Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

World Geothermal Generation 2001-2005: State of the Art

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Keywords: World Update, Power generation

ABSTRACT

The Rapporteur reviewed all the Country Update papers for the nations where geothermal electricity is currently in operation.

The relevant figures are:

1. Twenty-four countries generate power from geothermal resources;
2. The total installed capacity is 8 900 MW, corresponding to 8 000 MW of running capacity and supplying 57 000 GWh in 2003, an increase of 12% and 15% respectively with respect to year 2000;
3. Nineteen countries have performed significant drilling operations since 2000, with a total of 290 wells and 560 km of drilled depth, an average well depth of 1.9 km;
4. Costa Rica, France, Iceland, Indonesia, Italy, Kenya, Mexico, Nicaragua, and Russia all show an important increase of relevant power plant installation activities (above 10% with respect to year 2000);
5. New entries among the geothermal electricity community are Austria, Germany and Papua New Guinea;
6. Plants from Argentina and Greece have been definitely dismantled.

1. INTRODUCTION

This paper highlights only the relevant differences from the previous geo-electricity world reports (Huttrer, 1995, 2000 and 2001). For each electricity producing country the information from the Country Update Report presented in this Conference has been selected and integrated with first-hand direct data from International Geothermal Association members. Not all the details for each individual country have been included in this summary paper: they can be much better addressed in the country specific papers, given in the reference.

The first goal of this World Report is to identify the currently producing geothermal fields, their relevant characteristics (depth, temperature and pressure) and the present status of geothermal power plant in operation. There is limited emphasis on data concerning geothermal potential.

A series of tables are presented, giving the relevant present data (Table I) and some historical values (Table II). Attention is drawn to the two values of Capacity given in Table I: Installed and Running (Bertani, 2001):

❖ Installed Capacity

The Installed Capacity (in MW) is the reference value for the power plant, set by the manufacturer as its target output when the plant is operating at its design conditions. Possible reserve units should not be considered as part of the installed capacity, but may be accounted for in a separate list.

❖ Running Capacity

The Running Capacity (in MW) is the highest average value over one hour during the time of investigation of the output from the power plant as measured at the generator transformer supply voltage terminals, when operating at its stated design conditions or corrected to the design point conditions. The Running Capacity can be correlated directly with the produced energy and with the relevant reservoir characteristics (given in Table III).

Before starting the main body of this paper, it is important to recall the final words from IGA President’s message at WGC2000: *At the 1975 United Nations conference on geothermal energy, held in San Francisco, California, Mr. Patrick Muffler reported that some 1 300 MW of geothermal electrical power generation capacity were installed in 10 countries. At this meeting, WGC2000, Mr. Gerry Huttrer reported that installed geothermal generation capacity has reached 7 974 MW in 21 countries. In 25 years, we have added 6 700 MW of installed capacity around the world. This amounts to an average of only 270 MW of new geothermal generating capacity per year since Mr. Muffler’s report in 1975, and an average of only 240 MW of new geothermal generation capacity per year since the last WGC in Florence, Italy, in 1995. Mr. Huttrer also reported that the worldwide electrical energy production from geothermal power plants has reached 49 000 GWh/y. Energy production is a much better measure of our contribution than installed capacity since geothermal power plants usually operate at a higher capacity factor than other types of power plants. But, how are we to understand this figure of 49 000 GWh/y of energy production? To help form a perspective, let us note that the International Energy Agency reports that total electricity consumed worldwide in 1996 was 13 700 000 GWh. In other words, geothermal energy accounts for less than 0.4 percent of the world’s electricity.*

The trend has not improved since 2000: the installed capacity increased by 938 MW, only 190 MW per year. World energy electricity generation for 2002 was 15 300 000 GWh/y (Source IEA); the geothermal electricity plays the stabilized marginal role of 0.4%. The geothermal industry did not achieve any substantial increase in its contribution to electricity generation worldwide.

Figure 1 and Table 1 present the installed capacity and electricity generated.

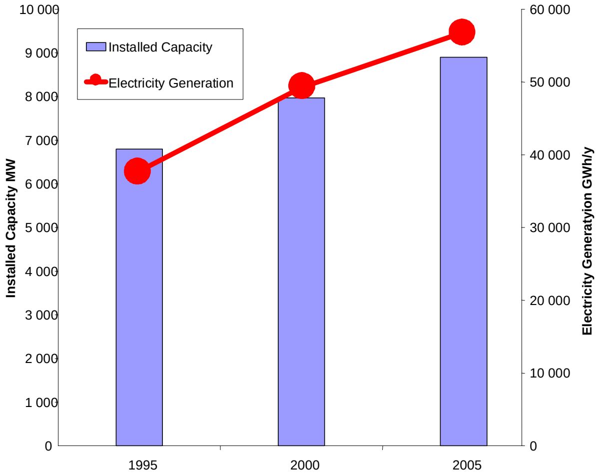

Figure 1: Installed Capacity and Energy Generation.

Table 1: Installed Capacity and Energy Generation.

Year	Installed Capacity [MW]	Electricity Generation [GWh/y]
1975	1 300	
1980	3 887	
1985	4 764	
1990	5 832	
1995	6 798	37 744
2000	7 974	49 261
2005	8 912	56 798

The recent increases of oil prices and the natural decline of its reserves over the coming years could be a beneficial factor for boosting the installation of geothermal power plant. However, this will be affordable only with a proper policy and regulation, and some sort of support in order to keep its economy at a sufficient level to attract investors.

We are going now on the right way, and the acceptance of the Kyoto Protocol could be another key factor in helping the geothermal electricity market to reach a possible share of 1% of world electricity production by 2010. This is still a long way from fulfilling the world's renewable energy demand, but for the coming five years it could be a reasonable target to be achieved with the standard available technology.

2. GEOTHERMAL POWER GENERATION STATUS SUMMARIES

2.1 Australia

There is only one unit generating electric power from geothermal energy currently in operation in the country: the 150 kW binary cycle plant at Birdsville in SW Queensland, (Chopra, 2005).

The electric power demand for the small town of Birdsville follows the standard seasonal pattern with highest demand in the hot summer months when air-conditioning is used extensively (150 kW) and relatively low demand in winter (120 kW). In order to supply the base load, a geothermal power station with a nominal power rating of 150 kW has been installed, using 98°C fluid from 1 200 m deep wells. This plant, installed in 1992, was upgraded and refurbished in 1999 and is currently in operation.

It is important to highlight the relevant research on Hot Dry Rock (HDR) technology. The most advanced project is in the Cooper Basin region of north east South Australia, with a 4.4 km deep borehole, at temperatures >250°C. The drilling of a second deep well in 2004 will be followed by a planned circulation test in early 2005. Drilling activity for the country is: two wells of 6 km have been realized and a third one of 4 km is scheduled.

The Mandatory Renewable Electricity Target (MRET) Schemewas introduced in 2001, requiring that by 2010 approximately 2% of the Australia's annual electricity consumption should be supplied from renewable technologies. Geothermal energy and, in particular, Hot Dry Rock has been identified as a technology that can be supported in future.

2.2 Austria

Research activity for geothermal energy in Austria is quite proactive, but it is focused mainly on thermal water exploitation. Only two small binary plants are installed in the country: Altheim and Blumau (Goldbrunner, 2005).

Altheim can be considered as a success story for exploration and exploitation of geothermal energy by a small community (5 000 inhabitants). A production/reinjection doublet of 2 500 m depth has been constructed. The fluid at 105°C is utilized both for district heating and for electricity production using an ORC (Organic Rankine Cycle) technology plant. The net output is 500 kW, after accounting for the 350 kW parasitic load of the submersible pump.

Blumau project reached the highest temperature from geothermal water in Austria: 110°C at 2 000-3 000 m depth. It is used for heating a Spa facility and an ORC turbine of 180 kW net output has been in service since 2001.

2.3 China

Geothermal energy exploitation in China started approximately around 1970. In the socialist planned economy geothermal exploration was handled by national bodies with public investments. Drilled productive wells were transferred free of charge to the final user. Since the mid-80s, under the framework of privatization and liberalization of the economy, national investment in exploration has been reduced. No new plants have been commissioned in the period 2000-2005 (Zheng et al, 2005; Battocletti L. et al, 2000). The only electricity producing fields are located in Tibet.

The most important field is Yangbajain, with eight double flash units for a total capacity of 24 MW, fueled from an water dominated shallow reservoir at 140-160°C with 18 wells of average depth 200 m. The field extension is only 4 km^2, although there are clear indications of a total thermal anomaly of 15 km^2. The annual energy production is approximately 100 GWh, about 30% of the needs of the Tibetan capital, Lhasa.

A deep reservoir has been discovered beneath the shallow Yangbajain field. It is characterized by high temperatures (250-330°C has been measured at 1 500-1 800 m depth). The field potential is estimated at about 50-90 MW. It is still un-exploited. A 2 500 m deep well has been drilled in 2004, reaching the deep reservoir at 1 000-1 3000 m. Its evaluation is ongoing.

The total number of wells drilled in Tibet for electricity production is 80, with a total depth of 20 km.

Additional plants are installed in Langju, West Tibet (two double flash unit, 1 MW each, 80-180°C) and a 1 MW binary power station (60-170°C) is operating in Nagqu. Two small 300 kW plants are operating in Guangdong and Hunan.

In Taiwan, a 3 MW single flash unit operated at Qingshui field from 1981 (the reservoir is shallow, less than 500 m depth, at 150-220°C). A 300 kW binary unit (Tu Chang) was installed in the same field, but exploiting fluid with a max. temperature of 170°C. In 1994 these plants stopped their operational activities.

2.4 Costa Rica

The only operational field in Costa Rica is Miravalles, a water dominated reservoir of approximately 20 km^2 at a depth of 1 000-2 000 m and 240°C (Mainieri et al, 1995). The first unit started its operative life on 1994 (single flash, 55 MW) followed by a small 5 MW well-head back-pressure unit and a second single flash 55 unit (Miravalles II) in 1998. In 2000 Miravalles III (single flash 29.5 MW) and in 2003 the binary unit Miravalles V (18 MW) completed the total installed generating capacity in the field up to a total of 162.5 MW. The total electricity generated in 2003 was 1 145 GWh/yr (Mainieri, 2005; Mainieri 2003). The field uses 52 deep wells (32 production, the remainder for gravity reinjection).

The binary unit Miravalles V has been the major improvement since WGC2000. This plant exploits the heat from the separated brine on the reinjection streamline.

At present the geothermal installed power contributes 8.4% of the country's total electrical capacity and 15.1% of the produced electricity. The total number of wells drilled in the country is 131, with a total depth of 124 km.

A further eastward expansion of the field is foreseen: the recent well PGM-55 at 1.5 km from the exploited field identified a new high permeability area, hydraulically connected with the present reservoir and with a potential of 4 MW. Since it is located near a protected natural area (virgin rain forest), future exploitation will require directional drilling for environmental protection. It will be the first experience in the country of multiple wells from the same drilling pad.

Geothermal energy is the second most important contribution to electricity generation: its economic relevance is highly strategic in the country, due to the great dependence of thermal plant on imported oil: despite of the installed capacity of 17%, their contribution to electricity production is only 2%. Due to the presence of such important geothermal resources, it is possible to operate fossil fired plants as reserve units.

In the northern part of the country, near the Nicaraguan border, the second geothermal area (Rincón de la Vieja Volcano) of the country will be exploited in the coming years. On the southern slope of the volcano, the Las Pailas field has been explored with 5 wells in 2001-2002. 18 MW has been proved from a 250°C reservoir, with a possible expansion up to 35 MW. On the northwestern slope, in the Borinquen field, the first of four planned exploratory wells is under construction. Preliminary results confirm the presence of an important thermal anomaly.

2.5 El Salvador

Electricity production based on geothermal resources has been continuous in El Salvador since 1975 (Rodriguez et al, 2005). In the competitive energy market adopted in the country, geothermal electricity supplies 22% of the needs. There are two major geothermal fields: Ahuachapán and Berlín (see Figure 2):

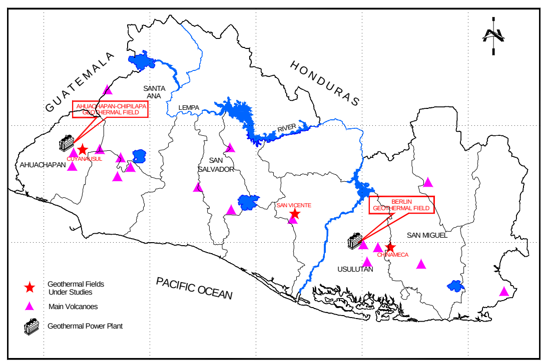

Figure 2: Geothermal field locations in El Salvador.

The first has been exploited since 1975, with three condensing units - two 30 MW single flash and one 35 MW double flash; due to the reservoir decline, only two out of the three units are currently in operation. A project for reaching the full capacity of the units (Ahuachapán optimization) is under study. The reservoir is shallow (600-1 500 m) at 230-240°C. There are 19 production and 5 reinjection wells on an area of 3-4 km^2. In 2004 the total reinjection of all the produced fluid was achieved 6 km from the Chipilapa area. The former reinjection into the ocean through a canal has been stopped. The possibility of a further increase of the residual heat exploitation through a 3.5 MW binary plant is planned for late 2005.

Berlín was explored in the 70s but (due to civil conflict) its commercial operation started in 1992 with small 2x5 MW well-head units. They were decommissioned in 1999 and two 28 MW single flash units have been installed. The field depth is approximately 2 000-2 500 m at a temperature of 300°C, with 9 production and 15 reinjection wells. An extensive upgrading project, aimed at installation of an additional 40 MW, is currently scheduled. The first four wells have already been drilled in the southern border of the reservoir. The presently exploited area is quite small: only 2-3 km^2. An additional 6.5 MW bottoming cycle binary unit is under evaluation.

Projects are currently on-going in other geothermal areas of the country: in Cuyanausul, near the Chipilapa reinjection field, an exploratory well is being drilled. If the estimates of field potential would be confirmed, one or two 5 MW back-pressure units could be installed. Further concessions have been released for explorations in San Vincente, Chinameca and Obrajuelo. The overall potential for these fields could be around 100 MW.

In 2002 the interconnection project with Honduras via a 230 kV transmission line has been inaugurated. It was the final link of the Central America grid: now power can be traded from Panama to Guatemala in the Regional Electricity Market (MER) (Lippmann, 2003; De La Torre, 2002). In 2006 the new SIEPAC transmission line will increase the transfer capacity up to 300 MW (see Figure 3).

Figure 3: First regional electricity grid: SIEPAC line.

2.6 Ethiopia

The only geothermal area exploited for electricity production in Ethiopia is Aluto-Langano, where eight deep wells (about 2 500 m) have been drilled, four of them productive (Teklemariam et al., 2005). It is located on the floor of the Ethiopian Rift Valley about 200 km south east of Addis Ababa. The maximum reservoir temperature is about 350ºC. The potential of the field has been evaluated up to 30 MW for 30 years.

A 7.3 MW pilot binary geothermal plant was installed in 1999. It is not fully operational for lack of operational experience. The next five year plan of the government includes the rehabilitation of the Aluto-Langano geothermal pilot plant, and the possible installation of an additional 20 MW unit if financial support could be available.

Another area of the country where geothermal development can be carried out is the Tendaho field, where three deep wells (2 100 m) found a temperature of over 270º.

2.7 France

The only high enthalpy utilization for electricity production in France is in the French Overseas Department at Bouillante in Guadeloupe. A new 11 MW power plant has been in operation since 2004, raising the total capacity to 15 MW (Laplaige et al, 2005).

In Martinique and La Réunion islands, geothermal exploration programmes are planned in the near future.

The old Bouillante 1 double-flash power plant is still operating after its rehabilitation in 1995-1996; a new power plant (Bouillante 2) was placed on.-line in 2004. The project for Bouillante 3 is currently in pre-feasibility phase. After the installation of the third unit, geothermal electricity should cover nearly 20% of the electricity consumed in Guadeloupe. For Bouillante 2 (simple-flash with 10 MW electric power), three new production wells were drilled.

The HDR project at Soultz-sous-Forêts is now in the construction stage of a scientific pilot plant module. The enhanced geothermal system, exploited with a three-well system in granite at a depth of 5 000 m, is expected to come into operation during year 2005.

2.8 Germany

The first geothermal plant for electrical power generation in Germany has been on-line since 2003 (Schellschmidt et al 2005). It is located at Neustadt-Glewe, with an installed capacity about 230 kW_e using an Organic Rankin Cycle. In addition, 10.7 MW_t are used for district and space heating. The energy production of 1.5 GWh/y will provide 500 households with electric power. The plant uses a flow rate of 100 m^3/h at temperature of 98°C, cooled down to 72°C.

Currently six new installations for power generation are being planned: Groß Schönebeck, Bad Urach, Offenbach, Speyer, Bruchsal and Unterhaching.

2.9 Guatemala

Geothermal exploration began in Guatemala in 1972 but the commercial exploitation started in 1998 in two areas: Zunil (where there are two geothermal fields, named I and II: despite their proximity, they have different heat and fluid sources and must be considered as separate reservoirs) and Amatitlán. In Zunil I there are 7 binary units with a total installed capacity of 28 MW (24 MW running), while in Amatitlán an old 5 MW backpressure unit is still in operation. The total geothermal electricity production in the country is 195 GWh/y. In Amatitlán a 20.5 MW hybrid power plant is currently under construction, and it is expected on-line for 2005 (Lima Lobato et al. 2003; Roldán Manzo, 2005).

These new developments are supported by the new renewable energy law (2004), which initiated a series of tax exemptions for renewable energy projects. A strong government commitment has been established in a four-year geothermal development program, signed in 2003.

Zunil I, located on the border of the Quetzaltenango caldera west of Guatemala City, has 300°C at 1 500-2 300 m depth. Its exploitation project has been completed recently with the reinjection facility, giving a total of 9 producing and four reinjection wells. In Zunil II a small steam cap linked to a deep hot aquifer has been discovered at shallow depth. Its potential has been estimated up to 50 MW. A development project started in 2003 with drilling of two production and one reinjection wells. A long term test will be performed for evaluation of reservoir decline.

In Amatitlán, following the first four deep exploratory wells (two of them producing steam), two new wells have been successfully drilled in order to define its extension. As a result of the positive field assessment, a project to increase the installed capacity gradually with modular binary units up to 50 MW in the next 5 years has been commissioned.

Geothermal exploration is active in other areas of the country: Tecaumburro, San Marcos, Moyuta, Totonicapán, but no drilling projects are ongoing.

1.10 Iceland

Geothermal electricity production in Iceland has increased significantly since 1999, with the installation of new plants in Svartsengi, Krafla and Nesjavellir, up to the present value of 202 MW. An additional 30 MW single flash unit at Nesjavellir is at an advanced stage of construction (Ragnarsson, 2005; Gunnlaugsson, 2003).

Two other new power plants for electricity production are currently under construction. The total capacity of these two plants (at Husavik and Reykjanes) is approximately 180 MW, almost doubling the installed capacity in the country (see Figure 4 for the location of geothermal areas in the country).

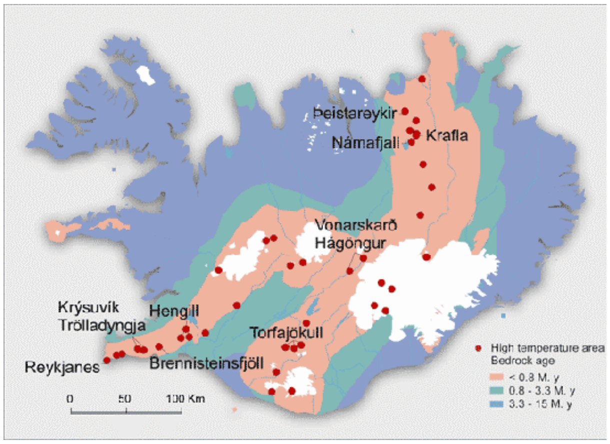

Figure 4: Geothermal fields location in Iceland.

The relevant geothermal areas are Krafla, in the northern part of the country, where two 30 MW double flash units are operating, Svartsengi and Nesjavellir, giving combined production of hot water for the Reykjavik district heating system with 45 and 30 MW of electricity respectively.

The new field of Hengill, in the same southern part of the country, is currently under exploration for a planned plant of 80 MW and a further improvement of the Reykjavik district heating supply.

An intensive drilling activity has been performed in the country, with 23 new wells of 50 km total drilled depth.

2.11 Indonesia

Despite of the huge geothermal potential of the country, only minor development has been achieved during the 2000-2005 period, due to the severe economic crisis which adversely affected power demand and growth in Indonesia (Ibrahim et at., 2005).

Indonesia currently utilizes 797 MW of installed geothermal capacity from the fields listed in Table 2 and in Figure 5. It should be noted that for three units at Salak field the total running capacity is 197 MW, while the installed capacity is only 165 MW. The same overproduction occurs for the Darajat field, with running capacity of 145 MW. The effective total running capacity for the country is 838 MW.

No new units have been installed since 2000, with the exception of Lahendong (on-line in 2002). An investment plan for a new unit in Darajat (100 MW) has been approved in 2004. A tender has been launched for an additional 20 MW at Lahendong. Another project is Kamojang's expansion of 60 MW, but it has not yet been ratified.

Table2: Geothermal fields in Indonesia.

Fields	Location	Installed Capacity [MW]	Units
Darajat	Java	135	2
Dieng	Java	60	1
Kamojang	Java	140	3
Gunung Salak	Java	330	6
Wayang Windu	Java	110	1
Sibayak	Sumatra	2	1
Lahendong	Sulawesi	20	1

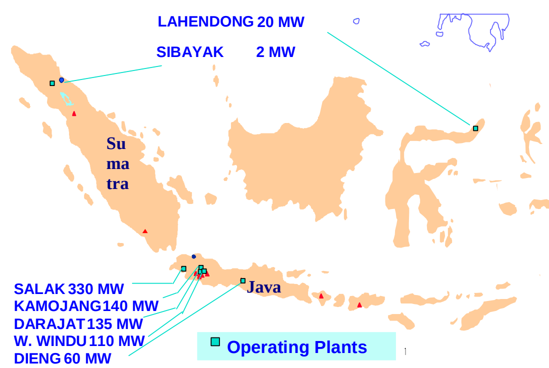

Figure 5: Geothermal fields location in Indonesia.

2.12 Italy

One of the major events of the period 2000-2005 was the 2004 celebration of the centenary of the first experiment carried out at Larderello in 1904. It is an outstanding acknowledgement of the relevance of geothermal electricity in Italy.

After the first pioneer age, the first industrial power plant (250 kW) was put into operation in 1913 in the same area; and geothermal power production has since increased continuously up to the present value of 790 MW installed capacity (699 MW running capacity). Electricity generation reached the historical maximum of 5 340 GWh in 2003, as shown in Figure 6. (Cappetti, 2005; Cappetti, 2000).

Ten new power plants (254 MW installed capacity) have been commissioned and placed on-line in the last five years, both for replacing old and obsolete units and as new capacity due to the extension of the explored area at depth beneath the old shallow fields. An additional new deep exploration programme has been launched with a 3D seismic survey and 11 deep wells (3 000-4 000 m). A total of 21 wells have been drilled in the last five years for a total of 64 km.

Due to environmental and technical problems, the 40 MW geothermal unit installed at Latera has been decommissioned and this field is not currently under exploitation.

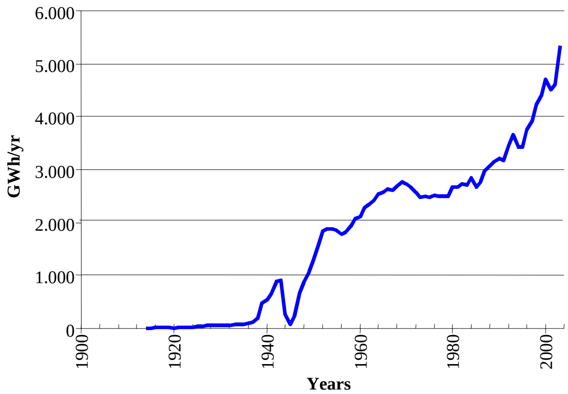

Figure 6: 100 years of electricity production in Italy.

There are two major geothermal areas in Italy: Larderello-Travale/Radicondoli and Mount Amiata.

Larderello and Travale/Radicondoli are two adjacent parts of the same deep field, covering an huge areal extension of approximately 400 km^2: this deep reservoir has the same temperature (300-350°C) and pressure (4 - 7 MPa) everywhere (Bertani et al., 2005). The field produces super-heated steam. In the Larderello side the exploited area is 250 km^2, with 180 wells and 21 units giving 542 MW installed capacity; in the southeast side of Travale/Radicondoli, covering an area of 50 km^2, 22 wells feed six units of 160 MW installed capacity. Sixty additional MW are under construction (Nuova Larderello 3 and Nuova San Martino).

The condensed water from Travale is reinjected into the core of the Larderello field through a 20 km-long water pipeline.

Mount Amiata area includes two water dominated geothermal fields: Piancastagnaio and Bagnore. In both the fields a deep resource has been discovered under the shallow one: it is characterized by pressurized water with 20 MPa and 300-350°C at 3000 m. Serious acceptability problems with local communities are slowing down the project for the full exploitation of this high potential deep reservoir.

Presently there are 5 units with 88 MW of installed capacity: one in Bagnore and four in Piancastagnaio; there is a reduction from the year 2000 value, due to the decommissioning of an old 20 MW unit (on line since 1987).

The relevant geothermal locations in Italy are listed in Table 3 and are shown in Figure 7.

Figure 7: Location of geothermal plants in Italy.

Table 3: Geothermal fields in Italy.

Location	Installed Capacity [MW])	Units	Annual Energy Produced [GWh/yr]
Larderello	543	21	3 606
Travale Radicondoli	160	6	1 109
Mt. Amiata	88	5	625

Liberalization of the electricity market has been completed in Italy: the incentive scheme (Green Certificates) for geothermal allow further extension of the investigation for deep seated resources. On the basis of the positive results of the scheduled programmes, we can expect the further installation of 100 MW in the next five years.

2.13 Japan

Sixteen geothermal power plants are in operation, most located in the Tohoku and Kyushu districts (see Figure 8). Total installed capacity from all geothermal power plants reached 535 MW (Kawazoe et al., 2005; Kawazoe et al., 2004). However due to the lack of financial support and of a favorable regulation, there have not been large developments of geothermal power plants in Japan in recent years. Only a small 2 MW binary unit was established at the Hatchobaru geothermal power station in February 2004: it is the first binary-cycle geothermal power plant in Japan.

A significant drilling activity has been undertaken, with 41 wells totalling 74 km of drilled depth, equally distributed among exploration, production and reinjection.

The relevant geothermal locations in Japan are listed in Table 4. The deregulation of power generation in the electricity market started in year 2000. As a consequence, electric power companies changed their investment policy for developments of new power plants. This process, in addition to the severe reduction of geothermal commitment by NEDO, was responsible for the stand-by situation experienced by the geothermal development in the country However, the recent renewable portfolio standard (RPS) system promulgated in 2003 may be an useful tool for attracting private investment toward the geothermal energy. Unfortunately, in practice only binary cycle plants are considered as eligible for RPS.

Because of this background, development of small-scale geothermal fields is a new trend. In 2004, NEDO started Geothermal Development Promotion Surveys, which are closely connected to exploitation, with a new concept of "local energy for local area." Three new target areas were carefully selected, based on economical and social aspects in addition to suggested potentials suitable for binary power plants of 10 MW or less. Although the capacity is rather small, each area has unique characteristics that may promote further utilization of geothermal energy in the area with the active support of the municipalities. The results of the surveys will be evaluated by the end of March, 2006.

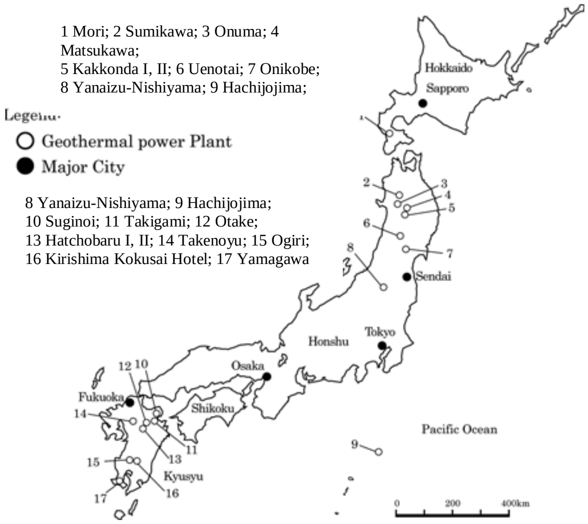

Figure 8: Location of geothermal plants in Japan.

Table 4: Geothermal fields in Japan.

Location (Prefecture)	Installed Capacity [(MW]	Units	Annual Energy Produced [GWh/yr]
Hokkaido	50	1	185
Akita	88	3	619
Iwate	103	3	644
Miyagi	12	1	81
Fukushima	65	1	400
Tokyo	3.3	1	15
Oita	153	7	1 108
Kagoshima	60	2	416

A strategy of geothermal development that is consistent with the expected earth environment of the 21st Century has been proposed in Japan. It is the so called *"EIMY; Energy In My Yard*": the local energy demands should be met from an optimum combination of local and renewable sources. Shortfalls and surpluses would be accommodated through an interface with the national grid (Niitsuma, 2003).

The integrated renewable energy systems have considerable advantage over independent utilization of renewable resources. For a rural area in Japan an integrated renewable energy system can decrease not only CO_2 emission but also the energy cost. Geothermal energy will play a key role in the *EIMY* systems. Heat pumps are of primary importance together with the geothermal technologies of reinjection, HDR/HWR, binary system. This concept will extend much more the penetration of geothermal electricity, bypassing many authorization problems and enhancing the local acceptance of such industrially small pieces of equipment. In the next years it will be interesting to monitor the rate of penetration of this new approach in Japan, hoping it will be successful.

2.14 Kenya

Geothermal electricity generation in Kenya has increased by 84 MW since 2000. In the Olkaria field a new 2x35 MW plant, a 12 MW plant and a 1.8 MW binary pilot plant have been commissioned between 2000 and 2004. The project for Olkaria IV has received financial support for appraisal drilling. Geothermal energy exploitation has increased by 280% from 45 MW in 1999 to 129 MW in 2004 (Mwangi, 2005).

The Olkaria geothermal system is located in the East Africa Rift valley about 120 km north west of Nairobi. The greater geothermal anomaly covers 80 km^2; only three sectors (east, west and northeast) are exploited.

In the Olkaria East field three 15 MW turbo generating units of Olkaria I power plant have been online for the last twenty three years. The earlier of the 33 drilled wells were shallow (<1 200 m); some later deep wells assessed the resources down to 2 500 m. The brine is partly (5%) reinjected hot and 20% cold, while the rest evaporates in an open-air pond.

In the Olkaria NorthEast field two 35 MW units of Olkaria II geothermal power station were commissioned in 2003. This new plant has a lower specific steam consumption of 7.5 [t/h]/[MW] than the 9.2 [t/h]/[MW] of the Olkaria I plant.

A private geothermal company is the developer of the Olkaria West area (Olkaria III). It drilled nine wells from 1 800-2 800 m depth. Currently some fluid is utilized in three standard binary units of 4 MW each.

A fourth minor project with a 1.8 MW binary plant was commissioned in September 2004 in Olkaria by a flower-growing company.

The overall potential of Kenya is enormous: it has been evaluated up to 2 000 MW. Many projects have already been defined, and their funding procedure is ongoing. The Government has proposed the creation of a special purpose geothermal development company (GDC), with the mandate to explore and sell geothermal energy for electricity generation and other uses. The government will finance the risks associated with geothermal exploration: it can give to private companies very appealing opportunities of investing in Kenya.

2.15 Mexico

Currently there are four geothermal fields operating in the country: Cerro Prieto, Los Azufres, Los Humeros and Las Tres Vírgenes. (Gutiérrez-Negrín et al., 2005) The total installed geothermal-electric capacity is 953 MW (see Figure 9 and Table 5).

Mexico is one of the most active countries in geothermal development for electricity production. Since 2000, eight new single flash units went on-line: four at Cerro Prieto (100 MW), four at Los Azufres (100 MW) and a new field, Las Tres Virgines, has started its exploitation with the first 10 MW installed. Further installations are planned at Los Humeros (50 MW) and at another area, La Primavera (75 MW).

The Cerro Prieto field is located near the border with the US. Its exploitation started in 1973, up to the present installed capacity of 720 MW composed of four plants of 110 MW each, four of 37.5 MW, four of 25 MW and one of 30 MW, all of them of condensing type. There are 149 production wells in operation. The discharged brine is disposed of in a 14 km^2solar evaporation pond and injection through 9 injection wells. The four units of plant IV for 100 MW started their commercial life in year 2000.

The Los Azufres geothermal field is located in the central part of Mexico, 250 km to the west of Mexico City, with

14 power units of diverse types (condensing, back-pressure, binary cycle) and capacities (1.5 to 50 MW) in operation, with an installed capacity of 188 MW, 29 production and 6 reinjection wells. In 2003 four new 25 MW units went online.

Table 5: Geothermal fields in Mexico.

Location	Installed Capacity [MW])	Units	Annual Energy Produced [GWh/yr]
Cerro Prieto	720	13	5 112
Los Azufres	188	14	852
Los Humeros	35	7	285
Las Tres Virgenes	10	2	32.8

Figure 9: Geothermal fields location in Mexico.

Los Humeros is another volcanic geothermal field, located in the eastern-central part of Mexico, with an installed capacity of 35 MW (seven back-pressure units of 5 MW net each) and 17 production wells. Separated brine is completely injected into the reservoir with two injection wells. Two new units for an additional 50 MW are scheduled in 2008.

The Las Tres Vírgenes geothermal field is located in the middle of the Baja California peninsula. Two production wells are utilized for two condensing units 5 MW each.

For the new area La Primavera there is the project of installing 75 MW in 2006-2008.

Fifty nine geothermal wells were drilled in Mexico between 2000 and 2003, for a total depth of 150 km.

2.16 New Zealand

In the 2000-2004 period three new plants have been under construction or completed: (i) start of construction of a binary plant (15 MW) at Wairakei; (ii) commissioning of an additional 6 MW at Rotokawa; (iii) start of construction for a further 30 MW at Mokai. The situation for the different geothermal fields in the country is shown in Table 6.

All but one of the geothermal fields are located in the Lake Taupo area, as shown in Figure 10 (Dunstall, 2005).

Table 6: Geothermal fields in New Zealand.

Fields	Installed Capacity [MW]	Units	Annual Energy Produced [GWh/yr]
Wairakei Poihipi	220	11	1505
Ohaaki	104	4	300
Kawerau	14.5	4	130
Rotokawa	31	5	290
Ngawha	10	2	79
Mokai	55	7	470

The Wairakei field has been in continuous operation for close to 50 years, with a stabilized decline. A new binary plant is under construction. The most recent installation of Poihipi station (55 MW) is exploiting fluid from the steam cap formed as a consequence of the liquid drawdown.

Figure 10: Geothermal fields location in New Zealand.

Mokai field, started in year 2000, is an unique example of a geothermal resource fully owned by a local community, Maori Trust, and operated via a state-owned enterprise. This is a key element for the local acceptance of geothermal energy. The Mokai example is important, but not exportable in different situations: the investment for the realization of the plants was made by a pool of banks who will take 100% of the revenues for the first five years of the operation: it is a long-term exploitation strategy (suitable for the local Maori situation), but no private firms will accept this short term no-revenue investment plan. A further 40 MW are currently under construction at Mokai.

However, the New Zealand Maori ethic of "*kaikiakatanga*" which in essence translates to "*look after the land (resources) for the good of all our people and safeguard it (them) for our children and future generation"* is an ethic we all must embrace.

2.17 Nicaragua

Despite the country's enormous geothermal potential, on the order of a thousand MW, the only exploited area by the end of 2004 is Momotombo field, in operation since 1983. It has been recently rehabilitated from the 1999 running capacity of 12 MW up to the present value of 77 MW installed capacity with the new binary unit (Zuniga, 2005), giving a running capacity of about 35 MW.

Two 5 MW back pressure units are currently being installed at the nearby San Jacinto-Tizate field, where seven exploration wells (between 700 and 2 200 metres) encountered temperatures from 264 to 289ºC, to be operational in early 2005, and with a planned expansion to a total of 66 MW over the following few years.

Four reinjection wells have been drilled, stabilizing the production from the present 12 producing wells. There is a plan for achieving the full production, drilling new deep wells and expanding the exploitation of the deep part of the reservoir (1 700-3 000 m), because the shallow area is affected by lake water infiltration with severe cooling effects.

The approval of the new geothermal law and energy policies will help in attracting local and foreign private investment in geothermal projects. In addition, the economic development of the whole area will improve with the implementation of the Sistema Eléctrico para America Central (SIEPAC).

2.18 Papua- New Guinea

Geothermal power development is focused on the tiny Lihir Island, located about 700 kilometers northeast of the national capital, Port Moresby. Its exploitation arises from an unusual combination of the geothermal resource, the gold mining environment, and the isolated location (Martin Booth et al., 2005).

Geothermal wells have been drilled, as well as large diameter dewatering wells used for mining purposes, and utilizes 250°C water from 1 000 m depth.

A 6 MW backpressure plant has been commissioned in 2003. The new plant displaces diesel generation, with a fuel cost savings of US$2 000 000 per year. An additional 30 MW geothermal power project is under construction and is scheduled for commissioning in year 2005.

2.19 Philippines

The Philippines is the world's second largest producer of geothermal energy for power generation, with an installed capacity of 1 931 MW and a running capacity of 1 838 MW. In the last five years only a minor increase of capacity has been achieved, with 22 MW at Tongonang. The drilling activity was mainly devoted to maintenance of 28 new wells with 63 km of drilled depth. (Benito et al. 2005).

The relevant fields are shown in Table 7 and Figure 11.

Table 7: Geothermal fields in Philippines.

Fields	Location	Installed Capacity [MW]	Units	Annual Energy Produced [GWh/yr]
Tiwi	Luzon	330	6	442
MakBan	Luzon	426	16	1 538
BacMan	Luzon	151	5	457
Tongonang	Leyte	723	21	4 746
Palinpinon	Negros	192	7	1 257
Mt. Apo	Mindanao	108	2	813

Tiwi running capacity has been derated from 330 to 275 MW because of rehabilitation of old plant. A minimum value of 232 MW is expected in 2005.

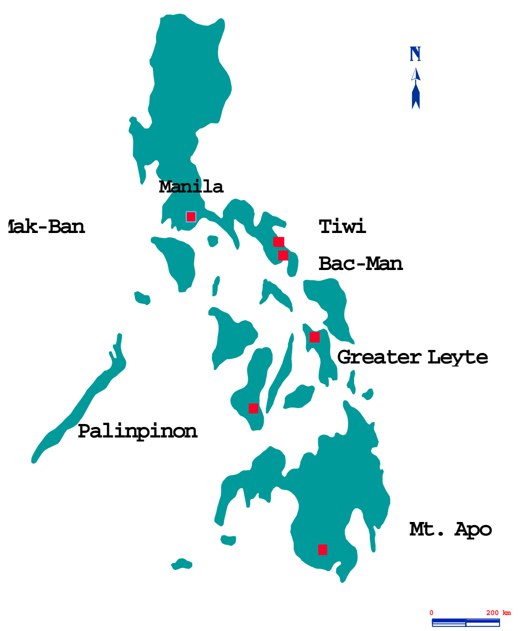

Figure 11: Location of geothermal fields in Philippines.

Mak-Ban has been in commercial production since 1979; despite its small surface area. The wide recharge from the surrounding aquifer is a key element for its sustainable development for such a long exploitation life. Make-up wells have been drilled, with 10 new wells in the deep reservoir (2 800 m). Its running capacity will be 402 MW after the current rehabilitation activities.

Tongonan and the adjacent geothermal fields in Leyte are the most important geothermal project of the country, with 723 MW of installed capacity. Drilling of make-up and replacement wells, working-over old wells and handling corrosion/erosion/scaling problems are the relevant activities performed to sustain its high energy production, with 4 745 GWh generated in 2003.

Palinpinon has a total installed capacity of 192 MW, in operation since 1983. There is an expansion project for additional 20 MW in 2006.

Bac-Man has operated since 1993 without substantial modification/additions. Mechanical problems affected the operating life of its unit I.

Mt. Apo is the sixth operative geothermal field of the country, with the most recent addition of the second unit in 1999, for a total of 108 MW. The project for a further 20 MW expansion is currently under evaluation.

New areas are under study; the most promising one being Northern Negros, where a feasibility study for 40 MW has been performed and its development is expected for 2006.

2.20 Portugal

In Portugal, exploitation of geothermal resources for electric power generation has been developed successfully on the largest and most populous Azores island, São Miguel. The high enthalpy resource is used in the Ribeira Grande plant, with four binary units completed in 1998. In a second island, Terceira, a project for installing 12 MW is ongoing, expecting to double the installed capacity in the islands by 2008 (Bicudo da Ponte, 2002; Carvalho et al., 2005).

2.21 Russia

The high enthalpy fields under exploitation at present in Russia are located in Kamtchatka and on the Kurili islands (Kononov et al., 2005). In the Kamchatka peninsula several geothermal power plants operate with the installed capacity of 12 MW and 50 MW on the Mutnovsky field and 11 MW on the Pauzhetsky field. On the Kurili islands, (Kunashir and Iturup) two small units of 2.6 MW and 3.4 MW are in operation.

The total installed capacity in the far east of Russia is 79 MW.

The relevant increase of the geothermal capacity in the country comes from the partially steam-dominated field of Mutnovsky, where 50 MW has been placed on-line and a further 100 MW unit has been considered, as well as a small binary unit in the same area.

The high-temperature North Mutnovsky thermal field is the primary object for electric power production in Kamchatka. In total, 82 wells in the range of 200-2 000 m were drilled here. A shallow vapour-dominated reservoir was found at depths of 700-900 m. It is underlain by a liquid-dominated reservoir at a temperature of 250-310^{0}C. Now, 17 wells producing 330 kg/s of fluids with an average enthalpy of 1 600 kJ/kg are ready for exploitation. This project was supported by a US$ 100 million loan from the European Bank of Reconstruction and Development (see Figure 12).

Another partially-explored promising site is Nizhne-Koshelev, with an estimated fluid enthalpy up to 2 800 kJ/kg. Other sites of the same kind are the Bolshe-Bannoe and Kireuna fields. In addition, there is the Semyachik field adjacent to the Kronotsky protected area (Natural Park) including the famous Geyser Valley. The limited use of the Semyachik field (for construction of a small power plant of 5 MW capacity) could help the development of tourist services in the protected area. Except for the geothermal resources of the Kronotsky protected area, resources identified in Kamchatka to date could provide electric power generation of approximately 1 000 MW.

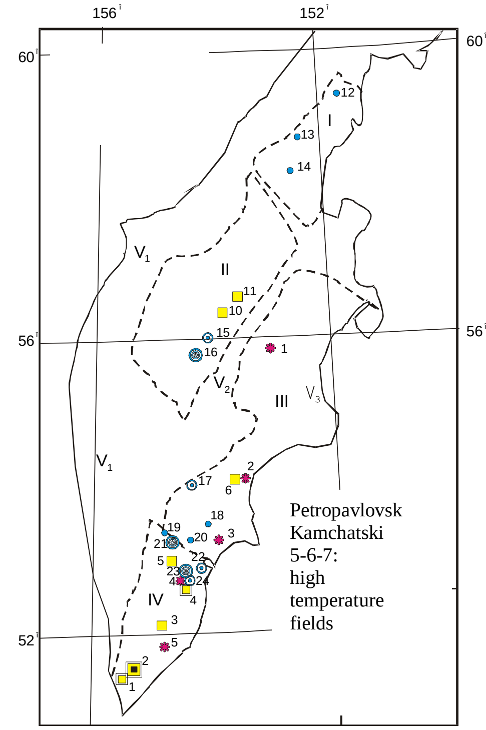

Figure 12: Location of geothermal fields in Kamtchatka.

2.22 Thailand

A small 300 kW binary plant provides electric power to the small village of Fang, using 116°C water. Hot water is used also for other direct applications. The power plant replace a diesel unit, with a saving of about US¢ 15 per kWh.

2.23 Turkey

The only active power production field in Turkey is Kizildere, started in 1968. The present plant went on-line in 1984, with an installed capacity of 20 MW and an average running capacity of 12-15 MW electricity annually (Simsek et al., 2005). No relevant activity has been performed in 2000-2005.

2.24 USA

Geothermal electric power plants are located in California, Nevada, Utah and Hawaii; since 1989, only 110 MW has been installed in the country. The relevant activity performed in these years was the reinjection project at The Geyser. Recycled wastewater has been delivered from some communities of the area to the geothermal field via a 48 km pipeline, which transports 1 230 ton/hr of effluent. The Southeast Geysers Effluent Recycling Project (SEGEP) can be considered as the first wastewater-to-electricity system. As a consequence of this massive reinjection of fluid, the power generation has increased by an estimated 77 MW (Figure 13); however, its trend of decline has not yet reversed. The second phase, called Santa Rosa – Geysers Recharge Project (SRGRP) for additional 1 700 ton/hr is on-going and it is expected to give an additional recovery of 85 MW. (Lund et al., 2005; Lund 2003; Sass et al. 2002; Campbell et al., 2004; Monastero, 2002).

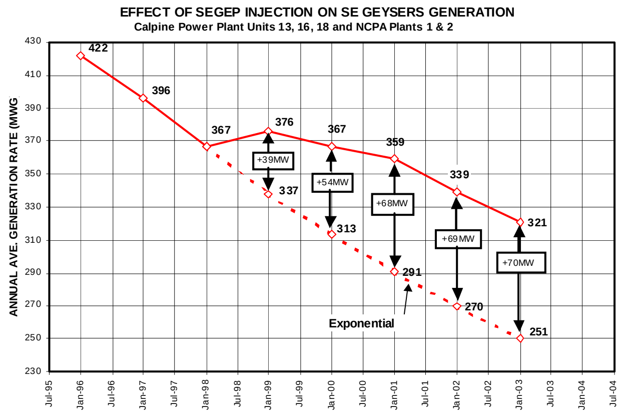

Figure 13: Reinjection effects of the Phase I SEGEP Project at The Geyser.

The present installed gross capacity is 2 544 MW, with a net running capacity of about 1 900 MW. The difference is mainly due to The Geyser plants, where the 21 units currently in operation have an installed capacity of 1 421 MW but, because of the overexploitation, steam is available only for approximately 888 MW of running capacity.

California

The relevant geothermal power plants are listed in Table 8 and Figure 14.

Table 8: Geothermal fields in California.

Field	Units	Installed Capacity [MW]	Annual Energy Produced [GWh/yr]
The Geyser	21	1 421	7 784
Imperial Valley East Mesa	52	79	782
Imperial Valley Heber	13	90	641
Imperial Valley Salton Sea	13	336	3 146
Coso	9	274	2 785
Casa Diablo	4	40	315
Other	5	4	26
California	**117**	**2 244**	**15 479**

The Geysers, after dismantling old units and adding the reinjection project, reached a total running capacity of 888 MW (net) with 21 units shared between two operators. Its maximum peak of installed capacity was 1,891 MW in 1987.

At Imperial Valley-Salton Sea, the operator installed in 1999 a new 50 MW unit of which 10 MW was aimed at a zinc-recovery project from spent geothermal brine. Unfortunately, this project has been abandoned due to a drop in zinc prices on the world market. Recent merging and acquisition processes concentrated Heber and East Mesa plant in a single operator. Projects for optimizing old units and expanding these fields are under evaluation.

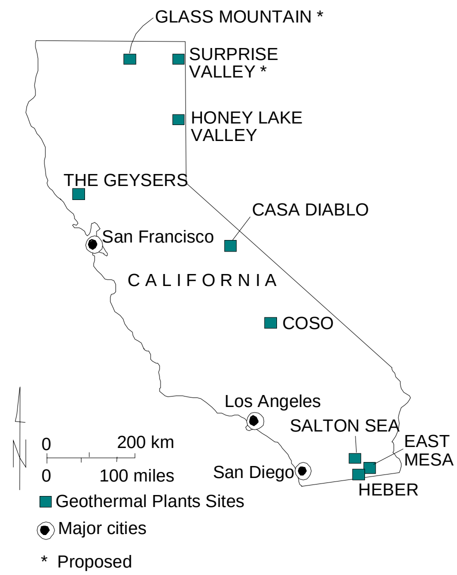

Figure 14: Geothermal fields location in California.

Nevada

The relevant geothermal power plants are listed in Table 9 and Figure 15.

Table 9: Geothermal fields in Nevada.

Field	Units	Installed Capacity [MW]	Annual Energy Produced [GWh/yr]
Beowave	1	16	131
Brady	4	26	181
Desert Peak	2	12	107
Dixie Valley	1	62	489
Empire	4	5	38
Soda Lake	9	26	206
Steamboat	13	58	488
Steamboat Hills	1	15	120
Stillwater	14	21	166
Wabuska	2	2	17
Nevada	**51**	**243**	**1 943**

All the Steamboat plants have recently been acquired by a single operator.

Other

No relevant activity can be highlighted for the other states, Utah (one unit of 26 MW at Roosevelt for 200 GWh of production) and Hawaii (20 small binary and single flash units at Puna, 30 MW for 218 GWh of production). The Puna Project suffered severe damage in 2002, due to casing failure from heat and corrosion; After months of work-over, it is now again operating on its rated capacity.

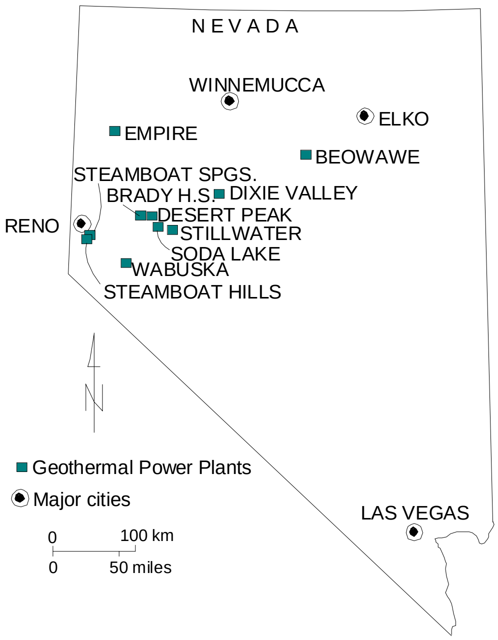

Figure 15: Location of geothermal in Nevada.

Future developments are planned at Glass Mountain in northern California: 50 MW approved at Fourmile Hill and 50 MW denied at Telephone Flats. New plants will be supplied in Nevada at Steamboat (42 MW), Desert Peak (30 MW) and in Utah at Sulfur Hot Spring (25 MW); a new 185 MW unit at Salton Sea has been announced. If all these projects succeed, new US geothermal electrical production will increase by 340 MW by 2010, corresponding to 20% increase in five years.

4. TABLES

All the world geo-electricity production data are collected in the attached summary tables.

In Table I the "World Summary" data are presented. For each country, the table shows:

- the Installed and Running capacity (as defined in the Introduction);
- the Energy produced in the last accounted year (for some countries it is 2004, for others 2003);
- the number of producing units which are currently in service (excluding not operating, retired or reserve);
- the percentage of national capacity and energy.

In Table II the "Installed Geothermal Generating Capacity" data are presented. For each country, the table shows the 1995, 2000 and 2005 installed capacity and its increase since WGC2000.

In Table III the "Relevant Geothermal Field Characteristics" data are presented. For each geothermal field (with important installed capacity) in each country, the table shows the following estimations:

- The field extension, based upon the drilled area;
- The reservoir characterizations (Liquid or Steam Dominated);
- The reservoir depth and temperature;
- The number of production and reinjection wells;
- The running capacity.

5. CONCLUSION

5.2 Country classification

It is possible to identify three categories among the presently geo-electricity productive countries:

New Entries: the countries where geothermal energy has been used for producing electricity for the first time since year 2000: they are Austria, Germany and Papua New Guinea. In the first two states the new plants are small (less than one MW) binary technology, while for the third one the 6 MW new back-pressure unit can be considered as first part of an additional 30 MW installation project.

Turtles: the countries with stabilized exploitation, with no new plants since year 2000: Australia, China, El Salvador (but with an important 50 MW project at Berlin on-going), Ethiopia, Guatemala, Japan (with some perspectives from EIMY projects), New Zealand (projects for the coming years at Wairakey and Mokai), Nicaragua, Portugal, Thailand, Turkey.

Hares: this list includes all the countries with a significant activity for geoelectricity in the last years:

- Costa Rica, with 14% of increase in installed capacity, due to the new 18 MW at Miravalles V;
- France, with a relevant three times increase in the installed capacity at Guadeloupe, with the new 10 MW Bouillante II;
- Iceland, where the new 30 MW plant at Nesjavellir increased the installed capacity by 19%;
- Indonesia, with 35% of new installed capacity; however, these additional plants (80 MW at Darajat, 60 MW at Dieng and 110 MW at W. Windu) were placed on-line around year 2000. No new installation since that time;
- Italy, where, despite of the modest increase of the installed capacity, 10 new units have been placed on-line for 254 MW, replacing old ones;
- Kenya, with two new units at Olkaria (II and III) for 92 MW, almost doubling the installed capacity in the country;
- Mexico, where a relevant installation activity has been carried out, with three new units: Cerro Prieto IV, Los Azufres and Las Tres Virgines, for a total of 198 MW, corresponding to a 16% increase;
- Nicaragua, with 10% increase due to the rehabilitation of Momotombo and the new binary unit;
- Philippines, with a modest increase of 22 MW (1%) due to the new unit at Tongonan;
- Russia, where the 56% increase has been achieved with the new 50 MW unit at Mutnnovsky;
- USA, with the new Salton Sea unit V (60 MW) corresponding to an increase of 3%.

5.3 Drilling activity

In the following Table 10 the relevant drilling data for the individual countries are presented.

Data for Costa Rica, Russia and New Zealand have been estimated.

Table 10: Drilling activity in the world.

Country	Wells	Total Depth [km]
Australia	2	6
China	1	2
Costa Rica	6	12
El Salvador	5	10
France	3	5
Germany	4	12
Guatemala	5	8
Iceland	23	50
Italy	21	64
Japan	41	74
Kenya	9	22
Mexico	59	150
New Zealand	9	25
Papua New Guinea	7	4
Philippines	28	63
Portugal	6	4
Russia	4	10
Turkey	4	3
USA	54	42
TOTAL	**291**	**566**

About 290 wells for electricity production (or reinjection of spent brines) have been drilled in five years, for a total of 560 km. The average well depth is 1.9 km.

The **Moles** are: Mexico, Iceland, Italy, Japan, Philippines and USA.

The most active drilling country is Mexico, which is also at top level among the country leaders listed in the previous paragraph. In the other countries the new wells have been used both for keeping stable the production level, compensating production drawdown and increasing energy production (Iceland).

5.3 Power Plant classifications

The total installed capacity has been classified under the following plant categories, as shown in Table 11 and Figure 16.

Table 11 Power Plants distribution

Category	Installed Capacity [MW]	%
Dry Steam	2 545	29%
Single Flash	3 296	37%
Double Flash	2 268	25%
Binary/Combined Cycle/Hybrid	685	8%
Back Pressure	119	1%
TOTAL	**8 912**	**100%**

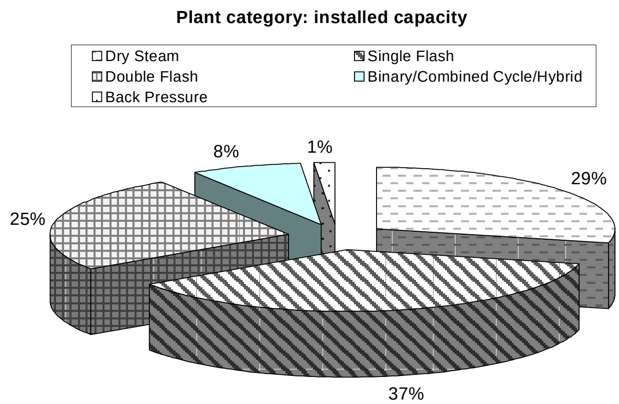

Figure 16: Plant Categories: % of installed capacity.

The highest values of installed capacity are for dry steam and single flash units, covering 2/3 of the total. Binary units, despite their low value in the present word-wide ranking, are increasing their presence in the market but with a lower value of capacity per unit.

Figure 17 shows the distribution of the number of units among the different categories. The maximum is given by the 192 binary units (41%) with installed capacity of 685 MW, corresponding to 3.6 MW per unit.

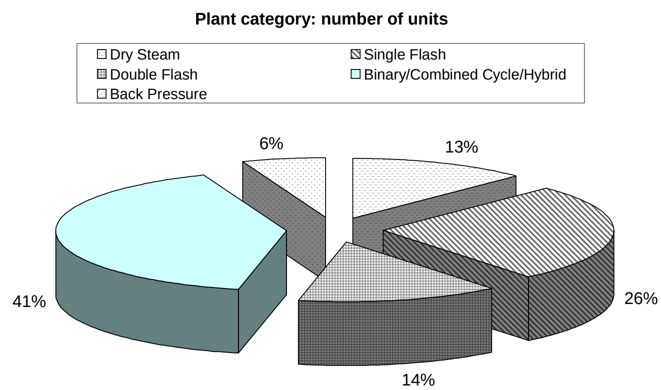

Figure 17: Plant Categories: percentage of number of Units.

The average size of single flash units is 26.6 MW per unit, followed by 34.4 MW per unit for double flash and 43.1 MW per unit for the dry steam plants

The total number of geothermal units operating in 2004 is 468.

5.4 Geothermal field power density

Data presented in Table III should be considered as preliminary and with the status of work-in-progress. For many fields it was not possible to fill all the requested information. However, the power density has been calculated from a relevant samples of 42 geothermal reservoirs, dividing the running capacity by the estimated reservoir surface (inferred from the drilled area). The results are shown in Figure 18.

The average value is **8 [MW]/[km^2]**, but it is clear from the shape of the distribution that smaller results are more common, in the range 2-10 [MW]/[km^2].

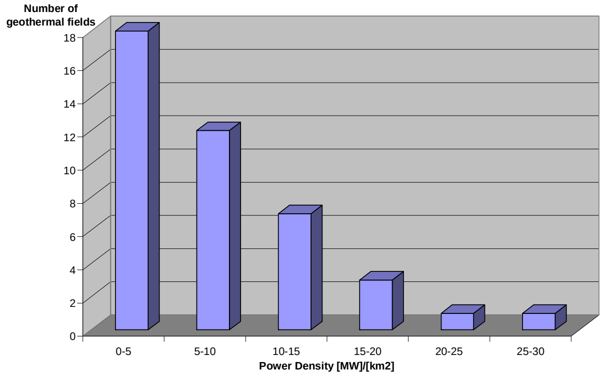

Figure 18: Power density distribution of developed geothermal fields.

It is useful to analyze the number of productive wells per square kilometer. This well-density distribution shows a clear reservoir temperature influence. In order to quantify this effect, the geothermal fields of Table III have been classified in two temperature categories: "HOT" (temperature >280°C) and "COLD". The number of productive wells taken into consideration is only the presently producing ones, not the total drilled in the reservoir itself. The average well-density for the two categories is the following:

HOT: **1.8± 1.4** wells per square kilometer

COLD: **2.9± 1.5** wells per square kilometer

The distribution of the well-density is shown in Figure 19.

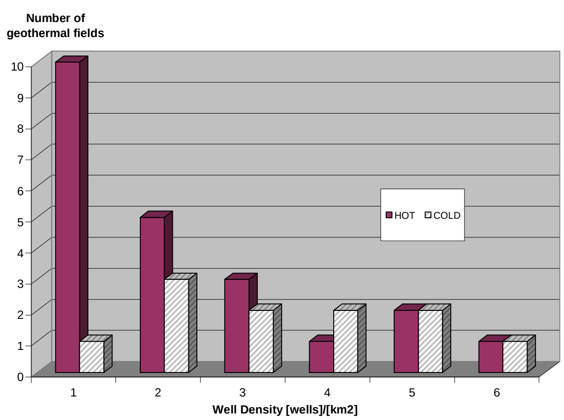

Figure 19: Well density distribution of developed geothermal fields for the two temperature categories.

ACKNOWLEDGEMENT

I express my gratitude to the IGA BoD members and to the Affiliated Organizations for their contribution in reviewing the data collected in this paper.

My thanks also to the authors of the country updated reports presented in this Conference for their help in clarifying many open questions.

Last but not least, it is necessary to express my appreciation to Marnell Dickson, John Garnish, John Lund and Roland Horne for the useful clarifications and final review of the manuscript.

Of course I am solely responsible for the remaining mistakes.

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Table I: World Summary data.

Country	Installed Capacity [MW]	Running Capacity [MW]	Annual Energy Produced [GWh/y]	Number of Units	% of National Capacity	% of National Energy
Australia	0.2	0.1	0.5	1	Negligible	Negligible
Austria	1	1	3.2	2	Negligible	Negligible
China	28	19	95.7	13	30% Tibet	30% Tibet
Costa Rica	163	163	1 145	5	8.4%	15%
El Salvador	151	119	967	5	14%	24%
Ethiopia	7	7	N/a	1	1%	n/a
France	15	15	102	2	9% Guadeloupe island	9% Guadeloupe island
Germany	.2	.2	1.5	1	Negligible	Negligible
Guatemala	33	29	212	8	1.7%	3%
Iceland	202	202	1 406	19	13.7%	16.6%
Indonesia	797	838	6 085	15	2.2%	6.7%
Italy	790	699	5 340	32	1.0%	1.9%
Japan	535	530	3 467	19	0.2%	0.3%
Kenya	127	127	1 088	8	11.2%	19.2%
Mexico	953	953	6 282	36	2.2%	3.1%
New Zealand	435	403	2 774	33	5.5%	7.1%
Nicaragua	77	38	270.7	3	11.2%	9.8%
Papua New Guinea	6	6	17	1	10.9% Lihir island	
Philippines[1]	1 931	1 838	9 419	57	12.7%	19.1%
Portugal	16	13	90	5	25% San Miguel island	
Russia	79	79	85	11	Negligible	Negligible
Thailand	.3	.3	1.8	1	Negligible	Negligible
Turkey	20	18	105	1	Negligible	Negligible
USA	2 544	1 914	17 840	189	0.3%	0.5%
TOTAL	**8 912**	**8 010**	**56 798**	**468**		

1 After rehabilitation of plants in Tiwi and MakBan their running capacity will be 232 and 402 MW respectively

Table II: Installed Geothermal Generating Capacity.

Country	1995 [MW]	2000 [MW]	2005 [MW]	2005-2000 Increase [MW]	% Increase
Australia	.2	.2	.2	0	Stable
Austria	0	0	1	1	New Entry
China	29	29	28	-1	Stable
Costa Rica[1]	55	143	163	20	14%
El Salvador[2]	105	161	151	-10	Stable
Ethiopia	0	7	7	0	Stable
France[3]	4	4	15	11	275%
Germany	0	0	.2	.2	New Entry
Guatemala	0	33	33	0	Stable
Iceland[4]	50	170	202	32	19%
Indonesia[5]	310	590	797	207	35%
Italy[6]	632	785	790	5	1%
Japan	414	547	535	-12	Stable
Kenya[7]	45	45	127	82	182%
Mexico[8]	753	755	953	198	16%
New Zealand	286	437	435	-2	Stable
Nicaragua[9]	35	70	77	7	10%
Papua New Guinea[10]	0	0	6	6	New Entry
Philippines[11]	1 227	1 909	1 931	22	1%
Portugal	5	16	16	0	Stable
Russia[12]	11	23	79	56	244%
Thailand	.3	.3	.3	0	Stable
Turkey	20	20	20	0	Stable
USA[13]	2 817	2 228	2 544	316	3%
TOTAL	**6 797**	**7 974**	**8 912**	**938**	**12%**

1 New 18 MW Miravalles V binary unit.
2 Decommissioning of 2x5 well-head units at Berlín.
3 New 10 MW single flash plant la Bouillante II at Guadeloupe.
4 New plant at Nesjavellir 30 MW.
5 On line plants already installed but not operating in 2000 (one unit at Darajat for 80 MW; Dieng for 60 MW and W. Windu for 110 MW); new plant at Lahendong for new 20 MW. The running capacity for the country is 838 MW, due to the overproduction of three units at Salak and Darajat.
6 Despite the modest increase of the installed capacity, the construction and start-up of several plants as substitution of old one) was very active, with ten new units for 254 MW.
7 New 70 MW Olkaria II and 12 MW Olkaria III (binary units).
8 New Units at Cerro Prieto IV (100 MW), Los Azufres (100 MW) and Las Tres Virgines (10 MW).
9 New binary unit at Momotombo and rehabilitation of the project.
10 New unit at Lihir Island; further 30 MW are under construction.
11 New 22 MW unit at Tongonan.
12 New 50 MW unit at Mutnovsky.
13 Despite the quoted increase in installed capacity, the country situation should be classified as stable, because the value accounted for in year 2000 was under-estimated for The Geyser capacity and Casa Diablo plants. In the last five years only the Salton Sea Unit V has been added (60 MW); the increase of installed capacity has been calculated with the additional 60 MW only over the total value.

Table IIIa: Relevant geothermal field characteristics.

Country	Field	Drilled Area [km^2]	Type	Depth [m]	Temperature [°C]	Wells Production	Wells Reinjection	Running Capacity [MW]
China	Yangbajain	4	Water	200	140-160	14	6	15
Costa Rica	Miravalles	30-35	Water	1 000 2 000	240	32	20	163
El Salvador	Ahuachapán	3-4	Water/Steam	600 1 500	230-240	19	5	63
El Salvador	Berlín	2-3	Water	2 000 2 500	300	9	15	56
France	Guadeloupe	4	Water	300 1 100	250	6		15
Guatemala	Zunil I	4	Water	1 500 2 300	300	6	2	24
Guatemala	Zunil II	8-10	Water/Steam	800 1 200	240	2		5 in testing
Guatemala	Amatitlán	6-9	Water/Steam	1 000 2 000	300	4		5 in testing
Iceland	Krafla	5-6	Water	1 000 2 000	190-210 350	21	1	60
Iceland	Nesjavellir	6-8	Water	1 000 2 000	300-320	18		90
Iceland	Svartsengi	6-8	Water	1 000 2 000	240	11	1	46
Indonesia	Kamojang	15-20	Steam	1 500	245	29		140
Indonesia	Salak	20-25	Water	1.000 2 000	240-310	30	15	361
Indonesia	Darajat		Steam	2 000	245	17		135
Indonesia	Dieng		Water		280-330	25		60
Indonesia	Wayang Windu		Water		250-270	18		110
Indonesia	Lahendong		Water		260-330	15		20
Italy	Larderello	250	Steam	1 000 4 000	150-270 and 350	180	23	473
Italy	Travale Radicondoli	50	Steam	1 000 4 000	190-250 and 350	22	0	147
Italy	Bagnore	5	Water	1 000 3 000	200-330	7	4	19
Italy	Piancastagnaio	25	Water	1 000 3 000	200-300	19	11	60
Japan	Ogiri	8	Water	1 000 2 000	260	19		30
Japan	Otake Hatchoubaru	8-10	Water	1 000 2 500				122
Japan	Takigami		Water					25
Japan	Yanauzu Nishiyama		Water					65
Japan	Onikobe		Water					12
Japan	Uenotai	9-10	Water	1 000 2 000	300-320	9	7	29
Japan	Kakkonda		Water		230-260 350-360			80
Japan	Matsukawa	4	Water		260	17		24
Japan	Sumikawa		Water			15		50
Japan	Mori	6	Water	500-1 500 2 000-2 500	230-250	10	9	50
Kenya	Olkaria E	5	Water	500 2 000		26	0	45
Kenya	Olkaria W	12	Water					70
Kenya	Olkaria NE	9	Water	1 800 2 700		9		12

Table IIIb: Relevant geothermal field characteristics.

Mexico	Cerro Prieto	150-200	Water	2 800	300-340	149	9	720
Mexico	Los Azufres	35	Water	1 600 2 000 3 000	150-200 280-300	29	6	188
Mexico	Los Humeros		Water			17	2	35
Mexico	Las Tres Virgenes	30	Water	2 100	280			10
New Zealand	Wairakei	15	Water/Steam		160-260			220
New Zealand	Ohaaki	5-8	Water		230-280			104
New Zealand	Rotokawa	25	Water	2 000 2 500	270-330			31
New Zealand	Kawerau		Water		240-300			15
New Zealand	Ngawha		Water	600 2 800	220-240	2	2	10
New Zealand	Mokai		Water		270-320			55
Nicaragua	Momotombo	4	Water	300-800 800-1 700 1 700-3 000	180-200 200-240 240-300	12	4	35
Nicaragua	San Jacinto-Tizate		Water	1 500 2 500	260-280	3	2	10 (by 2005)
Papua New Guinea	Lihir	3-5	Water/Steam	300 1 000	250-300	3		6
Philippines	Tiwi	13	Water	900 2 800	320	43	16	232
Philippines	MakBan	7	Water	900 3 400	345	72	21	402
Philippines	BacMan	10	Water	1 300 3 000	240 320	22	8	150
Philippines	Tongonang	53	Water	1 500 3 000	250 300	81	33	723
Philippines	Palinpinon	48	Water	2 500 3 000	250 300	36	13	192
Philippines	Mt. Apo	21	Water	750 3 000	230 310	17	6	108
Russia	Pahuzhetka		Water		200	7		11
Russia	Mutnovsky	12-15	Water/Steam	700 2 500	240-300	17	4	62
Turkey	Kizildere		Water		240			17
USA	The Geyser	100	Steam	600 3 000				888
USA	COSO	20	Water	500 3 500	200-330	90	20	270
USA	East Mesa	24	Water	1 500 2 500	150-190		41	107
USA	Heber	5	Water	1 200 1 800	160-180	21	23	65
USA	Salton Sea	16	Water					350
USA	Casa Diablo		Water	200	160			27
USA	Brady		Water					26
USA	Beowave		Water					16
USA	Dixie Valley		Water					68
USA	Soda Lake		Water					17
USA	Steamboat		Water					36
USA	Stillwater		Water					13
USA	Puna		Water	2 000	160			27
USA	Roosevelt		Water					20