86 MWe Upper Mahio Binary and the 77.5 MWe Malitborg units and
b) Tongonan III, including: 3 x 5.75 MWe at Tongonan I, 2 x 6.35 MWe at Mahanagdong A, 1 x 6.38 MWe at Mahanagdong B, 1 x 14.56 MWe at Mahanagdong A, 2 x 60 MWe at Mahanagdong A and 2 x 77.5 MWe at Malitborg.

At Palimpinon, there was no expansion in the past 5 years, however there have been some well workovers and reservoir monitoring conducted.
At Bac-Man in 1998, 20 MWe was built in the Botong sector of the field and one production well was drilled so that there are now 24 production and 12 injection wells in the field.

In 1998, flow from a low enthalpy well (MO-2) was used to generate 1.5 MWe dedicated to powering the Comprehensive Agrarian Reform Program. Though the plant generated 0.18 GWh of power prior to 25 January 1999, the plant has been shut down since then for well and turbine maintenance and repair.

At Mindanao, 52 MWe were commissioned at Mindanao I in 1996 and 48 MWe more went on line at Mindanao II in June 1999.

The Philippine government plans to add 526 MWe of new capacity between 2002 and 2008. Table 6 lists these projects:

By the year 2008, the Philippine Energy Plan has set goals of increased geothermal power generation from the current 9,900 GWh to 13,865 GWh. This will entail the drilling of 328 geothermal wells. Despite this planned increase in geothermal generation, the share of the Philippine energy mix that will, in 2008, be held by geothermal power, will decrease from 23.1% to 18.47% due to the planned onset of natural gas utilization.

Portugal
Most of Portugal's geothermal exploration and all of its exploitation for electric power generation has been in the Azores Islands. To date, 12 areas having potential for geothermal power generation have been identified on the islands of Faial (Flamengos, 7.5 MWe), Pico (Madalena, Capitae, and Lages, all 5 MWe), Graciosa (Guadeloupe, 5 MWe), Terciera (Pico Alto, 15 MWe, St. Barbara, 2.5 MWe, and Praia Vitoria, 15 MWe) and Sao Miguel Island (Mosterios, 5 MWe, Ribeira Quente, 10 MWe, Furnas, 80 MWe and Ribeira Grande, 80 MWe).

From 1978-1980, five wells were drilled at Ribeira Grande. They disclosed the existence of a 225-235°C, liquid dominated, NaCl (8 g/l) resource. In 1980, a 3 MWe back pressure Mitsubishi pilot power plant was built on the lower flanks of Agua de Pau volcano. It was fueled by fluids from one exploration well, but the flow rate, after equilibration allowed the production of only 0.6 MWe.

In 1986 and 1987, an American/Portuguese consortium was formed to drill Cachaco-Lombadas, a geothermal area immediately adjacent to Ribeira Grande. Four wells were drilled and a resource at 240°C was found at 1,200 meters. After one well, CL-1 was successfully drilled, the consortium was dismantled and an all Portuguese firm, SOGEO, was formed to drill three more wells and install 10-13 MWe in two phases. As of 1999, the power plants had not been built, though there are plans reported to drill a fifth well for production and to use well CL-4 for injection. In May 1994, two 2.5 MWe Ormat power plants were built. They were fueled by fluids from the CL-1 and CL-2 wells and produced almost 5.0 MWe net.

In 1998, a second plant was built at Ribera Grande. It comprises two 4.0 MWe binary units and, with its output, 16 MWe of geothermal energy now fuels about 21% of the power needs of the island. Plans are to build an additional 25-30 MWe of capacity on Ribera Grande in the next 10 years so that 40-45% of demand will be met geothermally by a total generation of 40-50 MWe.

Russia
There has been some expansion of the geothermal power generation facilities in Russia between 1994-1999 as exploration and development activities in the Kamchatka Peninsula and the Kurile Islands increased modestly. Seventy eight production and injection wells were drilled in this period, 12 MWe of new power came on line, a major transmission line was built and power plants are under construction.

The 11 MWe Pauzhetka single flash plant, built in 1966 and enlarged in 1980, is still in operation and produced about 35 GWh/yr. in 1999. This installation, in Southern Kamchatka, comprises three units of 2.5, 2.5 and 6.0 MWe respectively. Seven wells utilize 240 kg/s of fluids with an enthalpy of 760-800 kJ/kg to fuel the current capacity and there are a total of 79 wells drilled in the field. Plans are to retire the old units soon and to build three 7 MWe plants to replace them. Appropriate use of the existing wells will be made to fuel the new units.

Following exploration that began in 1979 and which included the drilling of 82 bore holes 255 to 2,266 meters deep, the Severo-Mutnovka field has now been developed. A shallow, vapor dominated resource with an enthalpy of 2,100-2,700 kJ/kg has been defined between 700 and 900 meters deep with a liquid-dominated reservoir having an enthalpy of 1000-1,500 kJ/kg below it.

As of 1998, there were 17 wells capable of producing 330 kg/s of fluids with an average enthalpy of 1,600 kJ/kg. These are now being used to supply 12 MWe via three 4 MWe Tuman 4K plants in the Verkhne part of the field. In 1999, a transmission line from this installation to the market was completed so that the total geothermal power being generated and used in Kamchatka has reached 23 MWe. This capacity equals only 0.01% of the national capacity and the energy generated is only 0.01% of the national energy total.

Plans are in place for a consortium comprising Nauka (Russia), West JEC (Japan) and GENZL (New Zealand) to build the second, third and fourth power plants in the Verkhne area. The second will output 40 MWe and it will be followed by phases that will bring the total to 80 MWe and then to 200 MWe. The current project is being supported by a $US 99.9 million loan from the European Bank of Reconstruction (EBRD).

There are at least four more highly promising prospects in Kamchatka: Nizhne-Koshelev with fluids having enthalpies up to 2,800 kJ/kg, Bolshe-Bannoe with boiling water discharges that reach 285 L/s, Kireuna where boiling waters have a 24 MWt capacity and Semyachik which is near the famous Geyser Valley in the Kronotskii Reservation. It has been estimated that the high temperature resources defined to date on the Kamchatka Peninsula could ultimately support generation of 1,130 MWe or more.

There is also great geothermal potential in the Kurile Archipelago. On Iturup Island, a 32 MWe power plant, comprising three 4 MWe and one 20 MWe units, is to be built between 2000 and 2003. To date, 9 wells have been drilled there and are ready for use in resource exploitation.

Finally, there appears to be significant geothermal potential in the Northern Caucasus Region. A 3 MWe pilot plant was planned at Kayasula, however technical challenges, associated high costs and potential environmental problems due to resources having high TDS (>100 g/kg), relatively low temperatures (150-170°C) at 4,000-4,400 meters depth and injection pressures to 7 Mpa, currently make the development of this project unlikely.

Various geothermal topics are studied at technical centers located in 14 Russian cities. The staffs at these centers comprise a large number of highly qualified engineers and 27 professionals holding PhDs in geology or other technical disciplines. They act to unite work conducted in 26 scientific institutes, 3 universities and 5 project bureaus.

Thailand

Cataloging of geothermal features in Thailand began in 1946 and since then more than 90 hot springs with temperatures ranging from 40-100°C have been mapped. Evaluation of the nation's geothermal potential began in 1979 and, after studies by a Working Group, a determination was made to concentrate exploration and development activities at Fang, San Kampaeng, Pa Pae, Mae Chaem and Mae Chan, all in the northernmost part of the country. Interestingly, geothermometry at Mae Chan suggests equilibration temperatures close to 180°C.

Thailand's first and only geothermal development is at Fang where in 1989, 134°C waters produced at about 60 t/h from three 150 meter deep wells were used to run a 300 kW (gross), 180 kW (net) Ormat binary cycle power plant. The availability factor since then has been 85-90% and the calculated generating cost, with a 5% interest rate, is $US 0.063-0.086 cents/kWh. It should be noted that a large portion of these costs is related to depreciation and that maintenance costs quintupled in the early 1990's.

Additional exploration at Fang, begun in 1990 under the auspices of EGAT and the French agency ADEME, included the drilling, in 1992-1993, of three 500 meter deep wells. Well FX-4 flowed 36 t/hr and has a bottom hole temperature of 130°C. Since the end of 1996, it has been connected to the system so as to increase the amount of hot water available at the plant.

At San Kampaeng, EGAT and JICA (Japan) initiated a technical cooperation project in 1981. From 1982-1989, exploration surveys were conducted and in 1989, two deep wells were completed. The wells failed to yield enough data to characterize the deep reservoir, however well GTE-8 produced 40 t/h of 125°C water from a fracture at a depth of 920 meters. Further work at San Kampaeng has been suspended pending the development of directional drilling techniques. Thai geothermists believe that San Kampaeng has the potential to produce about 5 MWe.

Pre-feasibility studies at Pai-Ban Muang Rae site were conducted by EGAT and Chang Mai University during 1994-1995. Preliminary studies have indicated the area to be similar to Fang but three 200-300 meter deep wells drilled in 1995 to test this anomaly were non-productive.

At the Pai-Ban Muang Paeng site, four 250 meter deep exploration wells were drilled in 1996. Three wells discharged hot water and had bottom hole temperatures of 94°C but development has been postponed due to the low temperatures.

Exploration in the following other areas was undertaken after 1995: Mae Kasa, Nong Haeng, Pai-Muang Rae Mae Chan and at Pha Sert. One well at Mae Chan "geysered" at a rate of 5.94 L/s. to a height of about 15 meters. The maximum temperature in this well is 122°C. Finally, in 1997, two 100 meter deep wells were drilled at Muang Ngam and at Pha Bong .

In 1996, it was agreed that a working group would submit a 2.5 million baht (US$ 67,000) proposal to the government to fund comprehensive studies of all Thai geothermal areas. It is not clear whether this plan has been approved and/or funded.

Turkey

Exploration of the Kizildere/Denizli field began in 1968. In 1975, a 0.5 MWe pilot plant was built and in February 1984, a 20.4 MWe (gross), 15 MWe (net) single flash power plant was installed. There are 9 production wells. Reservoir temperature at about 2,000 meters depth is 242°C and the resource carries 1.5% non-condensable gasses, primarily CO_2. Extensive $CaCO_3$ scale deposition required frequent cleaning until use of the scale inhibitor Dequest 2066 was begun. Though detailed information regarding the outcome of the scale inhibition has not been reported, scaling is claimed to now be diminished, though the average plant output is only 12-15 MWe.

Reinjection has been required by the high concentration (25-30 mg/L) of boron in the resource. Studies to identify the optimum reinjection sites, depths and techniques are under way. The economic returns on this technically challenging installation have been improved by construction of a 40,000 tonne per year liquid carbon dioxide and dry ice plant that is integrated with the power plant.

The Germencik/Aydyn field, west of Kizildere, has been evaluated via geologic, geochemical and geophysical studies and 9 wells have been drilled into a 216-232°C reservoir within marbles and quartzites at depths ranging from 285-1500 meters. The field is said to have a 100 MWe capacity, according to the results of feasibility studies.

A third field with power generation potential is at Canakkale-Tuzla in northwest Anatolia. The first well was drilled there in 1982. It encountered temperatures of 174°C in a reservoir at a depth of 333-553 meters in volcanic rocks. A second well was drilled to 1020 meters. Temperatures to 174°C were recorded, but permeability was low. Two shallow wells (81 and 128 meters) also produced 146 and 165°C waters.

To date, at least four other geothermal fields with electric power generating potential have been discovered and studied to varying degrees. These are: Yzmir-Seferihiser where temperatures of 153°C have been indicated, Aydyn-Salvatli with temperatures to 171°C, Kutahya-Simav which has resources of 162-171°C and Dikili-Bergama where temperatures reach 130°C. Plans are to be generating 500

MWe from Germencik, Kizildere, Canakkale and several of the other fields by the year 2010 and 1,000 MWe by 2020.

Details regarding exploration for additional high enthalpy resources during the 1995-2000 period have not been supplied.

United States of America

Geothermal power generation is alive in the United States, however its growth rate has decreased very significantly from 18% between 1980-1989 to 0.14% for the period 1990-1998. Geothermal installed capacity rose from 2,774 MWe in 1990 to 2,816 MWe in 1995 and then fell 588 MWe to approximately 2,228 MWe in 2000. A realistic estimate of the installed capacity in the US by 2005 is 2,376 MWe, an increase of 148 MWe. In 2000, the installed geothermal capacity is 0.25% of the total USA installed capacity and the geothermal energy generated equals about 0.4% of the full USA energy supply.

In California, at The Geysers, there were no new plants built since 1994. Four original PG&E units (78 MWe) were retired together with PG&E Unit 15 (59 MWe), the DWR Bottle Rock plant (55 MWe) and, in 1996, the 130 MWe CCPA Units 1 & 2. Thanks to the new Southeast Geysers Effluent Recycling Project (SEGRP), reinjected fluids have allowed power generation to increase.

The two biggest news items from The Geysers have been:

1) The transfer of ownership of the steam fields and power plants from PG&E and Unocal to Calpine Corporation between 1998 and mid-1999 and
2) The start-up of the SEGRP through which 5,400 gallons per minute (340 L/s) of treated wastewaters have been piped 48 kilometers to The Geysers for reinjection.

A second, 66 kilometer long pipeline from Santa Rosa to The Geysers is planned.

In the Imperial Valley of southern California, Salton Sea Unit 1 was expanded by 20 MWe in 1996 and a new 49 MWe Salton Sea Unit 5 plant was built in 1999. In addition, 10 MWe more will be produced at the Salton Sea plants thanks to hardware modifications that will optimize the energy conversion process. This power will be used at CalEnergy Company's Zinc Recovery Plant that is scheduled to be commissioned in mid-2000. Installed Imperial Valley generation capacity is now 452.7 MWe. It is generated at Salton Sea, Heber and East Mesa using 95 discrete power plants.

Between 1995 and 1999 there were no plant additions at Casa Diablo, Honey Lake Valley or Coso though ownership of the latter passed from CalEnergy to Caithness Energy LLC in January 1999. Installed capacity at Casa Diablo remained at 27 MWe, at Honey Lake Valley it is still 3.8 MWe and at Coso it is still 260 MWe.

Planned additional capacity in California by the year 2002 is 98 MWe comprising 49 MWe to be built at Telephone Flat/Glass Mountain by CalEnergy and 49 MWe to be constructed at 4 Mile Hill/Glass Mountain by Calpine.

In Hawaii, a 25 MWe hybrid single flash plant came on line in 1993 at Puna. Though one well was drilled at Puna since 1995, another 30 MWe plant in the same area is still in the planning stages.

In Nevada, 195.7 MWe of power is being generated at ten sites. Four plants started up between 1990-1999: Soda Lake II (15 MWe), Steamboat 2 (12 MWe), Steamboat 3 (12 MWe) and Brady Hot Springs (24 MWe). Currently, there are no plans for development of any new power plants in Nevada, primarily because of the very low prices being offered for power. In July 1999, U.S. Energy Systems, Inc. purchased the holdings of Far West Capital subsidiary Steamboat Development Corporation including the 40 MWe Steamboat 2 and 3 plants and the rights to 600 acres of underlying resources.

In Utah, there was no expansion at Cove Fort or at the 20 MWe Roosevelt field so that the total state geothermal capacity is still 31 MWe. As of 1999, no immediate plans for additional power plants in Utah have been announced.

Geothermal well drilling has tapered off in the US since the 1980's. In California, 4 wells were drilled in 1996 (1 at The Geysers and 3 at Salton Sea), 9 in 1997 (4 at Coso, 2 at The Geysers and 3 at Salton Sea) and 7 in 1998 (3 at Coso, 1 at The Geysers and 3 in the Salton Sea). In all, between 1996 and 1998 only 13 production and 7 injection wells were drilled in California.

Drilling activity in other states was also modest. In Nevada, 28 production wells were drilled between 1995-1999. In Hawaii, 1 well was drilled in the Puna area and in Utah, 1 well was drilled into the hot water resource at Cove Fort. No wells were drilled in Alaska, Idaho, Oregon or New Mexico between 1995 and 1999 and the Hot Dry Rock Project long active in the Valles Caldera was terminated by the US Department of Energy in 1997.

It is difficult to accurately determine the number of active geothermists in the US. Using the average membership in the Geothermal Resource Council (GRC) (661 for 1995-1999) as an indicator, and assuming that two or three people work in the geothermal industry for every one that is a GRC member, then 3000-4000 men and women are probably working in geothermally-related positions in the nation.

RAPPORTEUR'S CONCLUDING COMMENTS

It is difficult, in a Rapporteur's Summary, to do justice to the detailed in-country reports as eloquently presented by their authors. Too often, interesting side-topics must be briefly mentioned or ignored while dry statistics tend to dominate. In this report, while presenting statistics as is *de rigeur*, and accurately reporting the status of geothermal in each nation, an attempt has been made to retain and convey some of the enthusiasm and optimism regarding future geothermal development that is typical of most in-country reports. The author is honored to be the Rapporteur for this, the most comprehensive World Geothermal Congress convened to date.

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INSTALLED GEOTHERMAL GENERATING CAPACITIES

TABLE 1

NATION	1995 MWe	2000 MWe	2005(est. MWe)	1995-2000 MWe Increase	%increase
Argentina	0.67	0	n/a	-0.67	n/a
Australia	0.17	0.17	n/a	0	0
China	28.78	29.17	n/a	0.39	1.35
Costa Rica	55	142.5	161.5	87.5	159
El Salvador	105	161	200	56	53.3
Ethiopia	0	8.52	8.52	8.52	infinite
France	4.2	4.2	20	0	0
Guatemala	0	33.4	33.4	33.4	infinite
Iceland	50	170	186	120	240
Indonesia	309.75	589.5	1987.5	279.75	90.3
Italy	631.7	785	946	153.3	24.3
Japan	413.705	546.9	566.9	133.195	32.2
Kenya	45	45	173	0	0
Mexico	753	755	1080	2	0.3
New Zealand	286	437	437	151	52.8
Nicaragua	70	70	145	0	0
Philippines	1,227	1,909	2,673	682	55.8
Portugal	5	16	45	11	220
Russia	11	23	125	12	109
Thailand	0.3	0.3	0.3	0	0
Turkey	20.4	20.4	250	0	0
USA	2,816.7	2,228	2,376	-588	n/a
TOTALS	**6,833.375**	**7,974.06**	**11,414.12**	**1,141.385**	**16.69**

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WORLD INSTALLED CAPACITY TOTALS 1980 TO 2005

TABLE 2

YEAR	INSTALLED MWe	INTERVAL	%INCREASE
1980	3,887		
		1980-1985	22.6
1985	4,764		
		1985-1990	22.4
1990	5,832		
		1990-1995	17.2
1995	6,833		
		1995-2000	16.7
2000	7,974		
		2000-2005	42.9
2005	11,398		

%incr.1980-2005.xls

INSTALLED GEOTHERMAL GENERATING CAPACITIES

TABLE 3

NATION	Installed MWe	GWh Generated	% of National Capacity	% of National Energy GWh
Australia	0.17	0.9	n/a	n/a
China	29.17	100	n/a	n/a
Costa Rica	142.5	592	7.77	10.21
El Salvador	161	800	15.39	20
Ethiopia	8.52	30.05	1.93	1.85
France	4.2	24.6 *	n/a	2
Guatemala	33.4	215.9	3.68	3.69
Iceland	170	1138	13.04	14.73
Indonesia	589.5	4,575	3.04	5.12
Italy	785	4,403	1.03	1.68
Japan	546.9	3,532	0.23	0.36
Kenya	45	366.47	5.29	8.41
Mexico	755	5,681	2.11	3.16
New Zealand	437	2,268	5.11	6.08
Nicaragua	70	583	16.99	17.22
Philippines	1,909	9,181	n/a	21.52
Portugal	16	94 *	0.21	n/a
Russia	23	85	0.01	0.01
Thailand	0.3	1.8 *	n/a	n/a
Turkey	20.4	119.73 *	n/a	n/a
USA	2,228	15,470	0.25	0.4
Totals	**7,974.06**	**49,261.45**		

* = These figures are based on an estimated 67% utilization factor. The actual GWh were not included in Country Update Papers.

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1995-2000: WELLS DRILLED AND PROFESSIONAL GEOTHERMIST PERSON-YEARS WORKED

TABLE 4

NATION	Wells Drilled	Professional Geothermist Person-Years
Australia	n/a	n/a
China	n/a	n/a
Costa Rica	31	n/a
El Salvador	28	595.3
Ethiopia	6	50
France	n/a	n/a
Guatemala	4	72
Iceland	8	554
Indonesia	368	1,814
Italy	35	821
Japan	279	7,293
Kenya	9	144
Mexico	66	1,499
New Zealand	27	475
Nicaragua	52	169
Philippines	n/a	n/a
Portugal	9	n/a
Russia	78	135+
Thailand	47	n/a
Turkey	68	n/a
USA	50	n/a
Totals	**1,165**	**13,621**

INSTALLED CAPACITY AT PHILIPPINE GEOTHERMAL FIELDS

TABLE 5

Field	Installed Capacity (MWe)
Mak- Ban	425.73
Tiwi	330.00
Tongonan I	112.50
Tongonan II	209.36
Tongonan III	385.89
Palimpinon I	115.50
Palimpinon II	80.00
Bac-Man I	110.00
Bac-Man II	40.00
Mindanao I	52.00
Mindanao II	48.00
Total	1,908.98

PLANNED CAPACITY ADDITIONS IN THE PHILIPPINES

TABLE 6

Project	Planned Cap. Add. (MWe)	Year
Northern Negros	40	2002
Montelago	16	2002
Mt. Cabalian	110	2006
Amacan	40	2007
Mt. Labo	20	2007
Batong-Buhay	120	2007
Buguias-Tinoc	120	2007
Bato Lunas	60	2008
Planned Total	526	

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