TEE STATUS OF WORLD GEOTHERMAL POWER PRODUCTION 1990-1994

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INTRODUCTION

International geothermal meetings have, historically, been occasions upon which, ***inter*** alia, the status of the world's geothermal electric power generation has been described in detail by in-country geothermists and summarized for the congress attendees by a Rapporteur. Having undertaken the latter task in 1990 at the Hawaiian congress, the author is honored to be the Rapporteur for this, the most comprehensive geothermal congress convened to date.

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 dominate. In the report that follows, 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.

GEOTHERMAL POWER GENERATION STATUS SUMMARIES

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ARGENTINA

As a result of geothermal reconnaissance surveys covering more than 300,000 km^2, four areas having potential for high enthalpy projects have been identified at Tuzgle, Domuyo, Copahue, and Valle del Cura.

Of these, the project at Copahue is most advanced. It is located in Neuquen province, along the Chilean border, in the central part of the high Andes mountains. The geothermal field covers approximately 1.2 km^2 at the western side of a large crater associated with Copahue volcano. The field has been explored by three wells drilled to depths of **1,414,** 1,241, and 1,065 meters. The wells penetrated highly fractured basic volcanic rocks and a liquid-dominated, moderately productive reservoir at 230°C. It is believed that this reservoir is underlain at a depth of 1800 meters, but another reservoir at higher temperature.

In April 1988, a 670 kW binary cycle pilot plant, using an isopentane working fluid, was built at Copahue. The plant is at an elevation of 2000 meters and runs on 6.7 tonnes/hour of 171°C saturated steam that contains 8% non-condensable gas. The reservoir depth is from 850-1000 meters. Power generated at Copahue is transmitted to Loncopue via a 13.2 kv line and thence to the 132 kv interprovincial power line.

Plans are to use Copahue resources for spas and district heating in the village of Caviahue, neat the geothermal field.

Reconnaissance surveys of the Domuyo field, just north and east of Copahue, suggest the existence of a vapor-dominated zone at 218-226°C overlying a liquid-dominated reservoir at 186-190°C. Currently, hot waters from the Domuyo field are used for space and domestic hot water heating as well as for recreation at Villa Aguas Calientes, a small tourist hamlet.

Reconnaissance study results at Tuzgle and Valle del Cura are also encouraging, with geochemistry suggesting the presence of resources having temperature ranges of 130-200°C+.

AUSTRALIA

Since the 1990 report, 20 kW binary cycle and flash steam power plants have been constructed at Mulka cattle station in South Australia and a 150 kW binary plant at Birdsville, Queensland.

At Mulka, water was taken from hot artesian bores to power the generator, but no commercial development has followed.

At Birdsville, the powerplant uses 99°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 uses a refrigerant that is vaporized by the thermal water and passed through a screw expander to run an alternator producing 240 volt, 50 Hz, 3 phase AC power. The cycle efficiency is only 5% and parasitic losses reduce this to 4%.

The energy demand in the town varies between 60 and 150 kW. The geothermal power alone suffices when demand is low, but peaking with diesel power is needed when demand increases. The system has been operating since October 1992 and has achieved a service factor of about 50%.

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. During a four year demonstration period, the plant is being run the funding entities; afler 1996, the plant's future will depend on the performance that it achieved.

CHINA

China has more than 2700 thermal springs and, if thermal wells and mine outflows are counted, more than 4000 thermal features. Reports are that 181 geothermal systems have been mapped To date, most of their 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. This number is growing at 12% annually and continuation of this trend is planned. Estimates of the geothermal power potential are 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 largest power plant complex in China is at Yangbaijian, Tibet Autonomous Region. The total 1994 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°C fluids flowing from 18 wells approximately 200 meters deep. The plant was built in seven stages, with power increments as follows: 1977- 1 MWe, 1981-3 MWe, 1982-3 W e , 1985- 3 MWe, 1986- 3.18 MWe, 1989-6 MWe and 1991-6 MWe. 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.

In 1993, the first deep well (ZK4002) was drilled to 2006 meters at Yangbaijian. The recorded bottom-hole temperature was 330°C and the well is said to have 10 MWe potential. This success has led to predictions of 50-80 MWe generation capacity at Yangbaijian by the year 2000 and 100-150 MWe by 2010. Currently Yangbajain generates 41% of the power needed by Lhasa City in summer and 60% of their winter needs.

Several other geothermal fields have been explored in Tibet, western Sichwan and western Yunnan and geothermal power plants have been built at six sites in China in addition to the largest one at Yangbaijian: Dengwu U-2(386 kW), 1970; Dengwu U-3, (300 kW), 1982; Huitang (300 kW), 1975; Langjiu (2.0 MWe), 1987; Naqu (1.0 MWe), 1993; Quingshui (3 MWe), 1981 and Tuchang (300 kW), 1985.

Comments regarding eight of China's geothermal fields under investigation follow:

1. At Langjiu (Shiquanhe), in western Tibet, 13 wells have been drilled into a 180°C reservoir of less than 1 km' extent Downward leakage of cold waters has damaged part of the reservoir and the maximum capacity of the field may now be only 2 MWe.

2. The Naqu field covers about 10 km^2 and has temperatures up to 170°C. With the help of the UN, a 1 MWe binary plant was built in 1993.

3. The Yangyi field, near Yangbaijian, covers 11 km^2, has temperatures up to 207°C at 3 12 meters and is estimated to have 30 MWe potential.

4. At Rehai, in Yunnan, temperatures have been estimated at 276°C. Its capacity has been estimated at more than 200 MWe. The area is currently used as a health spa.

5. Reshuitang (Lanpu) field has estimated temperatures of 161-221°C and a possible capacity of 96 MWe.

6. Redian field has estimated temperatures of 189°C and a possible capacity of 47 MWe.

7. Reli field covers about 12 km^2, has temperatures to 227°C and an estimated capacity of 20 MWe.

8. Finally, in the area near Litang and Chaluo in western Sichuan, there are small fields with temperatures to 220°C and a potential of about 10 MWe.

There has been recent geologic, geochemical and geophysical exploration undertaken in several other parts of China. Wells drilled following such evaluations at Daiyun encountered water having a maximum temperature of 64°C while wells at Shanlingzi reported waters up to 96°C at depths ranging from 1440-1670 meters. No specific utilization of these thermal fluids was reported.

Chinese geothermists now recognize the significant potential for power generation in their country and they are recommending intensified work on scale inhibition, reinjection, inclined drilling technology and the generation of geothermally favorable policy and enabling legislation. Plans are to have 81-104 MWe on line by 2000, 210-295 MWe by 2010 and 400-590 MWe by 2020.

These projections are supported by ambitious policies favoring geothermal development. The results of the March 1994 16th Executive Meeting of the State Council of the People's Republic of China were to give priority to renewables, conduct a nationwide assessment of geothermal resources, become current with modern, foreign geothermal technology, and plan to utilize foreign technical and financial support to accomplish objectives.

COSTA RICA

On 25 March 1994, the first 55 MWe of power from the Miravalles field was generated by the Instituto Costamcense de Electricidad. Two plants were built; Unit 1 is a 50 MWe single flash condensing plant while 5 MWe more are generated using a noncondensing backpressure facility.

The Unit 1 plant, built by Toshiba, runs on 114 kgis 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. To date injectivity has been improving, probably due to the washing out of drilling mud residue andlor increases in permeability caused by the hydraulic pressures created by the injection process.

The Miravalles resource has a strong tendency to form calcite scale in production well casings above the flash point This situation is being mitigated by the injection, via a capillary tube ending below the flashing level, of polyacrilate inhibitor.

The drilling of production and injection wells for the second 55 MWe phase to the west and south of the main plant is underway and plans are to put the power on line in 1997.

In addition to the work done and being planned at Miravalles, studies have been conducted at the Tenorio and Rincon de la Vieja fields with favorable results. Tenorio appears to have the potential for generating 100-120 W e using 230-240°C, low salinity fluids. Rincon de la Vieja, though in a National Park. is estimated to have –140 MWe potential.

The 1995 geothermal generation capacity of Costa Rica was 60 MWe. With plants in construction and planned, their capacity bv the year 2000 should be 170 MWe.

EL SALVADOR

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. Currently, there is in progress a program that includes the drilling of injection wells and of 10-15 new production wells. The results of this work should be increased pressure support for the existing Ahuachapan field and the opening of a 55 MWe field expansion that should allow resumption of power production at close to rated capacities.

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. Though for some time only one of these units was operated at a time, two new **wells** were drilled at the end of **1993** and in the beginning of **1994.** These wells had better permeabilities and temperatures to **275°C.** Accordingly, the two plants are now being run simultaneously and a third **5** MWe installation in being built

A third geothermal **area** with commercial potential is at San Vicente in central El Salvador. To date numerous geologic, geochemical and geophysical studies have been conduced there. Temperatures to 230°C and good permeabilities have been recorded. The area potential has been estimated at 115 MWe and power could be on line by **2010** or earlier

The El Salvadorian geothermists plan studies in Chinameca, Coatepeque, Santa Rosa Lima and Obrajuelo Lempa in addition to the continued development and/or expansion of the three **areas** described above. Government intentions **are** to have **165** MWe on line by the year **2000** and **250** MWe ofgeothermal power available by the year **2010.**

Since **1990, 5-7** man-years of government effon have been expended annually on geothermal activities as well as **63-81** man-years per year of public utility time, about **3** man-years per year each of university and foreign consultant time, 0-2 man-years per year of time paid for by foreign aid programs and 30-70 man-years per year of private industry time.

Finally, since **1985,** El Salvador has spent about $US **22** million on R&D, including drilling of **6** wells, **$US 34** million **on** field development and equipment and about $US **56** million **on** electrical utilization.

FRANCE

To date, the Rapporteur has received no new information regarding electric power production by the French using geothermal **resources.** It appears, therefore, that the **4.2** MWe, double flash plant built in **1984** at La Boulliante on the French island of Guadeloupe remains the only installation completed. It is known that scale and corrosion have been problems at this plant and that power production was suspended for a time. It is reported that these problems have, to some degree, been mitigated and that the plant is back on line.

It is also **known** that BRGM, CFG and possibly some other French entities were, in the late **1980's,** evaluating the possibilities of building power plants at other French-controlled sites. Without updated information regarding these plans, no further comment is possible in this report.

GREECE

During the last four years, development of Greece's high enthalpy geothermal **resources** has been suspended while exploration of **low** and medium temperature fields and the planning? for their direct use development has been stressed.

At Milos, in the Cyclades Islands, a **2** MWe, single flash pilot plant was built in **1986** by Public Power Corporation. The local residents complained about environmental problems and the plant was shut down in **1988.**

A second high temperature **was** discovered on Nisyros in the Dodecanesus Islands in the **1970s.** Two deep test **wells** were drilled N2 for production and N1 for injection. N2 produced **8** t/h of steam and 11 t/h of brine at 17 atm **(198°C)**, but N1 could not be used for injection due to self sealing tendencies. Plans were made to drill **5** more wells and to build a power plant, but these plans were canceled when residents objected, again on environmental grounds.

Greek geothermists have expressed disappointment in the stagnation ofthese power projects, believing that the objections, on both islands, **were** based on misleading information. Their hopes are that in the near future, the resident's objections can be overcome and progress on these and other high enthalpy projects resumed.

ICELAND

Iceland has the enviable distinction of being the only country in the world where the availability ofelectricity exceeds the demand for it. This pleasant situation exists because of an abundance of relatively inexpensive hydropower together with many high enthalpy geothermal resources

Currently, geothermal power is generated at only three fields and one limited **area:** Bjornaflag, Krafla and Svartsengi plus the Reykjanes area. At Bjornaflag, a single flash back pressure turbine, built in **1969,** continues to generate **3 MWe**; 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. Ironically, the Krafla plant is shut down for four months each year, not because of these volcanic problems, but because, with abundant hydropower available, its power is not needed.

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 **1976,** 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, bringing the Svartsengi total to 16.4 MWe and the national installed capacity to **49.4**MWe.

Though it is not on the national grid, it is worth mentioning that a 500 kW back pressure plant was built at the Reykjanes salt plant. Its output is dedicated solely to use in processing sea salt for export.

Finally, there are plans to use known high temperature brines at Nesjavallir, currently used for district heating, to generate **80 MWe**. These plans will be implemented only when it can be foreseen that the demand for power will exceed the supply.

Orkustofnun, the National **Energy** Authority, is currently exploring Iceland's high enthalpy fields, but drilling in these **areas** has, since **1990,** been limited to four wells. A significant number of holes have been drilled into **low** temperature fields (for rural district heating purposes) and quite a few thermal gradient holes have been drilled in the suspected high temperature fields in the last **five** years, but on the whole, development of Icelands geothermal power potential has been and continues to be unhurried.

INDONESIA

Currently, there is **144.75** MWe of installed capacity in Indonesia. This is generated by one 30 **MWe** and two **55** MWe double flash plants and one **250** kW monoblock backpressure turbine at Kamojang, one **2.5** MWe binary plant at Lahendong and a **2.0** MWe monoblock at Dieng.

By the end of **1994,** there should be **two** more **55 MWe** plants in operation at Salak and one **55** MWe plant built at Darajat so that the total on line should be **309 MWe**. By the year **2000,** plans are to achieve a total installed capacity of **2000** MWe by building **740** MWe on **Java, 20** MWe on Sulawesi and 10 MWe of "mini-geo" (35-1000 kW) installations that would be constructed solely for electrification of off-grid, rural sites.

Among the major projects slated for development between 1995-2000, **are 55** MWe at Salak, **95** MWe at Dieng, **40** MWe at Ulubelu, **40** MWe at Lumut Balai, **22 MWe** at Sibyak and **20 MWe** at Lahendong. All but the Lahendong project will be built by private industry **working** under the terms of **JOCs** (Joint Operating Contracts) signed with Pertamina.

In addition to the major projects listed above, commitments have been made by developers to construct: 80 MWe at Kamojang, 40 MWe at Patuha, 55 MWe at Karaha, 40 MWe at Wayang Windu (all on Java) and 60 MWe at Candi Kuning on Bali. The Indonesians predict that by the end of 1999, they should have about 1079 MWe on line.

The government of Indonesia has recently passed two new regulations of importance to the geothermal industry. One allows Pertamina (the State Oil Company) to sell electricity to PLN (the State Power Company) and to other agencies. This is a first, because hitherto only PLN had been permitted to generate electricity. The other significant legal change allows for: 1) steam field development and power plant construction by private industry and 2) a decrease in their taxes from 46% to 34% The latter change has lowered the cost of private power generation and accordingly, the price charged to PLN for power purchases.

The Indonesians are very optimistic regarding their plans for geothermal development by private industry over the next 30 years. This enthusiasm is based, to no small degree, by the fact that the World Bank has obligated themselves to fund large (20-55 MWe), small (1-20 MWe) and "mini" (35-IO00 kW) projects at diverse sites

ITALY

During the 1990-1994 period, geothermal electric power generation in Italy increased to 665.7 MWe, with energy output reaching 3667 GWh in 1993 (1.6% of Italy's total power production). At Lardarello, Mt. Amiata and Travale-Radicondoli, 121 MWe was installed, 164 MWe are under construction while 139.7 MWe was decommissioned.

Specifically, 120 MWe was built at Valle Secolo in 1991, 60 MWe were installed in three units at Piancastagnaio in 1990, 1991 and 1994 and 20 MWe were commissioned at Cornia in 1994.

Since 1990, a total of 70 wells were drilled for exploration, production , injection andlor thermal gradient measurements. The depths of these wells ranged from 292-3828 meters, maximum recorded temperatures ranged from 128-363°C and flow rates varied from 0-165 kg/s.

The amount of time worked on geothermal projects by professional geothermists in Italy continues to grow In 1990-1991, there were 220 man years of effort expended; in 1992-1993 the time increased to 240-245 man years and in 1994 it reached 250 man years. Accordingly, since 1985, $US 260 million was spent on R&D and $US 930 million on field development. Of these funds, 99% were obtained from private sources and only 1% were derived from public coffers.

JAPAN

In March 1994, a 27.5 MWe power plant was commissioned at Uenotai, in Yazawa City, Akita Prefecture. The plant is operated by Tohoku Electric Power Co., Inc. and the steam is supplied from 5 wells by Geothermal Energy Co., Ltd., a subsidiary of Dowa Mining Co., Ltd. This is the first new geothermal power plant built in lapan since June of 1990 when Hatchobaru II was constructed and it brings Japan's total rated output to 298.7 MWe

Another geothermal improvement took place at Matsukawa (at 29 years, the oldest power plant in Japan) where the rated output was increased from 22 to 23.5 MWe by installing a new high efficiency turbine and rewinding the generator's stator coil.

Finally, field tests were completed at the Kirishima Kokusai Hotel of a 300 kW back-pressure unit and of a 200 kW condensing plant. The tests were devised to identify simplified construction methods and to gain experience with different steam conditions. In the future, plans are to use steam from existing low capacity wells to continue these studies

In 1993, at the 11 geothermal power plant sites in Japan, Load Factors ranged from 39.1-91.3%, averaging 76.8%. Utilization Factors ranged from 39.0-99.8%, averaging 70.4%. The total energy produced by all plants was 1,722,372 MWh.

At the end of 1993, there were plans to build new power plants at 7 sites: 50 MWe single flash at Sumikawa by 3/95, 65 MWe single flash at Yanaizu-Nishiyama by 5/95, 30 MWe single flash at Kakkonda II by 3/96, 30 MWe single flash at Yamagawa by 3/95, 30 MWe single flash at Ogiri by 3/96, 25 MWe single flash at Takigami by 11/96 and 25-30 MWe double flash at Oguni after 1997. Additionally 40 sites, on all three main islands, had been at least preliminarily evaluated before active promotion of geothermal development.

The reported investment by Japanese government agencies from 1985-1994 was $1,632 million US. Plans are to have 529 MWe on line by 1996, 600 MWe by 2000 and 2,800 MWe by 2010. Power generation increased from 1,400 GWh in 1985 to 1,724 GWh in 1990 and it is expected to reach 4,000 GWh in 2000. Though this will only be 0.4% of the overall Japanese power demand, geothermal energy continues to be considered highly important by the Japanese government.

KENYA

From 1991-1994, no new power plants were built in Kenya. Power produced at the Olkaria three-unit, 48 MWe gross (45 MWe net), single flash, Mitsubishi installation built in 1981 decreased about 3 MWe to 31 MWe. The decrease was said to be due to declines in the steam produced from the connected wells. Plant availability was reported to be very good and efficiencies continued near the levels recorded at commissioning :8.94, 9.66 and 8.94 kg/kWh for units 1, 2 and 3 respectively.

Exploration activities continued in the vicinity of Olkaria. Tracer studies were conducted in the Olkaria East and Nonh East fields Flow tests were completed an all wells in the Olkaria North East field with a result being the calculation of a capacity of 77.3 MWe and the planning of a new 64 MWe plant in this area. Additionally, geologic, geochemical and geophysical studies were conducted in the Olkaria Domes and Suswa regions where surface manifestations include fumaroles and altered ground

Geothermal energy has been identified as the least cost power alternative in Kenya and work is now under way to modify existing legal impediments to involvement of the private sector in its development Current plans are to have a total of 448 MWe of geothermal power, or 30% of Kenya's anticipated power demand, on line by the year 2012.

Kenya's geothermal infrastructure and human resources were significantly upgraded in the past 4 years and equipment was purchased with the assistance of World Bank funding. Over the past 4 years an average of 12 professional geothermists per year have attended schools world wide.

Kenya is optimistic that the resolution of political questions that have delayed its plans for geothermal expansion and the enactment of legislation favoring privatization with (assistance from the public sector) will lead to renewed geothermal development, at a ngorous rate, in the near future.

MEXICO

Mexico currently has an installed capacity of 753 MWe that is generated at three fields. Ceno Prieto has 620 MWe, Los Azufres generates 98 MWe and Los Humeros outputs 35 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 a Phase IV in **1997** and two **2** MWe experimental plants in Phase I in the near future.

At Los Azufres, there are nine **5** MWe backpressure units, one **50** MWe single flash plant (Tejamaniles) and two **1.5** MWe binary plants. In **1990, 80** MWe were generated, thus there has been a **22.5%** increase over the last four years.

The Los Humeros field features seven **5 MWe** backpressure plants currently Plans are to add a 3 MWe experimental unit in **1995.**

At Cerra Prieto, between 1990-1994, **39** wells were drilled: **33** for production and **6** for injection. Twenty one of the production wells were drilled by **a** private firm operating under the terms of a contract to supply steam to CFE. At Los Azufres, **4** wells were drilled bringing the number of wells in that field to **68.** At Los Humeros, **2** wells were drilled into a field that now has been explored with **35** wells.

Between 1990-1994, detailed geascientific studies were conducted in Las Tres Virgenes, El Ceboruco-San Pedro, Araro, Pathe, Santa Rita, Domos de Zitacuaro and Bahia Concepcion. Results of the work were discouraging at Santa Rita and Domos de Zitacuaro but encouraging enough at the other sites to warrant the drilling of **12** thermal gradient holes and **8** exploratory wells to depths ranging from **114- 2801** meters

Currently, there are **127** MWe planned for installation in the near future This should include 84 MWe at Cerro Prieto, **40** at Los Azufres and **3** MWe at Los Humeros. By the year **2000,** Mexico plans to have **960** MWe on line with additions at Cerro Prieto. Los Azufres or at La Primavera where **70** MWe potential has been calculated using mathematic models.

Mexico's CFE continues to expend a great deal of professional scientist time on geothermal activities with the man-years of effort ranging from **195** in **1990** to **202** in **1994.** During the same period, universities have put in **38-40** man-years and private industly has expended **15-20** man-years of effort.

Annual funding levels for R&D, Field Development and Power Plants have, respectively, been **6.2-8.75,** 42.22-68.46 and 48.42-**77.28** for the years 1990-1994.

NEW ZEALAND

Since **1990,** there has been no increase in geothermally generated power in New Zealand. This is primarily because of the low cost of power (average **1994** wholesale price 5.67 cents NZ/kWh) and also because afthe restructuring of New Zealand's electricity industly.

The latter has developed in accordance with the recommendations of a Task Force established to review the industly in **1984.** These recommendations included the promotion of competition in generation, development of a wholesale electricity market, separation of the National grid system from the Electricity Company of New Zealand (ECNZ) and commercialization of electricity supply authorities (ESAs) ie local Electric Power Boards and Municipal Electricity Departments.

The purposes of these changes are ultimately to lower the cost of power still more, to make it possible for a free market to function in both generation and transmission and to give local authorities jurisdiction over the development of resources in their geographic areas.

Currently, geothermally generated electric power in New Zealand totals **286 MWe**. This is produced **via** 18 units installed at **4** sites. The power plant types include high, intermediate and low pressure condensing, back pressure and binary The output ratings range from 1.2-46 MWe. Total annual energy produced is **2353** GWh/yr.

Wairakei is still the largest field with 157 **MWe** on line and **24** MWe planned. Ohaaki is next with **108** MWe produced but no planned additions. Then come Kawerau-Tasman P&P (10 MWe, no new) and Kawerau-Tarawera **(6** MWe, **6** MWe planned). Additionally, **18** MWe are planned at Rotokawa, **8** MWe at Ngawha, **55 MWe** at Rotorua, 15 **MWe** at Wairaki-Geotherm and **30** MWe at Mokai. Thus, by the year **2000,** a total of **440** MWe should be geothermally generated.

At Wairaki, pressures have held relatively constant, but steam production continues to decline at about **4%** per year due to declining fluid temperatures. Efforts have been made to decrease the pressure drop from the well field to the plant and to increase reinjection. Both measures should have measurable positive effects on the longevity ofthe field.

At Ohaaki, the high pressure steam production has declined at a much faster rate than anticipated; the plants are likely to be decommissioned in **1996** rather than **1999** as planned. Reservoir temperatures in fluids drawn from depths of **500-1400** meters, are also decreasing at about **5°C** per year. Reservoir assessments suggest that there exists a **270-310°C** resource below **a** depth of **2500** meters and plans are being made to tap this resource in **1995** via three deviated **(45")** wells drilled to **3500** meters.

At Ngawha the low heat content and high dissolved solids inhibit power production. Nevertheless **plans** are to install **8 MWe** by **1997** and **16** MWe more in a second development stage

At Mokai, the drilling of6 exploration wells in 1981-1983 disclosed what, at 326°C, may be the hottest resource in New Zealand. Fluid chemistry is similar to that at Wairaki, but with more gas, silica and chloride. A proposal to build two **50** MWe plants **is** awaiting resolution of **resource** ownership **issues.**

Eight wells at Rotokawa have discovered a **320°C** resource and an **18** MWe installation **is** planned there by the Maoris and associates; exploration at Tauhara failed to find a permeable steam cap and plans there to build a 10 MWe facility for power plus a **20 t/h** steam line for timber drying are in abeyance; finally, exploration at Lake Rotoma has indicated the existence of a resource sufficient to sustain **50-150** MWe generation. Development there is almost certain when all permits are granted.

The time spent on domestic and overseas geothermal projects by New Zealand's professional geothermists was about **69** man-years in **1990** and **1991.** Since then it has increased to **81-87** man-years despite the disbanding of DSIR and other restructuring disruptions.

New Zealand's demand for power is expected to grow at 3-5% per year through the year **2000.** Small private power companies are expected to fill the need for new power. Steps taken to optimize steam field management are expected to streamline geothermal development and maximize its cost-effective utilization

PHILIPPINES

The Philippines have now become the world's second largest producer of geothermally generated electricity. In **1990,** the Philippines had an installed capacity of **890** MWe. Since then, 161 MWe have been built (Bac Man-130 **MWe,** Palimpinon-20 MWe and Tiwi-11 MWe). Thus a total of 1051 MWe is now being generated from five fields on **Luzon** and in the Visayas Islands.

The fields now in production and their respective gross outputs are: Mak-Ban - **345.73** MWe, Tiwi - **330 MWe,** Tongonan - **112.5** MWe, Palimpinon - 135.5 MWe and Bac-Man - 130 MWe. In addition, there are reported to be proven geothermal reserves of **927** MWe at nine other sites and **1250-2630** MWe of potential power ultimately available from a total of nineteen fields. Contracts (Build-Operate-Transfer) to private industry have recently been let for the development before **1998** of fields on Luzon, Leyie, Negros and Mindanao for generation of **927** MWe as shown in Table 1.

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Table 1

Philippine BOT Contracts

Island	Field	Size (MWe)	Date	Developer
Luzon	Mak Ban	80	1995	NPC/PNOC
	" "	11	"	" "
	Bac Man	20	"	" "
Leyte	Sambaloran	30	1997	PNOC
	Upper Mahio	118	1996	Ormat/CEC
	Malitborg	77	1996	Magma
	S. Sambaloran	154	1997	
	Mahanagdong	180	1997	Cal. Energy
	Alto Peak	77	1997	Magma
S. Negros	Palimpinon I	60	1995	NPC/PNOC
Mindanao	Matangao	40	1996?	B-O-T
	sandawa	80	1998?	B-O-T

The total installed capacity by 1995 should approximate 1227 MWe and by 1998 it is anticipated to be 1978 MWe.

The development of all this geothermal power has not been without problems. Among the more significant of these that seem to be relevant to most fields are: corrosion caused by acid fluids, anhydrite wellbore scale formation, high non-condensable gas content necessitating expensive mitigation, a lack of adequate injection capacity at distances far enough from production wells, maintenance of production capacity in the face of silica scale buildup and thermal breakthrough from injection wells into production wells.

On the positive side, there have been technical improvements of which the Filipinos are proud.

- Gains in the optimization of the thermodynamic and economic matching of fields and power plants
- Increased efficiency in secondary heat recovery (use of underflow for additional power generation or industrial purposes).
- Common use of nitrogen for well stimulation
- The use of acidization to improve the performance of silica damaged injection wells and mud damaged production wells.
- The use of tracers to measure well performance
- Pipe design improvements.
- Testing of silica inhibition chemicals
- The commercial recovery of silica from waste brines
- The drilling of large diameter (17 inch) production wells.
- The improvement of drilling hydraulics so as to better clean holes and reduce incidents of stuck drill pipe.

Philippine geothermists now believe that the ultimate potential for geothermal power generation is 3000-4000 MWe. This is about half of the 8000 MWe estimated to be available by workers in 1990. The primary reasons for this lowered prediction is that: 1) many of the high temperature fields previously believed to be highly prospective have been found to have very low permeabilities, precluding extensive development and 2) acidic, highly corrosive conditions associated with active volcanism have been found to exist in many of the prospects originally thought to have commercial potential.

In the immediate future, the Philippine geothermists plan to develop or expand new fields and build new plants in collaboration with private industty partners, improve the management of their existing reservoirs, install topping and bottoming cycles where feasible, recover waste heat for industrial uses and improve the degree of control over scale-causing conditions in produced brines.

PORTUGAL

Though there have been indications the existence of low temperature geothermal resources in mainland Portugal (a Lisbon-area hospital is being geothermally heated), virtually all of Portugal's geothermal exploration and exploitation 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 We), Terciera (Pico Alto, 15 MWe, St Barbara, 25 MWe, and Praia Vitoria, 15 MWe) and Sao Miguel Island (Mosterios, 5 MWe, Ribeira Quente, 10 MWe, Fumas, 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 We.

In 1986 and 1987, an American/Portuguese consortium was formed to drill Cachaco-Lombadas, a geothermal area immediately adjacent to Ribeira Grande. After on 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.

In May 1994, 2 2.6 MWe Ormat power plants were built. They were fueled by fluids from the CL-I and CL-2 wells and produced 4.9 MWe net. CL-2, the better of the two wells, flows 152 t/h at a WHP of 8 bar-g with a steam flow of 39 t/h and an enthalpy of 1300 KJ/kg.

SOGEO now plans to build three more 2.6 MWe plants so that 60-65% of the power demand of Sao Miguel will be met geothermally. Plans for the future include the drilling of two more wells in the vicinity of the pilot power plant, building of direct-use facilities fed by underflow (~90°C) from the Agua de Pau power plants and the initiation of exploration and exploitation of the Terciera Island geothermal prospects.

Azorean geothermists are optimistic that the success of the first phase at Cachaco-Lombadas will be repeated in Phase B and also at other sites throughout the archipelago.

Because of the political upheavals that affected the former Soviet

Union, there was no expansion of the geothermal power generation facilities between 1991-1994. The 11 MWe Pauzhetskaya single flash plant, built in 1966 and enlarged in 1980, was still in operation, producing about 28.3 GWh/yr. This installation, in Kamchatka, comprises three units of 2.5, 2.5 and 6.0 MWe respectively. A 7 MWe addition is planned by the year 2010. There are a total of 9 fields in Kamchatka with resources of high enough quality to fuel power generation and an estimated aggregate capacity of 380-550 MWe.

In the construction stage in one of these Kamchatka areas is an 80 MWe plant at Mutnovsky This facility of 4, 20 MWe increments, should produce 577 GW/yr by the year 2001 and 210 MWe by 2010. Discharged waters from this field will be piped 80 km to the town of Elizovo. The cost of the power plant is estimated at $US 512 million and the cost of the pipeline is estimated at $US 120 million. Of special interest in this field is the presence of a 2,100-2,700 kJ/kg steam resource sandwiched between two liquid-dominated reservoirs of lower enthalpy.

Also planned is a 30 MWe power plant on Iturup Island in the Kuril Archipelago. To date, 9 wells have been drilled there and are ready for exploitation. Finally, a 3 MWe pilot plant is planned at Kayasulinskaya in the Northern Caucasus, however high TDS (>100 g/kg), relatively low temperatures (150-170°C) and injection pressures to 7 MPa make this project problematical.

There are 14 geothermal administrative centers in Russia. They include 26 scientific institutes, 2 universities and 5 project bureaus. Their staffs comprise a large number of highly qualified engineers and 27 professionals holding PhDs in geology or other technical disciplines. With this strong cadre of geothermists, hopes are high that development of Russia's abundant geothermal resources will progress rapidly in the near future.

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, afler studies by a Working Group, a determination was made to concentrate exploration and development activities at Fang, San Kampaeng and, most recently, at Pai all in the northernmost part of the country.

Initial development at Fang, in 1989, utilized 134°C waters produced at about 60 t/h from three 150 meter deep wells to run a 300 kw (gross), 180 kw (net) Ormat binary cycle power plant. The capacity factor since then has been about 90% and the calculated generating cost, with a 5% interest rate, is 63-86 mils/kWh. It should be noted that a large portion of these costs is related to depreciation and that maintenance costs quintupled from 1991 to 1992.

Additional exploration at Fang, begun in 1990 under the auspices of EGAT and the French agency ADEME, included geological, electrical and geochemical surveys designed to characterize the anticipated deep reservoir and its controlling structures. Pursuant to these studies, in 1992-1993, EGAT drilled three 500 meter deep wells. Well FX-2 produced 25 t/h of 125°C water from a fracture at 290 meters; the other two wells were not productive with bottom hole temperatures of 108 and 113°C.

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 that can economically test the vertical fractures thought to comprise the reservoir conduit system.

Thai geothermists believe that San Kampaeng has the potential to produce about 5 MWe of power, but development awaits the availability of cooling water and lower cost drilling techniques.

Pre-feasibility studies at Pai are being scheduled by EGAT for 1994-1995. Preliminary studies have indicated the area to be similar to Fang and to have geothermometric temperatures of 140-180°C. The results of ten, 50 meter thermal gradient holes, drilled in 1994, suggest that an anomaly exists down to 50 meters for at least 0.5 km along the Pai River. Accordingly, the drilling of five 200-300 meter deep test wells is now scheduled for 1995. If they confirm the existence of a resource, generation of power using binary techniques will be planned for the near future.

TURKEY

Exploration of the Kizidere/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. 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, scale is claimed to now be minimal.

The Germencik/Aydin 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 recently completed and plans for an initial 30 MWe plant are being formulated.

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. Plans are to drill another well to test suspected deep resources.

To date, at least four other geothermal fields with electric power generating potential have been diswvered and studied to varying degrees. These are: Seferihiser, Salvatli, Simav and Dikili-Bergama. Holes drilled to evaluate these fields found temperatures up to 171°C with variable degrees of permeability.

The Turkish geothermists claim to have virtually overcome the consequences of scaling and corrosion in both high and low temperature wells, so we know that scientific research continues. Plans are to be generating 125 MWe from Germencik, Kizildere, Canakkale and several of the other fields by the year 2000, 150 MWe by 2005 and 258 MWe by 2010.

Details regarding exploration for additional high enthalpy resources during the 1990-1994 period have not been supplied but judging by the boom in direct use of thermal waters, geothermal development appears to be a continuing government priority.

UNITED STATES OF AMERICA

Geothermal resource development for electric power generation is alive and well in the United States, however its growth rate has decreased very significantly from **18%** between **1980-1989** to **0.3%** for the period 1990-1994. Geothermal power production fell from **1990** to **1991,** recovered in **1992,** but slipped by **6-9% in 1993** and early **1994**. Nevertheless, installed capacity in the US could reach nearly **3400 MWe** by the year **2000** if all planned additions materialize; more realistically, a total of about **2237** MWe of actual, operable capacity should be anticipated.

In California, at The Geysers, there were no **new** plants built since **1989.** Four original PG&E units **(78 MWe)** were retired together with PG&E Unit 15 **(59 MWe)** and the DWR Bottle Rock plant **(55 MWe)**. **In** addition to the **loss** of these 193 **MWe,** the field generation capability fell from **1326 MWe** in **1991** to **1221** MWe in **1992** and to **1193** in **1993.** These declines continue and their rate is, unfortunately, accelerating.

In the Imperial Valley of southern California, a 40 MWe (gross), 33 MWe (net) binary plant was built at Heber while Unit **2 (18 MWe** net) came on line at the Salton Sea field. At the latter site, the method used to control scaling has shifted to acid injection (pH control) from the previously used reactor-clarifier system. Imperial Valley capacity is now at 402.8 MWe.

At Casa Diablo, two, 10 **MWe** modular binary plants were built by Pacific Energy Corp Of special interest is the utilization of Rotoflow turbines in these units. Twenty seven **(27)** MWe are now generated in the area.

There were no additional plants built at the Honey Lake or Coso fields and their capacities remain at **32.3** and **240** MWe respectively.

Planned additional capacity in California by the year **2000** totals **242** MWe and includes **20** MWe at Salton Sea (Magma), **150** MWe at Coso **(LADWP), 30** MWe at Glass Mountain (CECI), 12 MWe at Casa Diablo (Pacific Energy) and **30 MWe** at Surprise Valley (TGP/CON).

In Hawaii, a **25** MWe hybrid single flash plant came on line in **1993** at Puna. Another **30** MWe plant in the same area is in the early planning stages.

In Nevada, **195.7 MWe of** power is being generated at ten sites. **Four** plants started up between **1990-1994:** Soda Lake II (15 **MWe),** Steamboat **2 (12 MWe),** Steamboat **3 (12 MWe)** and Brady Hot Springs **(24 *W e)* .**

Additional generation aggregating **204.9** MWe is planned at Dixie Valley **(25 MWe), San** Emidio **(30 MWe),** Fishlake Valley(14 **MWe),** Hot Sulphur Springs **(9.9 MWe),** Steamboat **(36 MWe),** Rye Patch (size undetermined) and Fallon Naval Facility **(90** MWe) Of interest **is** the planned use of a Kalina cycle to power **12 MWe** of the Steamboat expansion.

In Utah, a **7** MWe single flash plant was built in **1990** at Cove Fort bringing the total installed capacity of that field to 11 MWe. There was no expansion at the **20** MWe Roosevelt field so that the total state geothermal capacity is now **31** W e . No immediate plans for additional power plants in Utah have been announced

In other states, reported plans are lo build 15 **MWe** at Unalaska, Alaska, **0.5 MWe** at Cotton City, New Mexico, **30 MWe** at Newberry Crater, Oregon and **30** MWe at Vale, Oregon. The latter two schemes are demonstration projects to be built in conjunction with the Bonneville Power Administration.

Geothermal well drilling has tapered off in fhe **US** since the **1980's.** In California, **38** wells were drilled in **1990, 26 in 1991** and **1992** and **32 in 1993.** The total number of production and injection wells increased from **685** in **1990** to **750** in **1993** while actual capacity fell as previously cited. Thus it can be seen that the megawatts per production **well** decreased from **3.7** in **1990** to **2.8** in **1993.**

Drilling activity in other states was also modest. In Nevada, **36** production wells, **17** injection wells and **38** gradientlobservation wells were drilled between **1990-1994** for a total of **91** wells. In Hawaii, **9** wells were drilled in the Puna area and in Utah, 1 well was drilled into the hot water resource at Cove Fort. In Oregon, **5** wells were drilled in the 1990-1994 period. In **1990, 2** wells were drilled in the Central Cascade Mountains, in **1993, 2** wells were drilled in Pueblo Valley and in **1994** a single well was drilled at Vale.

There was no drilling between 1990-1994 in Alaska or Idaho **In** New Mexico, **a** new interest area at Rincon may have been identified by a slim hole drilled to **365** meters in **1993.** This well **is** scheduled to be deepened in hopes of finding a resource suited for power production using **a** binary cycle.

It is difficult to accurately determine the number of active geothermists in the US. Using the average membership in the Geothermal Resource Council (GRC) 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.

During the next **5** years, prices paid by utilities for geothermal power in numerous locations will drop dramatically and the "then present" avoided cost will be paid. It will be interesting to note the effect of this event on the geothermal industry. On the positive side, there are predicted **a** near-term end to the excess capacity in the western states and increases in the costs of natural gas. When these events come to pass, they should stimulate a return to stronger growth patterns within the USA geothermal industry

REPORTS **REGARDING** NATIONS NOT **YET GENERATING ELECTRIC POWER USING GEOTHERMAL RESOURCES BUT WHICH HAVE THAT** POTENTIAL

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CANADA

During the period 1974-1982, **a** significant amount of time, effort and money was spent investigating the geothermal potential **of** the Meager Mountain area in British Columbia. The work showed that there **is a 250°C** geothermal reservoir on the southern side of the mountain and the probability of a similar **resource** on the northeast side at Pebble Creek.

Current plans are to drill new wells at Meager Creek and to pursue additional exploration at Pebble Creek. If results are encouraging at the latter site, **a** 10 MWe pilot plant will be built, followed by **a** 100 MWe working plant

CHILE

Studies of Chile's geothermal potential began **in 1917,** but **no** serious work was initiated until **1967** when the UNDP funded pre-feasibility investigations at El Tatio and Puchuldiza. In 1993, reconnaissance phase studies of Chile were undertaken and revealed significant potential at Panmavida Hot Springs, Catillo Hot Springs and Chillan Hot Springs.

El Tatio is the largest an best known of the Chilean geothermal fields. Resistivity studies have suggested that the field covers at least **30** km^2. **Six** exploration wells drilled between **1971-1973** to 600 meters revealed temperatures between **180-253°C** in acid ignimbritic rocks. Seven production wells drilled in **1973** and **1974** disclosed three discrete reservoirs with temperatures up to 260°C.

Three of these wells flow and produce an average of 14.7 kg/s (adequate for 6 MWe each); two other wells produce less but might still be capable of 5 MWe each. If El Tatio is fully developed, the estimated potential for 100 MWe might be realized.

In addition to El Tatio, indications are that prospective fields may exist at: Polloquere, Jurase, Chanchoco-Copahue (across the border from the 30 MWe Copahue development in Argentina), Petrohue, Alitar and several other sites in central and southern Chile.

Currently, the Chilean Parliament is defining geothermal resources and considering legislation that will make geothermal franchiseable to "for-profit" entities, with annuity payments to the government after successful development. Even as these positive events occur, Chile is arranging for importation of Bolivian gas to the northern part of the nation. This means that geothermal developers will have to sharpen their pencils and minimize their costs to be able to compete for that market share.

CROATIA

Though no electric power is generated in Croatia yet, there are at least two reservoirs with resources at temperatures high enough to fuel binary cycle power production.

The first is at Lunjkovec-Kutnjak where records from two oil wells show the existence of waters at temperatures ranging from 125-140°C in carbonate rocks at depths of about 1800 meters. Each well drilled into this resource, under optimum conditions might produce 1-2 MWe.

A second, similar geothermal reservoir, also discovered via wells drilled during petroleum exploration, is at Velika Ciglena. This reservoir is at temperatures of about 170°C with a wellhead temperature in the oil well recorded at 151°C. The reservoir host rock is dolomite with variable permeability. If sufficiently high permeability zones can be produced, each well in this reservoir should be able to fuel more that 2 MWe of power.

The Croatian Oil Company (INA) is now beginning detailed evaluations of these two potential geothermal areas. When these studies, together with market and institutional reviews, are finished, Croatia will know better if and when they will join the roster of geothermal power producing nations.

ETHIOPIA

Geothermal exploration in Ethiopia has been in progress since 1970 and to date, prospects having an estimated 700 MWe potential have been identified. There is reported to be the potential for 170 MWe from seven sites in the Lake 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-North, Langano and Corbetti in the Lake District and Tendaho in the Central Afar region.

At Aluto, eight wells have been drilled to a maximum depth of 2500 meters. Temperatures up to 180°C have been recorded, but permeabilities are rather low. Ethiopia Electric Lighting and Power Association (EELPA) plans are to install 30 MWe in three phases by 1997 and to use underflows to extract soda ash and to process diatomites.

Tendaho has been evaluated via prefeasibility and feasibility stage studies. Well TD-1 was drilled to 2196 meters with marginal results. A second well, TD-2, is in progress.

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 at the bottom of one of these holes. Gradients were not reported.

In addition to these three partially explored areas, there are also prospects yet to be explored at: Abaya, Wendo Genet, Ziway, Shala, Butajira, Teo, Lake Abbe, Allalobeda, Dubti, Gawa Graven Sardo, Duroyita, Filao, Wonji, Fantale, Dofan, Meketa, Danal, Boina, Alaita, Afrera, Lake Bakili and Dallo.

EELPA plans to increase capacity to 1405 MWe by 2010 and to export more than 200 MWe by that date. Despite an abundance of undeveloped hydropower sites, it would appear that geothermal power will certainly play an important role in this EELPA scheme for expanded capacity over the next fifteen years.

GUATEMALA

As a result of geothermal studies conducted since the early 1970s, there have been 14 areas in the southwestern Guatemala volcanic belt identified as having significant potential for development and eventual provision of steam for power generation.

To date the project most advanced towards this goal is Zunil I where seven wells have encountered temperatures to 297°C at depths ranging from 1500-2330 meters and where a 24 MWe Ormat plant is planned for start-up in December 1995.

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. Though explorationists believe that the primary, liquid-dominated reservoir has not yet been penetrated, it is estimated that the Zunil II field may have the potential for fueling 40-50 MWe after deep exploratory drilling is completed.

In east-central Guatemala, four wells drilled in 1992-1993 at the Amatitlan field, 28 km southeast of Guatemala City, encountered temperatures to 300°C at depths to 2058 meters. The reservoir seems to be a fractured andesitic lava and the ultimate potential of this field is being conservatively estimated at 25-30 MWe.

In addition to the fields summarily described above, the Tecuamburro and San Marcos fields, in eastern and western Guatemala respectively, show commercial potential. Temperatures in an 806 meter deep slimhole at Tecuamburro reached 235°C and geothermometry suggests equilibrium temperatures of 300°C. At San Marcos, geothermometry indicates equilibrium temperatures of about 250°C and confirmatory drilling is planned for late 1994.

The Guatemalan geothermists drilled 16 wells from 120-2230 meters deep between 1990-1994. They plan to have 24 MWe on line by the end of 1995; they have funds committed for a total of 70 MWe, and they project 94 MWe installed by the year 2000.

HUNGARY

Though no geothermally fueled electric power is currently generated in Hungary, research has disclosed the existence, in several parts of the country, of resources having qualities that would seem to make them suitable for use in binary installations.

These resources of medium enthalpy are found in: 1) high capacity wells with water temperatures above 80°C and 2) in wells drilled originally for petroleum exploration that contain waters at temperatures up to 171°C. The former are found all over the country. The latter type have been reported in southern Hungary between the Danube and Tisza Rivers, in the Békés subsidence, in the oil and gas fields of the Zala Deep Karst and in the Mid-Transdanubian areas.

It has been estimated that power production using the lower temperature resources could be accomplished for about $US 2,805/kW while development using the higher temperature resources could be undertaken for about $US 1,348/kW. The estimated capacity of the lower temperature resource is only 1 W e , but the higher temperature waters could fuel about 24 W e . The estimated total possible power production using geothermal resources could be 215 Gwh/yr. Its use would save 500,000 t/yr of oil and reduce CO_2 emissions by 810,000 t/yr.

Hungarian geothermists have many years of experience in the direct use of geothermal energy. Their knowledge of the subsurface geology, cost-effective drilling techniques and the locations of prospective areas should soon allow them to initiate power generation using the improved technologies available today.

The existence of more than 300 thermal springs has been reported as a result of geothermal investigations initiated in 1973-1974. Eleven discrete geothermally prospective districts have been identified. Most of these appear to have resources at temperatures of about 100-120°C, but some appear to have reservoirs at 1-3 km with calculated equilibration temperatures of 200-250°C.

To date, the most promising fields appear to be Tatapani (M.P.) and Puga-Chhumathang in NW Himalaya. Plans to build a 20 kW and a 1 MWe binary in these two areas respectively, have yet to be realized.

Despite the significant low to moderate temperature potential postulated to exist in India, geothermal development to date has been hampered by the abundance of inexpensive coal that is universally used for power generation and for heating in the high country. Financial assistance will be needed to allow geothermal resources to be developed in the face of such competition.

Numerous 300-900 meter deep thermal gradient holes have been drilled since the 1960s, but no deep wells have been drilled to date It is likely that assistance from the international geothermal community in the forms of drilling expertise and construction of binary power plants will be needed in order to begin serious geothermal development.

IRAN

Exploration for Iranian geothermal resources began in 1974 and as a result of this work, the Sabalan, Damavand, Khoy-Maku and Sahand regions were given priority. Since 1993, feasibility studies have been conducted in the Sabalan and Damavand areas. The Sabalan region seems most prospective with an estimated power potential of 48×10^{18} joules.

The Sabalan region is underlain by young volcanic rocks. There are reported to be at least 17 thermal springs whose maximum temperature is 85°C (at Mishkin Sharhr) but whose average temperature is only 40°C. Typical of the Sabalan springs is the presence of CO_2, H_2S, travertine deposits and moderately extensive alteration. Flow rates of the springs range from 4000-9000 l/min. TDS values are up to 6300 mg/l with salinities increasing in proportion to temperature.

Geothermometry has been attempted, but most of the waters sampled are mixed with groundwaters, so that equilibration temperatures are uncertain. Best estimates are in excess of 150°C in the Mishkin Shahr region.

Iranian geothermists recommend that the next step in exploration be the drilling of deep wells at Mishkin Shahr, though thought could be given to conduct of further electrical studies prior to selection of drill site(s).

LITHUANIA

To date there has been no electric power generated in Lithuania using geothermal energy. Nevertheless, calculations, based on the known thermal gradients in the western part of the nation near Klaipeda and Silale, suggest that with hydrofracing, waters having temperatures up to 140°C might be produced from Cambrian formations, 3-4.3 km deep, at a cost less than $US 5.00/GJ.

There are said to be additional possibilities for power production, without stimulation, using fluids at lower (–40°C) temperatures pumped from shallower (1.8-2.2 km) formations. The cost. effectiveness of such exploitation for power generation must still be proved, but the Lithuanian geothermists are optimistic and are actively seeking financial assistance for demonstration projects from the international lending and private investment communities.

MOZAMBIOUE

Mozambique is geographically located astride the southern end of the East African Rift System. There are at least 38 thermal features in the country, some of which may be related to that major tectonic feature.

Studies conducted since the 1980s suggest that heat flow and thermal gradients in several parts of the country are above average and above the regional background level. Geohydrological studies suggest that there are at least 6 geothermal areas with geo-thermometric temperatures that could reach 140-166°C at unspecified depths.

In light of the generally positive structural environment, the elevated heat flows/thermal gradients and the existence of hydrochemical data indicating the likely presence of medium enthalpy resources, Mozambique must be considered to have potential for eventual generation of some power using geothermal resources and binary technology Knowledgeable workers have estimated this potential to be at least 25 MWe.

Since 1975, the government has expended only $US 40,000 on exploration and 2 man-years of professional geothermist time annually since 1990. Significant increases in the intensity of geothermal studies, field work and drilling will have to take place if Mozambique's geothermal potential is to be realized in the near future

NEPAL

Geothermal resources in Nepal are manifested by 23 thermal springs located in three discrete groups that span the width of the nation. There are no young intrusive centers mapped in Nepal, thus all of these spring waters appear to have been heated via deep circulation along fault conduits.

Recorded surface temperatures range from 73°C at Sribagar to 21°C at Josom; flow rates from 0.2 l/s at Josom to 1.39l/s at Sadhu Khola and Total Dissolved Solids from 148 mg/kg at Chilime to 1840 mg/kg at Tatopani-Myagadi.

Current use of thermal waters is confined to balneology and personal washing since surface temperatures and even geothermometrically calculated temperatures (to 115°C at Sadhu Khola) are too low to consider for use in power generation.

Nepal is now planning to inventory all of its geothermal resources, but a national goal to maximize geothermal utilization for space heating, hygienic improvement, aquaculture and agriculture has yet to be set. Nepalese geothermists can envision many beneficial uses for their nation's geothermal resources. They have high hopes that exploitation will increase rapidly in light of the fact that the economic merits of geothermal are now becoming more widely appreciated within their government

SLOVENIA

Geothermal resources have been *used* increasingly for more than 10 years in Croatia. By far the majority of the use has been for balneology and recreation. Currently, emphasis is being placed on district heating and, to a lesser but growing degree on the possibilities for power generation.

The Pannonian Basin, in northeastern Slovenia, contains waters at temperature of up to 200°C at depths of about 2,500 meters. Prefeasibility studies regarding the potential for geothermal power generation are being conducted at five areas within the Basin. At one site, Ljutomer, plans are to generate at least 1 MWe of power in addition to use of the thermal fluids for space heating.

Slovenian geothermists are cautiously optimistic about growth in the industry, but the need for financial assistance from the international lending community and the private sector is stressed.

TABLE 2

INSTALLED GEOTHERMAL POWER GENERATION CAPACITY

COUNTRY	1990	1995	2000
Argentina	0.67	0.67	n/a
Australia	0	0.17	n/a
China	19.2	28.78	81
Costa Rica	0	55	170
El Salvador	95	105	165
	4.2	4.2	n/a
Greece *	0	0	n/a
Iceland	44.6	49.4	n/a
Indonesia	144.75	309.75	1080
Italy	545	631.7	856
Japan	214.6	413.705	600
Kenya	45	45	n/a
Mexico	700	753	960
New Zealand	263.2	286	440
Nicaragua	35	35	n/a
Philippines	891	1227	1976
Portugal (Azores)	3	5	n/a
Russia	11	11	110
Thailand	0.3	0.3	n/a
Turkey	20.6	20.6	125
USA	2774.6	2816.7	3395
Totals	5831.72	6797.975	9,960

* Greece has closed its 2.0MWe Milos pilot plant 1/24/95
n/a = information not available

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