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Geothermal Power Generation in the World 2005–2010 Update Report

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ABSTRACT

We have analyzed the major activities carried out for geothermal electricity generation since WGC2005.

New data has been taken from WGC2010 Country Update reports, private communications from IGA members and Affiliated Organizations, and we would like to acknowledge all IGA friends for their valuable help. Other updates have been collected from websites of private and public organizations involved in geothermal development. Plants under construction, which are expected to be commissioned in 2010, are included in the installed capacity. An increase of about 1.8 GW in the five year term 2005-2010 has been achieved (about 20%), following the rough standard linear trend of approximately 350 MW/year, with an evident increment of the average value of about 200 MW/year in the precedent 2000-2005 period (Bertani, 2005a, 2005b, 2006 and 2007).

1. INTRODUCTION

The total installed capacity from worldwide geothermal power plant is given in table I and figure 1.

For reaching the forecasting of 2015, based on an accurate accounting of all the existing projects at an executive stage, a clear change in the present linear growing trend should be necessary.

In table II data from all the countries currently generating geothermal electricity are presented, with the 2005 and the updated at 2010 values of installed capacity and the produced energy per year, the increment since 2005 both in absolute terms and in percentage, and the aforesaid mentioned short term forecasting to year 2015 for the installed capacity. In figure 2 a world map of the year 2010 installed capacity is presented. In figure 3 the forecasting for year 2015 is also shown.

Table I: Total worldwide installed capacity from 1950 up to end of 2010 and short term forecasting.

Year	Installed Capacity MW	Produced Energy GWh
1950	200	
1955	270	
1960	386	
1965	520	
1970	720	
1975	1,180	
1980	2,110	
1985	4,764	
1990	5,834	
1995	6,833	38,035
2000	7,972	49,261
2005	8,933	55,709
2010	10,715	67,246
2015	18,500	

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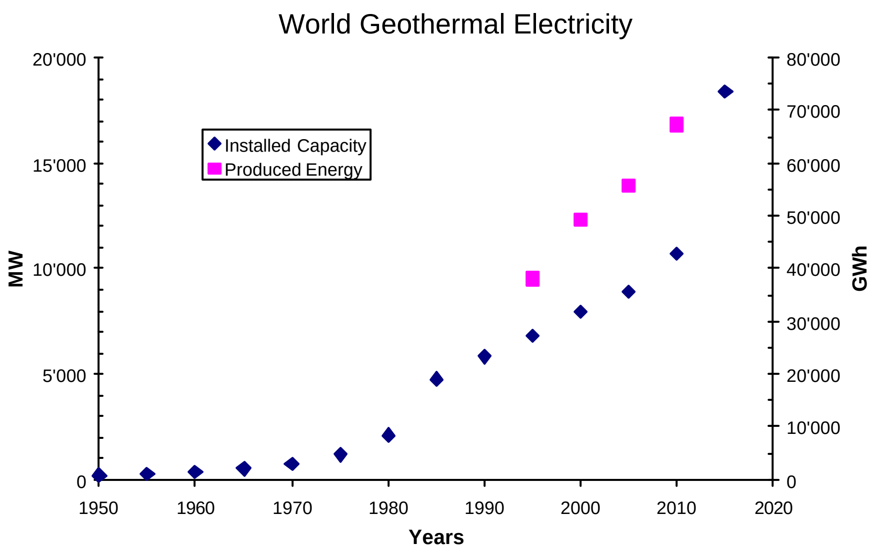

Figure 1: Installed capacity from 1950 up to 2015 (Left, MW) and produced electricity (Right, GWh).

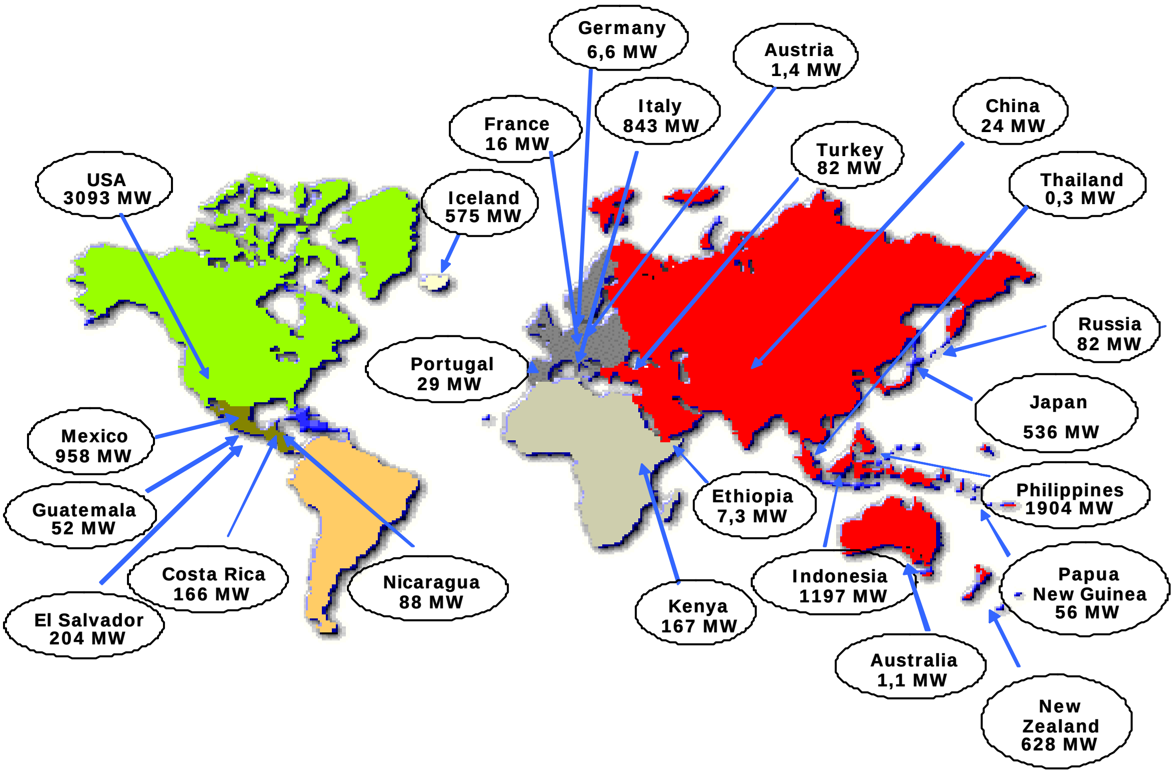

Figure 2: Installed capacity in 2010 worldwide [10.7 GW].

Figure 3: Forecasting of the installed capacity in 2015 [18.5 GW].

Table II: Installed capacity and produced energy for 2005, 2010, and forecasting for 2015.

COUNTRY	Installed in 2005	Energy in 2005	Installed in 2010	Energy in 2010	Forecast for 2015	Increase since 2005			
	MW	GWh	MW	GWh	MW	MW	GWh	Capacity %	Energy %
ARGENTINA	0	0	0	0	30	0	0		
AUSTRALIA	0.2	0.5	1.1	0.5	40	1	0	633%	-5%
AUSTRIA	1.1	3.2	1.4	3.8	5	0	1	27%	19%
CANADA	0	0	0	0	20	0	0		
CHILE	0	0	0	0	150	0	0		
CHINA	28	96	24	150	60	-4	54	-13%	57%
COSTA RICA	163	1,145	166	1,131	200	3	-14	2%	-1%
El SALVADOR	151	967	204	1,422	290	53	455	35%	47%
ETHIOPIA	7.3	0	7.3	10	45	0	10	0%	
FRANCE	15	102	16	95	35	2	-7	10%	-7%
GERMANY	0.2	1.5	6.6	50	15	6	49	2,774%	3,249%
GREECE	0	0	0	0	30	0	0		
GUATEMALA	33	212	52	289	120	19	77	58%	36%
HONDURAS	0	0	0	0	35	0	0		
HUNGARY	0	0	0	0	5	0	0		
ICELAND	202	1,483	575	4,597	800	373	3,114	184%	210%
INDONESIA	797	6,085	1,197	9,600	3,500	400	3,515	50%	58%
ITALY	791	5,340	843	5,520	920	52	180	7%	3%
JAPAN	535	3,467	536	3,064	535	1	-404	0%	-12%
KENYA	129	1,088	167	1,430	530	38	342	29%	31%
MEXICO	953	6,282	958	7,047	1,140	5	766	1%	12%
NEVIS	0	0	0	0	35	0	0		
NEW ZEALAND	435	2,774	628	4,055	1,240	193	1,281	44%	46%
NICARAGUA	77	271	88	310	240	11	39	14%	15%
PAPUA-NEW GUINEA	6.0	17	56	450	75	50	433	833%	2547%
PHILIPPINES	1,930	9,253	1,904	10,311	2,500	-26	1,058	-1%	11%
PORTUGAL	16	90	29	175	60	13	85	78%	94%
ROMANIA	0	0	0	0	5	0	0		
RUSSIA	79	85	82	441	190	3	356	4%	419%
SPAIN	0	0	0	0	40	0	0		
SLOVAKIA	0	0	0	0	5	0	0		
THAILAND	0.3	1.8	0.3	2.0	1	0	0	0%	11%
THE NETHERLAND	0	0	0	0	5	0	0		
TURKEY	20	105	82	490	200	62	385	308%	368%
USA	2,564	16,840	3,093	16,603	5,400	530	-237	21%	-1%
TOTAL	**8,933**	**55,709**	**10,715**	**67,246**	**18,500**	**1,783**	**11,538**	**20%**	**21%**

2. GEOTHERMAL POWER GENERATION

2.1 Argentina (Pesce, 2010)

The only geothermal plant of the country, the small demonstration binary unit of Copahue (670 kW), installed in 1988 has been decommissioned in 1996. It was powered by a single well with 171°C fluid, at 800-1,200 m depth and flow rate of about 2 kg/s. A new plant for 30 MW in that site is under consideration (figure 4). Six other projects are at different stage of development, even if the geothermal electricity contribution of the country is expected to be modest.

Figure 4: Location of Copahue.

2.2 Australia (Beardsmore and Hill, 2010)

Despite of the quite low traditional hydrothermal resources, in Australia a very big effort is on the way, both from the legislation side and from researcher investment in order to exploit the EGS perspectives of the country.

Several projects are under executions, and several new leases have been released to a very aggressive pool of companies. There is the realistic hope to have from this country in the near future the first industrial experience of EGS, after the EU pioneristic activities of Soultz.

The Birdsville geothermal power plant is Australia’s only operating source of geothermal electric power at the end of 2009. The organic rankine cycle binary plant operates on 98°C water flowing at 27 kg/s from a 1,200 m deep well generating net 80 kW. Additional 300 kW are planned.

Geodynamics Ltd is commissioning a new 1 MW pilot plant at its Habanero EGS project at Innamincka. This plant is the first stage in a planned 40 MW initial development at the site. A temperature of 250°C at a depth of 4,400 m has been reported.

Panax Geothermal Ltd operates the Penola Geothermal Project, a reservoir at about 3,500 m depth to produce water at an average temperature of 145°C from a naturally permeable formation.

Petratherm Ltd is developing a project at Paralana to extract heat from meta-sedimentary formations at depth of 3,500–4,000 m. (Figure 5).

The total expected geothermal EGS installed capacity for 2020 is about 100 MW.

Figure 5: Location of Birdsville [A], Habanero [B], Paralana [C] and Penola [D].

2.3 Austria (Goldbrunner, 2010)

In the country three small binary plants are installed: Altheim, Bad Blumau and the cross-border project of Simbach/Braunau, commissioned in 2009 (figure 6).

In Altheim a 106°C fluid is utilized both for district heating and for electricity production using a binary plant. The net output is 500 kW, after accounting for the 350 kW for submersible pump parasitic load.

The Bad Blumau project with 110°C fluid is exploited for heating a Spa facility and a binary plant of 180 kW net output.

At Simbach/Braunau an important district heating project has been realized, with about 40 MW_{th} of geothermal heat and a small binary unit of 200 kW (figure 7).

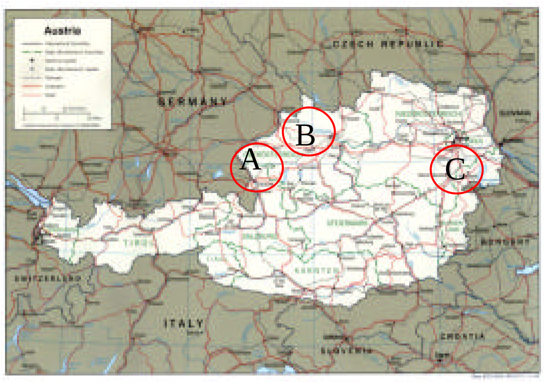

Figure 6: Location of Simbach/Braunau [A], Altheim [B] and Bad Blumau [C].

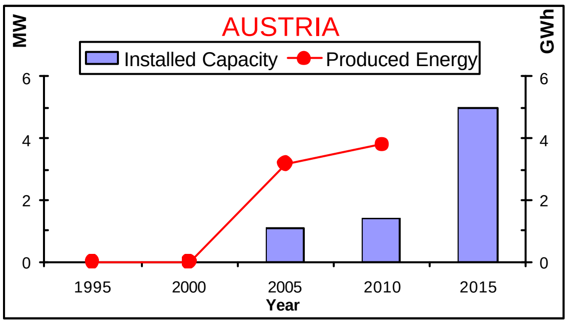

Figure 7: Installed Capacity and Electricity.

The obstacles and barriers to the geothermal development in this country are quite severe and important, and it is expected only a moderate increase up to 6 MW for the year 2015.

2.4 Canada (Thompson, 2010)

The relatively important high temperature geothermal potential of the country is still untapped. For year 2015, we can estimate the realization of the first plant, the South Meager Creek project, owned by Western GeoPower (figure 8), where an hydrothermal reservoir at 220-275°C has been assessed through 8 wells.

Figure 8: Location of South Meager Creek.

2.5 Chile (Lahsen, 2010)

No new power plant has been added to the country geothermal capacity, even if an important geothermal exploration is in process. The high temperature fields are located on the Andes mountains, at very high elevation, in severe climatic and logistic conditions, without an easy access to the national electricity grid. A joint venture of Enel Green Power and the ENAP (national oil company) is going to develop four projects, in different location of the country, for an aggregate capacity of about 150 MW (figure 9). The expected reservoir temperature is above 200°C at depth less t hen 2,000 m.

2.6 China (Zheng et al., 2010)

No new power plant has been added to the country geothermal capacity, which is at present only from the Yangbajain field, in Tibet (figure 10). Its exploitation (operated by Electric Power Tibet) started in 1977, and its installed capacity increased continuously up to 1991, when further investments has been halted, despite of the discovery of the high temperature deep geothermal resources below the shallow one: a 2,500 m deep well was drilled in 2004, reaching the deep reservoir (figure 11). Temperatures in the 250-330°C range have been measured at 1,500-1,800 m depth. Geothermal potential for Yangbajain is estimated at about 50-90 MW.

Figure 9: Location of Apacheta [A], El Zoquete [B], Chillan [C] and Calabozo [D].

Figure 10: Location of Yangbajaing field [24 MW].

2.7 Costa Rica (Protti, 2010)

No new power plant has been added to the country geothermal capacity, which is 165 MW at Miravalles (figure 12), producing 13% of the country electricity. Costa Rica has a very important mix of renewable energy generation, with hydro accounted for 80% of the total electricity, and wind for additional 2%.

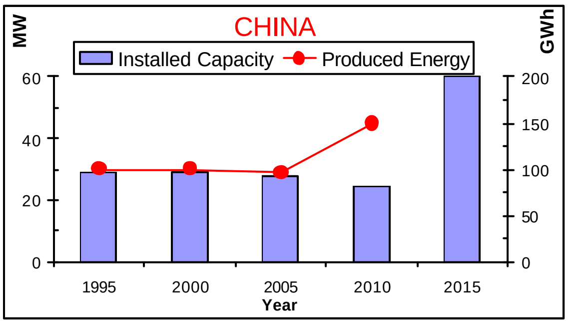

Figure 11: Installed Capacity and Electricity.

The exploitation of Miravalles, from Instituto Costarricense de Electricidad (ICE), with temperature of about 240°C, started in 1994, and it has reached its steady state in 2003 (figure 13). Two new projects are at different stage of planning: 41 MW at Las Pailas (a binary plant from reservoir fluid at 260°C is under advanced construction) and a feasibility plan has been completed and finalized at Borinquen, on the same volcanic system of Rincón de la Vieja. The expected installed capacity of the country will overcome 200 MW in few years.

Figure 12: Location of Rincón de la Vieja [A] and Miravalles field [B, 165 MW].

2.8 El Salvador (Herrera et al., 2010)

There are two major geothermal fields in this country: Ahuachapán and Berlín (figure 14), for a total capacity of about 200 MW, producing 25% of the electricity needs of the country. Both the fields are operated by LaGeo, in partnership with Enel Green Power. The increase from 2005 was of 53 MW (35% in capacity, 47% in energy), for the two new units at Berlin of 44 MW flash and 9 MW binary (figure 15).

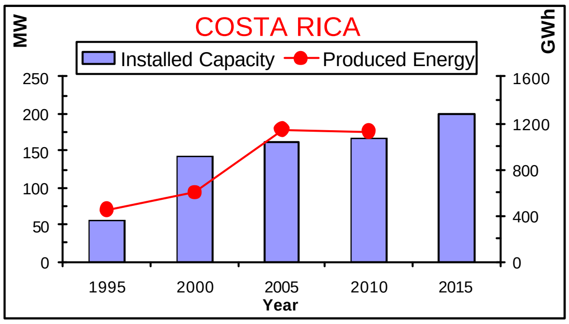

Figure 13: Installed Capacity and Electricity.

Figure 14: Location of Ahuachapán [A, 95 MW], Berlín [B, 109 MW] and Chinameca [C].

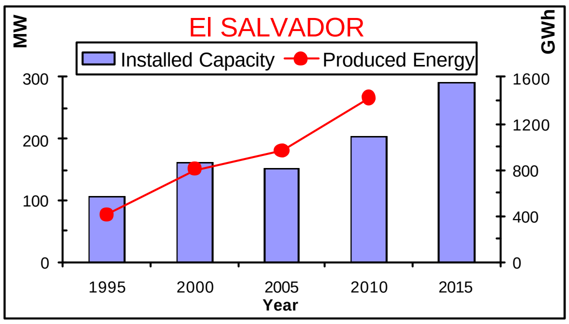

Figure 15: Installed Capacity and Electricity.

In the Ahuachapán area (temperature of 250°C) two 30 MW single flash and one 35 MW double flash are currently online (1975-1981); due to the reservoir decline, only 84 MW net units are currently in operation. A project for reaching the full capacity loading of the units (Ahuachapán optimization) is under study. In 2006 the reinjection reached the target of 100% of the exploited fluid. It is under consideration also the possibility of repowering unit 2, adding 5 MW to the total capacity of the field.

In Berlín (where 300°C have been recorded) two 28 MW single flash units have been installed before 2005 (1992-1999); two major additions have been placed online up to today: a bottoming cycle binary unit for 9.4 MW (on line in 2008) and a single flash 44 MW units (commissioned in 2006), built by Enel Green Power under a shareholder agreement with LaGeo. In 2003 it has been drilled the most productive well of the Latin America, with a production of 20-30 MW from the steam cap at about 1,000 m depth. A new unit for additional 28 MW is planned. In the Chinameca area feasibility studies for a 50 MW units are on going (a single well at 1,900 m reached temperature around 240°C).

The total installed capacity of the country is foreseen about 290 MW.

2.9 Ethiopia (Teklemariam, 2010)

Despite of the very promising potential of the country, located on the African rift geothermal anomaly, in Ethiopia since 1999 no new plant has been realized, and the 7.3 MW unit installed at Aluto-Langano field (Ethiopian Electric Power Corporation), after several operational problem, is currently producing for about 3 MW (figure 16), from a reservoir with 300°C at 2,000 m depth. The second proven field of the country (Tendaho, 250°C at shallow depth) has a feasibility project for about 20 MW. Six additional geothermal prospects have been launched, but the lake of foreign investors is the most important limiting factor for the future development in this country.

Figure 16: Location of Aluto-Langano [A, 7 MW] and Tendaho [B].

2.10 France (Boissier et al., 2010)

Geothermal electricity is not available on the mainland, but only in the Caribbean islands it can reach up to 20% of electricity needs (figure 17).

The high enthalpy utilization for electricity production in France is only in the French Overseas Department, at Bouillante on Guadeloupe island (Geothermie Bouillante). Its exploitation started in 1984, and a second unit in 2004 has been commissioned. The reservoir temperature is 250°C at shallow depth. The total capacity of 15 MW, not increased since 2005, produces 95 GWh, corresponding to 8% of the local consumption. The activity for the third unit of 20 MW is ongoing. The final target will reach 20% of geothermal contribution to the electricity needs (figure 18). On the islands of La Martinique and La Réunion, geothermal exploration programs are planned in the near future.

The EGS project at Soultz-sous-Forêts is now operating a scientific pilot plant module of 1.5 MW. The enhanced geothermal system, exploited with a three-well system in the granite formation at depth of 5,000 m, is expected to stabilize its operation in the coming year. In December 2008, the output ranged around 12 MW_{th} for a cumulative flow-rate ranging around 28 l/s. The first kWh has been produced in June 2008.

Figure 17: Location of Bouillante [15 MW].

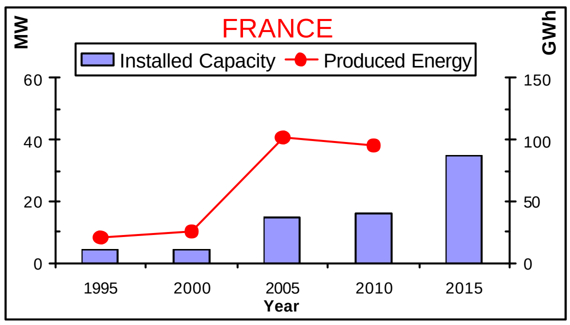

Figure 18: Installed Capacity and Electricity.

2.11 Germany (Schellschmidt et al., 2010)

Germany is not blessed by high-enthalpy reservoirs. Its electricity production, strongly supported by local administration and central government, is limited to binary plant applications, with massive utilization of the hot water for district heating (figure 19). The first geothermal plant for electrical power generation in Germany is at Neustadt-Glewe, with an installed capacity of about 230 kW with a binary cycle using 98°C geothermal fluid. In addition 10.7 MW_{th} are used for district and space heating.

Two new plants in Landau and Unterhaching started in 2008, each with a capacity of about 3 MW, and an heating capacity of about 3.5 and 38 MW_{th} respectively. Additional projects for further installation of 10 MW are planned in several sites (figure 20).

For a minimum of at least three projects (Hagenbach/Upper Rhine Graben and two in the Munich region) drilling works are already scheduled. Construction has also started on the biomass/geothermal energy hybrid plant at Neuried (Upper Rhine Graben). Research activities at the EGS R&D site at Groß Schöneck are ongoing.

Figure 19: Location of Neustadt-Glewe [A], Landau [B, 3 MW] and Unterhaching [C, 3 MW].

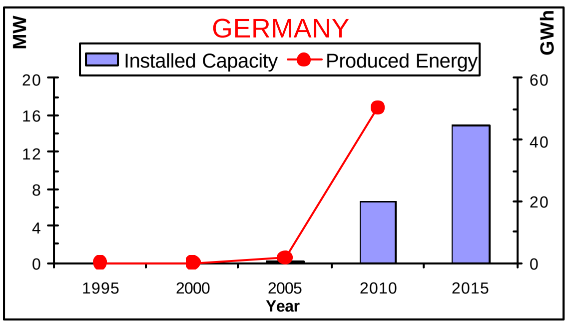

Figure 20: Installed Capacity and Electricity.

2.12 Greece (Andritsos et al., 2010)

Geothermal energy in Greece, despite of its relative high potential in the volcanic arc islands, does not have encountered a favorable support from government and local population. The small 2 MW unit at Milos, installed in 1987, has been decommissioned and dismantled (figure 21).

Several other projects are under evaluation (Nisiros, Tracia), both from PPC/Renewables and foreign investors, but the authorization process is still slowing the development. The most advanced is the 8 MW binary plant project in Lesvos, where few wells have already been drilling, identifying a shallow promising resource.

2.13 Guatemala (Asturias and Grajeda , 2010)

In this country the geothermal resource is present in two fields, Zunil and Amatitán (figure 22). The decline of production since year 2000, due to low permeability and poor hydro geological connection between reinjection and production (from 200 GWh down to 142 GWh in 2006), has been partly recovered and a new 24 MW binary unit has been installed in Amatitlán (figure 23). The increment on 2005 in percentage was significant (about 58%).

The two fields are operated by Instituto Nacional de Electrification (INE) and Ormat.

Figure 21: Location of Milos [A], Nisiros [B], Lesvos [C] and Tracia [D].

Figure 22: Location of Zunil [A, 28 MW], Amatitlán [B, 24 MW], Tecuamburro [C] and Moyuta [D].

Zunil, located to the west of Guatemala City, is divided in two areas; the first is the most developed until now, with temperatures up to 300°C , and an estimated capacity of 50 MW whereas the second one, with 240°C has an estimated capacity of 50 MW; there are 28 MW installed, but only 16 MW running, due to reservoir decline. Drilling and testing new wells is in progress.

Amatitlán geothermal area is located about 25 km to the south of Guatemala City in the active volcanic chain. This field, with 285°C of temperature, has an estimation of a total capacity of 200 MW. After the decommissioning old 5 MW backpressure unit (to be moved to Zunil), a new 24 MW binary plant at Amatitlán has been commissioned in 2007, and a second one is under construction.

An exploration of the Tecuamburro field, aimed to a 40 MW project, is currently under preliminary stage of permitting. Also in Moyuta area there is a development project. The two sites are under exploration by Enel Green Power.

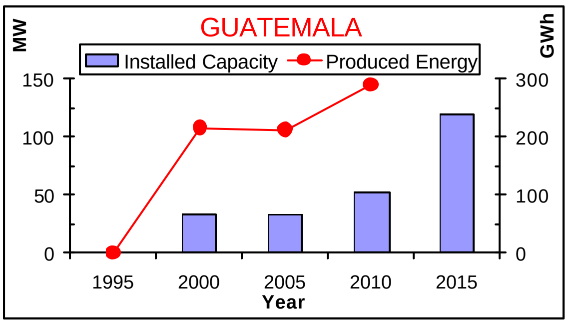

Figure 23: Installed Capacity and Electricity.

2.14 Honduras (Lagos and Gomez, 2010)

In this country the geothermal resource is present in few regions, but only in the Platanares area the project is in a relatively advanced stage of development, with indications for 200-220°C at 1,200-1,500 m. A 35 MW plant is planned (figure 24).

Figure 24: Location of Platanares.

2.15 Hungary (Toth, 2010)

In this country the geothermal resource is relatively abundant, even if it is bounded to the low/medium temperature system; the national oil company (MOL) drilled several wells, and some of them could be used for geothermal energy generation. A pilot project of 5 MW is planned at Ortaháza. (figure 25).

Figure 25: Location of Ortaháza.

2.16 Iceland (Ragnarsson, 2010)

The geothermal electricity production in Iceland has increased significantly since 2005 (about 370 MW, 184%, the highest value among the countries with a relevant geothermal electricity production), with the installation of new plants in Nesjavellir (30 MW), Hellisheidi (the entire field started its production after 2005: 5 units for 213 MW), Svartsengi (30 MW) and Reykjanes (2x50 MW).

The most important fields of the island are listed below (figure 26).

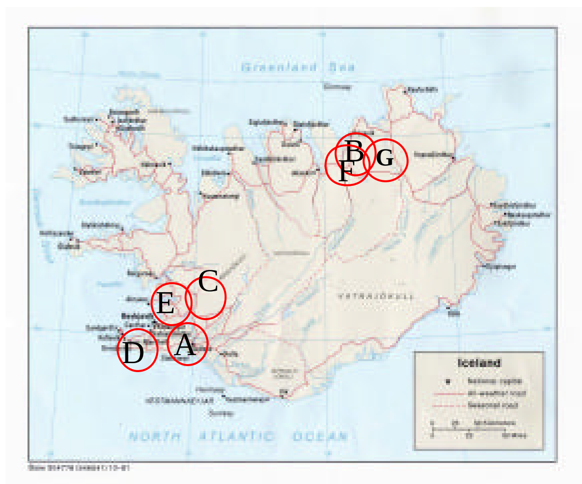

Figure 26: Location of Hellisheidi [A, 213 MW], Krafla [B, 60 MW], Nesjavellir [C, 120 MW], Reykjanes [D, 100 MW], Svartsengi [E, 76 MW], Bjarnaflag [F, 3 MW] and Husavik [G, 2 MW].

Krafla: in the northern part of the island, its operation started in 1977 from Landsvirkjun, with several initial problem in producing enough steam for feeding the plants, due to the volcanic activity in the area. Now, after 20 years, some degassing of the productive reservoir has been achieved, and two 30 MW double flash turbine are in operation with additional 40 MW planned.

Bjarnaflag (Námafjall): the oldest geothermal field in Iceland is still in operation since 1969 (Landsvirkjun), with an old 3 MW back-pressure unit.

In Husavik an experimental Kalina binary unit (using 120°C hot water, operated by Orkuveita Husavikur) of 2 MW has been installed in 2000, but only in 2008 it started a commercial operation.

Hellisheidi: on the active volcanic system of Hengill; it has 210 MW and 400 MW_{th} of thermal output for district heating of the Reykjavik area (27 km away); the electricity is supplied mainly to local aluminum refineries. All the plants of the field have been commissioned after 2005 by Orkuveita Reykjavikur: 2x45 MW in 2006 (Unit I), 35 MW in 2007 (Unit II) and again 2x45 MW in 2008 (Unit III).

Nesjavellir (Orkuveita Reykjavikur): in the southern part of the country, four 30 MW units (total 120 MW), combining heat/electricity production with 300 MW_{th} for district heating (about 1,800 l/s of hot water). The most recent unit has been commissioned in 2005.

Reykjanes: in south-western peninsula, operated by Hitaveita Sudurnesja, it has been commissioned in 2005 and 2006, with two 50 MW units, and additional 50 MW under construction.

Svartsengi: near the International Airport and the famous outdoor swimming/spa facilities of Blue Lagoon (visited yearly by about 400,000 people, probably the most popular Icelandic touristy attraction), feed by the discarded water (rich in surplus mineral) of two flash units (reservoir fluid at 240°C) for about 66 MW and a 8 MW binary unit (Hitaveita Sudurnesja); there is also an important additional hot water production of 150 MW_{th} for district heating. Also here the most recent addition was a 30 MW unit in 2005.

Other Projects

The Icelandic Deep Drilling Project (IDDP) has been finally placed nearby Krafla geothermal area, in the Northern part of the country. The aim of the project is the exploitation of supercritical fluid at 4-5 km depth and 400-600°C of temperature. Unfortunately, in 2009, the well reached a magma body and the project has been placed in stand-by.

An agreement has been signed between the Century Aluminum Co and two major Icelandic geothermal producers (Hitaveita Sudurnesja and Orkuveita Reykjavikur) for supplying electricity to the production of an initial amount of 150,000 tons of aluminum per year, utilizing 250 MW of geothermal electricity. The initial stage of the project will be commissioned in 2010. The agreement is expandable up to 435 MW, for a production of 250,000 tons of aluminum. This will be a very efficient way of exporting the surplus of cheap and abundant geothermal electricity production from Iceland.

The total installed capacity of the country is 575 MW, and additional 230 MW under construction (figure 27). The country with 300,000 inhabitants is 100% renewably powered, with 25% of its electricity and 90% of heating needs provided by geothermal energy (figure 28).

Geothermal energy contribution to the total energy consumption sums up to 62%, probably the highest in the world.

Space Heating

The main use of geothermal power is for space heating which amounted to about 25 PJ per year; an extensive district-heating systems has been realized into the country. The share of geothermal heat in space heating is almost 90%, whereas the remainder is mainly heated with electricity (which results 100% renewable), so that fossil fuels account for only a small fraction of the total.

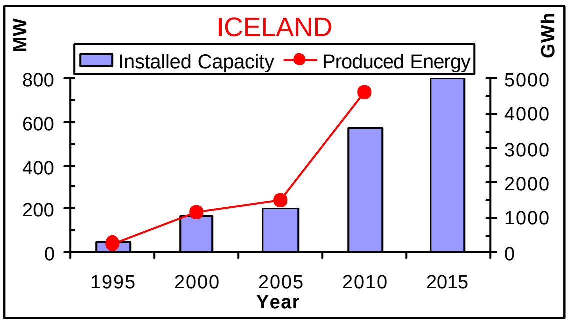

Figure 27: Installed Capacity and Electricity.

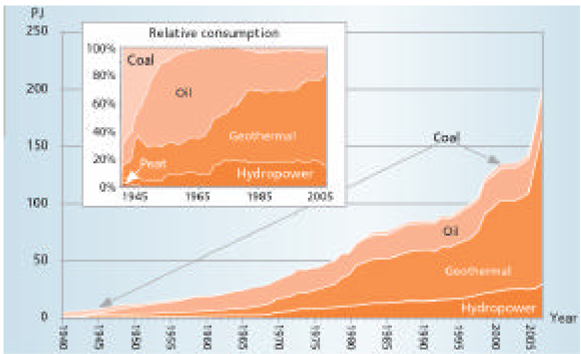

Figure 28: Primary Energy Consumption in Iceland (from Orkustofnun Energy Statistics 2008).

As an example, the Reykjavik district heating system, serving 200,000 inhabitant of the capital, with a thermal capacity of 1.2 GW_{th} and about 80 million m^3 of hot water provided yearly, can be considered as one of the most important in the world, 100% heated from geothermal energy.

As final remark, the growing on geothermal electricity is presently in a clear impressive exponential phase, as seen in figure 29.

2.17 Indonesia (Darma et al., 2010)

After the economic crisis of the recent past, this country is starting a very important geothermal activity with important power plant construction and exploration, strongly supported by Government, through regulation and policies. There are good perspectives and positive signal from the market, still to be confirmed over the next months (figure 30).

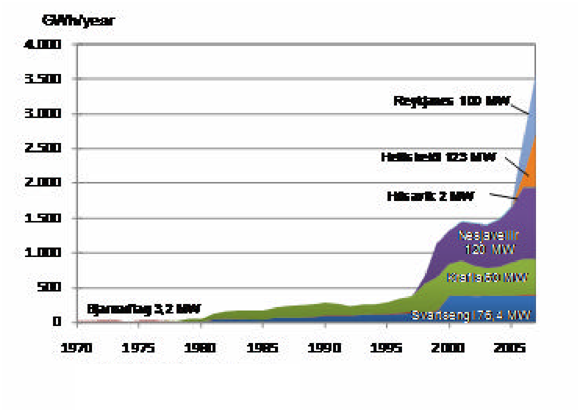

Figure 29: Growing of geothermal electricity production in Iceland (from Ragnarsson, 2010).

The new plant commissioned since 2005 are 110 MW in Darajat, 117 MW at Wayang Windu, 2x20 MW at Lahendong, 60 MW at Kamojang, and 10 MW at Sibayak, reaching the total installed capacity of about 1.2 GW (including also the upgrading of the six units of Salak, 60 MW and two in Darajat, 15 MW), confirming Indonesia at third position in the world ranking. The geothermal fields of the country are shown in figure 31.

Sulawesi

Lahendong: three 20 MW units have been installed (the first in 2002, the other two in 2008 and 2009 respectively) and further 20 MW under construction, following a development plan of additional 60 MW; after the past negative experience in binary plant in Indonesia (only an old 2.5 MW experimental unit, which has never been operated), the first new generation 7.5 MW binary bottom unit is planned in this field for year 2012. The field is operated by Pertamina Geothermal Energy and the national electrical utility PLN.

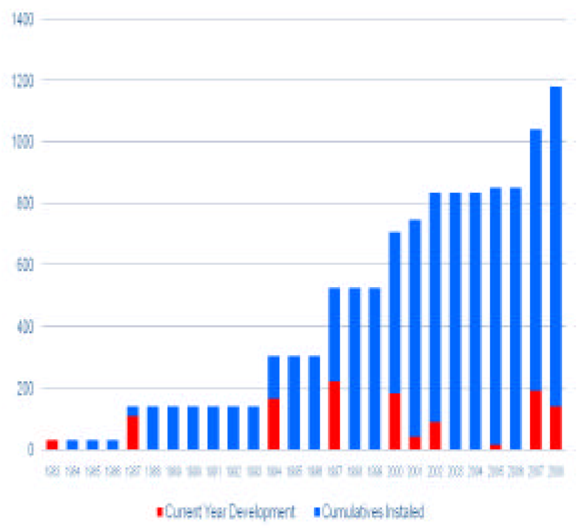

Figure 30: Geothermal capacity growing in Indonesia (from Darma et al., 2010). The steady-state situation since year 2000 is the evidence of the economical crisis of the country.

Sumatra

Sibayak: the exploitation started in 1996, with a small 2 MW unit. Two new units, for 13.3 MW in total has been commissioned in 2007; further 10 MW are planned, if the expansion of the production area will be confirmed after the surface exploration activities (Pertamina Geothermal Energy).

Java

Kamojang: a new addition of 60 MW has been commissioned in 2007, increasing to 200 MW dry steam plants. It was the first exploited geothermal field in Indonesia, where in 1978 a small 250 kW unit has been commissioned. The three units performed quite well during their entire operative life (since 1982 and 1987). Moreover, there are additional 60 MW currently under construction (Pertamina Geothermal Energy and PLN).

Dieng: one 60 MW unit has been installed in 1998, first step of a four-plant project. After the economic crisis and as a result of the arbitration, the ownership of the field has been transferred to Geodipa and the plant started its operative life. Two more 55 MW plants have been planned.

Wayang Windu: in 2009 a new 117 MW has been added to the old 110 MW, in operation since 2000. The field is operated by Star Energy, an Indonesian oil company. Drilling activity and resource evaluation are on going, for almost double the production from the field.

Gunung Salak: no new plant since 1997; the six 65 MW similar units are currently operated 20% above the reference installed capacity (55 MW), due to the power shortage in Java/Bali, for a total of 375 MW. The BOT scheme will end its effect in 2012, and the three units currently operated by Chevron will be transferred to PLN.

Darajat: the geothermal resource is vapor dominated, in exploitation since 1994, and a new unit of 110 MW has been commissioned in 2008; further development for additional 110 MW are on going. The field and power plant are operated by Chevron since 2006, and the two old units have been upgraded of 15 MW in total.

Bali

In the Bedugul field the Bali Energy Ltd. confirmed the development plan for 175 MW, with a first 10 MW pilot plant and three 55 MW units, for the exploitation of the liquid reservoir at 280-320°C and 1,500-2,000 m depth.

New Areas

On Sarulla, in North Sumatra, the development of three 110 MW projects has been recently assigned to an international consortium, including Medco Power, Itochui, Ormat, Kyushu Electric and Pertamina as field operator. The expected ambitious schedule is to reach 330 MW in 2013.

In Central Sumatra, Hulu Lais field have been explored and a development plan has been launched.

In Ulu Belu, South Sumatra, the good liquid reservoir at 240-260°C is under advanced exploration stage, and four 55 MW unit will be commissioned in the coming years. The same development is scheduled for the similar area of Lumut Balai and Sungai Penuh, where the first units are expected for 2012.

In Pathua, Java, the original exploration done before the crisis identified a good resources, which has been transferred, after the arbitration, to Geodipa. Three 60 MW units are planned. In the nearby zone of Karaha Bodas, 140 MW are scheduled, with the first 30 MW in 2012.

Finally, in Sulawesi two new projects in Kotamobagu and Tompasu identified a 250-290°C reservoir; 120 MW in total are planned.

Figure 31: Location of Lahendong [A, 60 MW], Sibayak [B, 13 MW], Gunung Salak [C, 377 MW], Kamojang [D, 200 MW], Wayang Windu [E, 227 MW], Darajat [F, 260 MW] and Dieng [G, 60 MW].

In total, an impressive amount of project for reaching the expected target of 3.5 GW in 2015 is on going, strongly supported by government, foreign and domestic investors. It is a very challenging opportunity: to become the first geothermal country in the world, tripling the present capacity in only five years. At the next WGC it will be very important to verify the effective results obtained in this very promising geothermal country. However, as it is quite evident from figure 32, this tremendous increase in installed capacity in only five years is unlikely. A more solid value in the range of 2-2.4 GW can be considered as an affordable and realistic goal. In the last five years term, the installed capacity increased of 400 MW, corresponding to about 50%.

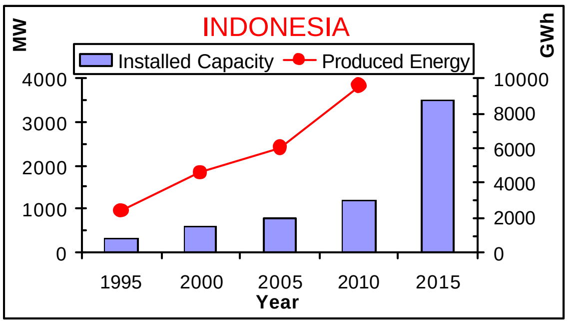

Figure 32: Installed Capacity and Electricity.

2.18 Italy (Cappetti et al., 2010)

There are two major geothermal areas in Italy: Larderello-Travale/Radicondoli and Mount Amiata. In the year 2008, with the installed capacity of 810.5 MW (711 MW efficient capacity) the gross electricity generation reached 5.5 TWh and in 2009 two additional units were commissioned, increasing the capacity up to 843 MW (figure 33). All the Italian fields are operated by Enel Green Power. The geothermal production is only 1.8% of total national electricity, but it is a relevant regional quota of 25% for the entire Tuscany.

Larderello and Travale/Radicondoli are two nearby parts of the same deep field, covering a huge area of approximately 400 km^2, producing super-heated steam at pressure of 2 MPa and temperature in the range 150-270°C. In the Larderello side the exploited area is 250 km^2, with 22 units for 594 MW installed capacity; in the Southeast side of Travale/Radicondoli, covering a surface of 50 km^2, there are 160 MW (6 units) of installed capacity. The condensed water from Travale is reinjected into the core of the Larderello field through a 20 km long water pipeline. Four additional units were thus installed in the period 2005-2009 with a total capacity of 100 MW, of which 52 MW represent a net capacity increase, while 48 MW replaced old units, decommissioned because obsolete: Nuova Lagoni Rossi (20 MW), Nuova Larderello (20 MW), Nuova San Martino (40 MW) and Sasso 2 (20 MW)

The very long exploitation of Larderello and Travale/Radicondoli fields is an excellent example of a sustainable production a from geothermal system (figure 34). After the stabilization of production in the period 1970-1980, the exploitation of the deep reservoirs (with pressure of 6-7 MPa and temperature of 300-350°C, at depth of 3,000-4,000 m) and the massive positive effect of the reinjection into the field have given an impressive contribution to the increasing of the steam extraction. The much more evident increase in electricity production is a consequence of the introduction of the new generation power plant after year 2000, with an overall better efficiency.

Figure 33: Location of Larderello [A, 594 MW], Travale/Radicondoli [B, 160 MW], Bagnore [C, 20 MW] and Piancastagnaio [D, 68 MW].

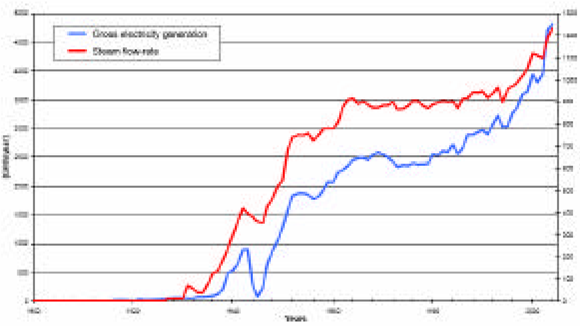

Figure 34: Trend of net electricity generation and steam flow rate from Larderello (from Cappetti, 2009).

Mount Amiata area includes two water dominated geothermal fields: Piancastagnaio and Bagnore. Their exploitation started in 1960. In both the fields a deep water dominated resource has been discovered under the shallow one, with pressure of 20 MPa and temperature around 300°C. 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.

New Projects

Projects for further 112 MW are approved and will be realized in the coming years (figure 35): four new plants in Larderello/Travale, one in Bagnore and investement in the field development in Piancastagnaio, with a net increase of 80 MW, considering the decommissioning.

Enel Green Power

In response to the growing demand for renewable energy, recorded in recent years as a result of commitments signed by many governments aimed at reducing CO_2 emissions, a new company, Enel Green Power, fully owned by Enel Group, was established in December 2008.

At present, Enel Green Power operates in sixteen countries and it is one of the world leaders in renewable energy sector, with about 20 TWh produced (covering the energy consumption of 8 million families and avoiding 16 million tons of CO_2 emissions every year). The installed renewable capacity is around 4.5 GW and there are over 500 plants currently in operation or under construction around the world.

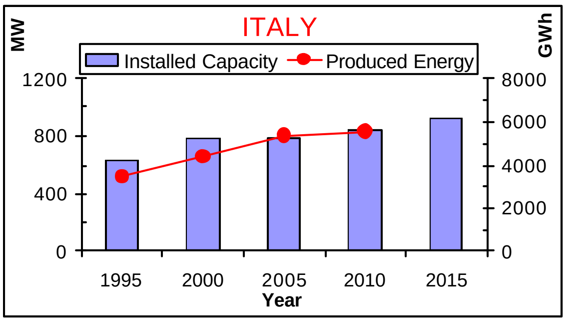

Figure 35: Installed Capacity and Electricity.

For the "zero-emission in geothermal program", an important investment plan has been launched, in order to mitigate the H_2S and Hg effluent to the environment with a specific treatment, using a technology fully designed and developed by Enel: AMIS plant (Baldacci et al., 2005), reaching a very high efficiency in H_2S and Hg removal, lower capital and O&M costs in comparison with commercial process, no solid sulphur by-products (liquid streams reinjected in the reservoir) and unattended operation (remote control). Approximately 80% of the effluents are currently treated by AMIS systems (figure 36).

2.19 Japan (Sugino and Akeno, 2010)

Japan is one of the most tectonically active countries in the world, with nearly 200 volcanoes and the evidence of tremendous geothermal energy resources. Its geothermal development started in 1925, with an experimental unit, and the first commercial plant on Matsukawa started in 1966 (figure 37).

About twenty geothermal power plants are in operation at 17 locations nationwide, scattered all along the country. Most are located in the Tohoku and Kyushu districts. In these years, there have not been significant developments of geothermal power plants in Japan, with the exception of two small binary units, in Hatchobaru and Kirishima Kokusai Hotel.

Figure 36: AMIS plant (from Baldacci et al., 2005).

Total geothermal power capacity in Japan has changed little since 1995. No new plants are planned in the coming years (figure 38).

The historical trend is shown in figure 39. It is very clear the effect on the production of the reduction in the investment in power plant and field maintenance.

Geothermal energy need a continuous effort for ensuring sustainable cultivation of the resource!

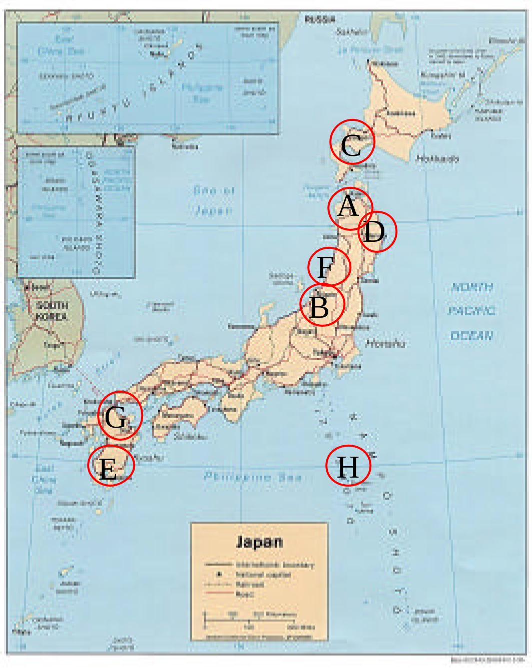

Figure 37: Location of Akita [A, 89 MW], Fukushima [B, 65 MW], Hokkaido [C, 50 MW], Iwate [D, 103 MW], Kagoshima [E, 60 MW], Miyagi [F, 12 MW], Oita [G, 153 MW], and Hachijyojima [H, 3 MW].

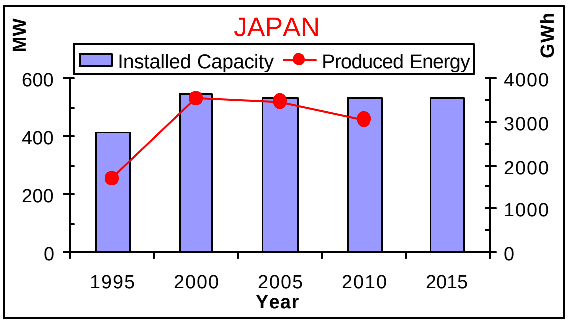

Figure 38: Installed Capacity and Electricity.

2.20 Kenya (Simiyu, 2010)

An important addition since 2005 was the 36 MW at Olkaria III, from Ormat, finally reaching the initial planned target of 48 MW; moreover, projects for additional units at Olkaria I, II and IV have been approved and it is expected to be completed within two years (figure 40). The installed capacity increased of 29%, a very good result for counties with a significant amount of operating plant.

The geothermal production at Olkaria started in 1981, with the first 15 MW unit, and it has been under a continuous and increased exploitation till now, with the two plants of Olkaria I and II, operated by KenGen (figure 41).

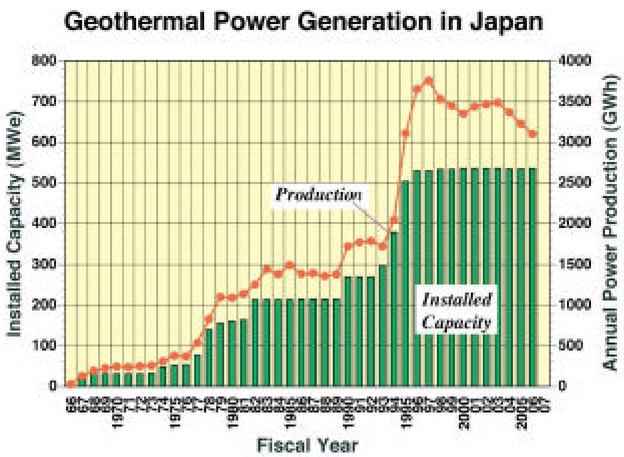

Figure 39: Historical trend of capacity and energy (from Uchida, 2008).

It should be highlighted also the minor utilization of two small 2 MW plants at Oserian Development Company Greenhouses.

Oserian began as a 5 hectares vegetable-growing farm in 1969. Today it has grown to be a 210 hectares farm specializing in floriculture with an annual output of 400 million stems to Europe, covering 30% of the cut-flowers European market. It has to make sure that the thousands of flowers growing in its massive greenhouses have a constantly mild temperature. The wells Oserian uses are not suitable for the mass power production KenGen needs, but are perfect for supplying the warmth and CO_2 needed for growing roses (Geothermal Rose Project).

The greenhouse heating system is powered by 2 MW Ormat binary-cycle power plants commissioned in 2004 and an additional Elliot 2 MW steam turbine in 2007, making the company self-sufficient in electricity need for heating and controlling the humidity in the greenhouses, which in turn protects the flowers from fungal diseases and so reduces the amount of fungicides used.

Figure 40: Location of Olkaria [167 MW].

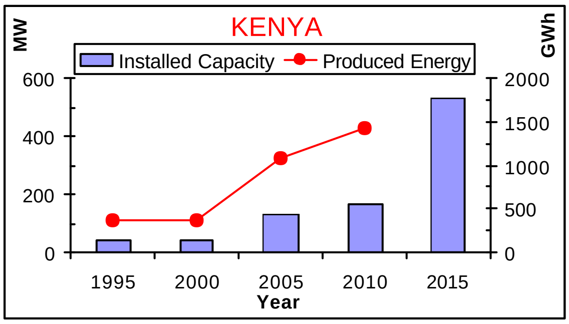

Figure 41: Installed Capacity and Electricity.

The only other field outside of Olkaria is the adjacent region of Eburru, where a small binary pilot plant is planned.

2.21 México (Gutiérrez-Negrín et al., 2010)

The installed geothermal capacity in México is 958 MW from 37 units, currently operating into four geothermal fields (figure 42): Cerro Prieto (720 MW), Los Azufres (188 MW), Los Humeros (40 MW) and Las Tres Vírgenes (10 MW). No new important addition has been realized since 2005, except one 5 MW unit at Los Humeros. However, the projects Cerro Prieto V (100 MW) and Los Humeros 910 (50 MW) have been approved and it is expected that both will be completed by 2011 (figure 43). All the fields are operated by Comisión Federal de Electricidad (CFE).

The project Cerritos Colorados (75 MW), formerly known as La Primavera, has been programmed for 2014.

With the planned decommissioning of some old units, the net increase for 2015 of the country will be about 160 MW.

Figure 42: Location of Cerro Prieto [A, 720 MW], Los Azufers [B, 188 MW], Los Humeros [C, 40 MW], Las Tres Vírgenes [D, 10 MW] and Cerritos Colorados [E].

Cerro Prieto is the oldest and largest Méxican geothermal field in operation. It is located in the northern part of Mexico, and its first power units were commissioned in 1973. There are currently 13 operating units of condensing type: four 110 MW double-flash, four single-flash of 37.5 MW each, four single-flash of 25 MW each and one 30 MW single-flash, low pressure, amounting 720 MW.

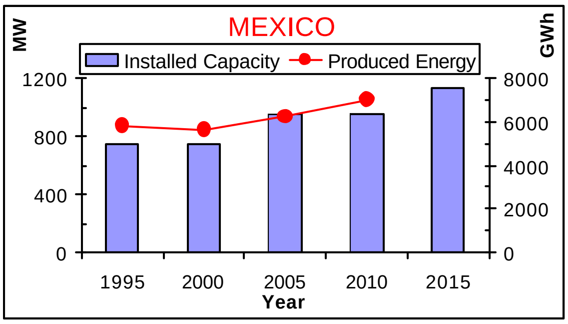

Figure 43: Installed Capacity and Electricity.

Los Azufres is the second geothermal field operating in México. It is located in the central part of the country, 250 km away from México City. The first power units were commissioned in 1982, and presently there are 14 power units in operation: one condensing of 50 MW, four condensing of 25 MW each, seven 5 MW back-pressure and two 1.5 MW binary cycle. The total installed capacity is 188 MW.

The geothermal field of Los Humeros is also of volcanic type. It is located in the eastern-central part of México, at the eastern end of the Méxican Volcanic Belt. Its power units number 1 and 2 started to commercially operate in 1990, and currently there are eight back-pressure units of 5 MW each with a total operating capacity of 40 MW. The more recent unit (Unit 8) was commissioned in April 2008.

Las Tres Vírgenes is the most recent field in operation in México. It is located in the middle of the Baja California peninsula, at the north of the state of Baja California. There are only two condensing 5 MW power units in operation that were commissioned in 2002.

The electricity production from geothermal resources is quite stabilized and it plays a very important role in the energy market of the country, despite of its minimal value of 3% on the national basis. The long term yearly production is shown in figure 44.

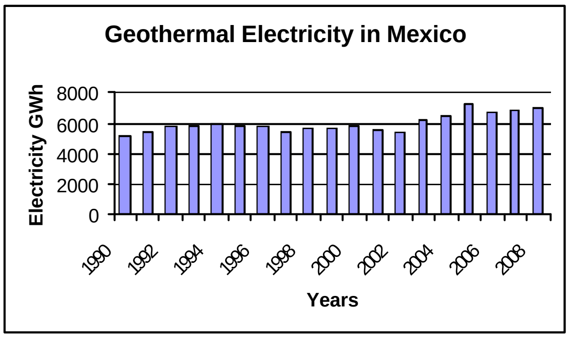

Figure 44: Geothermal Electricity production since 1990 (from UN statistic division web site).

2.22 Nevis (Huttrer, 2010)

In 2008, West Indies Power drilled three slim holes at 1,000 m depth, finding temperatures of 225ºC. A 35 MW project has been launched. The excess of production could be exported to St. Kitts via sub-sea cable crossing the narrow strait that separates the two islands.

2.23 New Zealand (Harvey et al., 2010)

All the geothermal projects in this country are in the central North Island or the Northland region (Ngawha), as in figure 45. Since 2005 the following new plants have been realized: a binary unit of 14 MW at Wairakei, a second stage at Mokai (19 MW flash and 17 MW+4x5 MW of binary units), an important realization of 100 MW plus an 8 MW binary unit at Kawerau, and finally 15 MW binary at Ngawa.

The total geothermal capacity overcome 600 MW, with a contribution of 10% of the total country electricity generation. Several additional projects are on going, with very ambitious target for year 2015, reaching 15% of geothermal electricity. Presently, there are 122 MW at Kawerau, 111 MW at Mokai, 25 MW at Northland (Ngawha), 103 MW at Reporoa (Ohaaki), and 232 MW at Wairakei (figure 46).

Wairakei celebrated the fifty years of operation, since the commissioning of its first turbo-generator in 1958. It is operated by Contact Energy. Many modifications have been made over the years, the latest being the installation of a 14 MW net binary cycle in 2005. Development project for a new unit is on going. It is planned a future replacement of several old units with a new power block, called Te Mihi, with a net increase of 65 MW due to the increase of efficiency.

In Reporoa, the Ohaaki plant was originally developed to 114 MW, and after the decommissioning of one unit it has been reassessed to 103 MW; however, its production was dramatically low, down to 25 MW; since 2006 the operator (Contact energy) invested in new wells, reaching 65 MW of production, maintaining it through alternative production and injection strategies to minimize concerns over subsidence affecting Waikato River.

Figure 45: Location of Wairakei [A, 232 MW], Reporoa [B, 103 MW], Mokai [C, 111 MW], Kawerau [D, 122 MW], Rotokawa [E, 35 MW], and Ngawha [F, 25 MW].

Mokai had progressive development since 1999 up to 112 MW using binary cycle technology, operated by the largest independent private generator of electricity nationally, Tuaropaki Power Company. A further 39 MW in 2005 and re-engineering of the first stage with another 17 MW in 2007 have been realized.

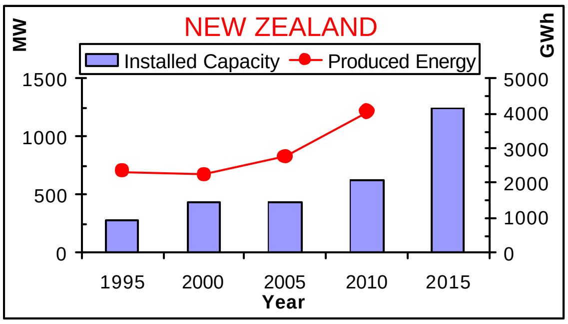

Figure 46: Installed Capacity and Electricity.

Kawerau field started electricity production with a small generator in 1966, replaced by in 2005. The single largest step in New Zealand's geothermal generation have been done by Mighty River Power, with the development of a 100 MW double flash power station, commissioned by the end of August 2008. The field is operated by Ngati Tuwharetoa Geothermal Assets. Moreover, a 8 MW binary unit (KA24) has been added to the overall field capacity.

Rotokawa field is large, hot and permeable and has significant potential for large scale development (Ngati Tuwharetoa Geothermal Assets and Mighty River Power). The first development for electricity generation took place in 1997 with the commissioning of a 29 MW binary cycle plant, later expanded to 35 MW. Construction work is well advanced for a new Nga Awa Purua triple flash, single Fuji unit development of 132 MW, expected to be commissioned in May 2010: it will be the largest development in New Zealand after the initial exploitation of Wairakei 50 years ago, and the largest single geothermal turbine in the world.

Top Energy in association with local Maori Trusts, started in 1998 with a 10 MW Ormat binary plant installed in Ngawa, Northland field. In October 2008 a 15 MW binary extension was commissioned; the field capacity is estimated larger than the currently installed, but it is not clear when further development will be realized.

The growing of the geothermal electricity in New Zealand, starting since 1950, after an initial increase had a long stabilization in production; an impressive new construction phase started in '90 and after 2005, with very good short term perspectives, and the ambitious target of doubling the present capacity in year 2015.

The 2005-2010 period had about 200 MW of new plant installed, with the very good increase of 44% (figure 47).

2.24 Nicaragua (Ruiz Cordero, 2010)

Despite of the impressive geothermal potential of the country, only a minor addition has been realized since 2005, not in the traditional exploited field of Momotombo, (three units since 1983, with an installed capacity of 77 MW, but a current generation of only 28 MW, operated by Ormat), but in San Jacinto-Tizate area, from Polaris, where 10 MW has been placed on line in 2007, with 2x5 MW back pressure units (figure 48). A project for an expansion to 34 MW and subsequently 72 MW at is on-going.

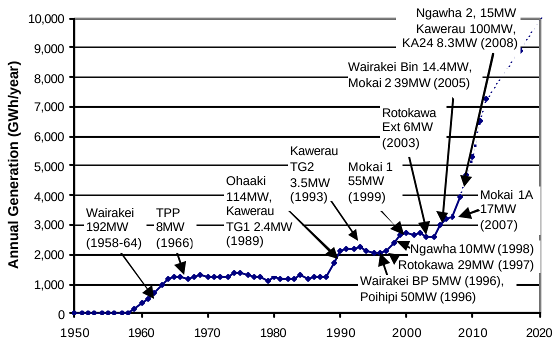

Figure 47: Geothermal Electricity production since 1950 (from Harvey et al., 2010).

An exploration program at El Hoyo-Monte Galan and Managua-Chiltepe, for two 44 MW projects each has been launched jointly by Enel and LaGeo; the deep exploration is expected to be completed by year 2009 (figure 49). In the first field a shallow well showed high temperature (220°C), even if with low permeability. In the second area, a first slim hole was unsatisfactory, with very low temperature (80°C).

2.25 Papua - New Guinea (Melaku and Mendive, 2010)

Geothermal power development is focused at a major gold mine on the tiny Lihir Island, located about 900 km northeast of the national capital. Its exploitation arises from an unusual combination of the geothermal resource, the gold mining environment and the isolated location remote from the power grid.

The geothermal resource of 240-250°C at depth of about 1,000 m has been utilized, with very good well productivity: some of them has about 10 MW output (figure 50).

Figure 48: Location of Momotombo [A, 77 MW], San Jacinto [B, 10 MW], El Hoyo [C], and Chiltepe [D].

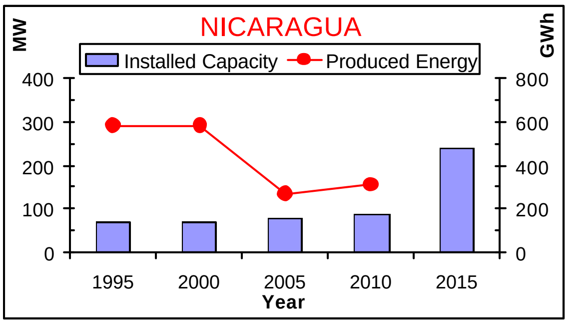

Figure 49: Installed Capacity and Electricity.

Figure 50: Location of Lihir Island [56 MW].

After an initial 6 MW plant was constructed in 2003, a new 50 MW power station has been constructed and commissioned in stages over the last two years (one 30 MW in 2005 and two 10 MW modules in 2007). This lifts total capacity to 56 MW, covering 75% of the current capacity needs of the island, with a significant saving estimated at approximately 40 million USD, replacing heavy fuel oil for power generation. It will also generate revenues of 4.5 million USD per year from the sale of carbon credits on global market.

This geothermal power plant was the first project in Papua New Guinea to be registered for carbon credit trading under the Clean Development Mechanism of the Kyoto Protocol. The plant reduces greenhouse gas emissions by approximately 280,000 tonnes per annum, which equates to approximately four percent of Papua New Guinea's total CO_2 emissions (figure 51). New areas are under advanced exploration stage. With its 50 MW of increment from 2005 value, corresponding to an impressive 833% of percentage, the Papua-New Guinea reached an impressive the record in the relative increase of geothermal installed capacity with significant size of power plants.

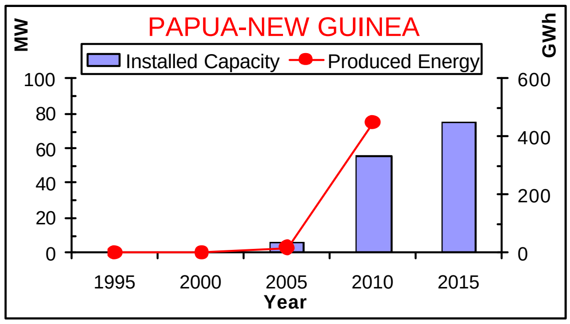

Figure 51: Installed Capacity and Electricity.

2.26 Philippines (Ogena et al., 2010)

The Philippines is the world's second largest producer of geothermal energy for power generation, with an installed capacity of 1.9 GW for a running capacity of about 1.8 GW (figure 52), accounting for 12% of the nation's total electric power supply. The relatively high availability of the geothermal plants resulted in the delivery of about 10 TWh of generation, 17% of the nation's electricity production. There was a minor increase since 2005 (figure 53), with the 49 MW at Northern Negros plant (it will operate with electricity supply contracts between Energy Development Corporation - EDC and electricity cooperatives and distributors) commissioned in 2007, and an upgrading and rehabilitation of Mak-Ban, for 25 MW, with an increase of 2%.

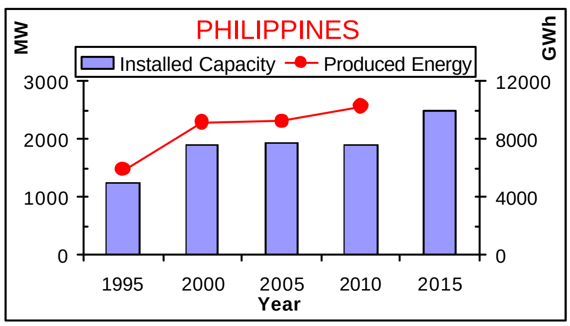

Figure 52: Installed Capacity and Electricity.

The decrease of installed capacity is mainly due to the decommissioning of 110 MW units in Tiwi.

The most important event in the period was the expiration of several BOT contract, with the transfer of ownership of the plants to EDC (from Cal Energy, Ormat and Marubeni in Leyte and Mindanao).

As an additional important change, the state PNOC/EDC has been privatized and now as EDC is operating steamfields and power plant in the country. The geothermal business is 100% private, owned by a company (Red Vulcan) of the local FirstGen group. The Government plans to double the current installed capacity from renewable energy in the next decade and the geothermal sector will undoubtedly benefit. The geothermal area are listed below.

Figure 53: Location of Bac-Man [A, 152 MW], Mak-Ban [B, 458 MW], Mindanao [C, 103 MW], North Negros [D, 49 MW], Palinpinon [E, 192 MW], Tiwi [F, 234 MW] and Tongonan [G, 716 MW].

Bac-Man (Bacon-Manito, Sorsogon/Albany): exploitation started in 1993-1998 (EDC and National Power Corporation - NPC), a small 1.5 MW back pressure turbine plant (combined with drying plant), two units for 55 MW and two for 20 MW, for a total of 152 MW.

Leyte (Tongonan): five flash (661.5 MW), and 3 topping cycle (back pressure turbines), 1 bottoming (flash), and 1 bottom cycle binary plants, with a total capacity of 61 MW, for the optimization of the overall energy recovery from the geothermal system, reaching the installed capacity of 716 MW. The entire plants have been transferred to EDC from CalEnergy and Ormat at the end of the BOT period.

Mindanao (Mount Apo, North Cotabato/Davao): two flash units (one single and one dual pressure) for 103 MW in total have been transferred to EDC from Marubeni in 2009. A new unit is planned.

Northern Negros (Negros Occidental): EDC commissioned in 2007 one flash (dual pressure) unit of 49 MW; it is operated by NPC as "merchant plant", selling electricity to the local consumers through the new electricity environment. It will provide stability in the supply of power in Negros Island. In terms of power generation mix, Negros Island is now utilizing 100% renewable energy with geothermal providing 99.6% while the remaining 0.4% comes from hydro.

South Negros (Palinpinon, Negros Oriental): five flash units for 192.5 MW are in stable operation since 1982; an optimization project for 20 MW binary is under development by EDC/NPC.

Mak-Ban (Mount Makiling-Banahaw, Laguna/Quezon): it is under strong development by Chevron, with four units rehabilitated in 2005, despite its starting of operation in 1979: ten flash units and a 15.7 binary plant, for a total of 458 MW; there are 72 production and 16 reinjection wells; the average production is 6 MW/well.

Tiwi (Albany): also this field started its operative life in 1979. Today there are four operative flash units (on a total of six) for 234 MW, rehabilitated in 2005. The field is exploited through 38 production and 21 reinjection wells, with 5.5 MW/well. It is operated by Chevron.

The electricity production from geothermal resources shows a first period of stable generation, and an important step up around year 2000, jumping above the 10 TWh threshold. The long term yearly production is shown in figure 54.

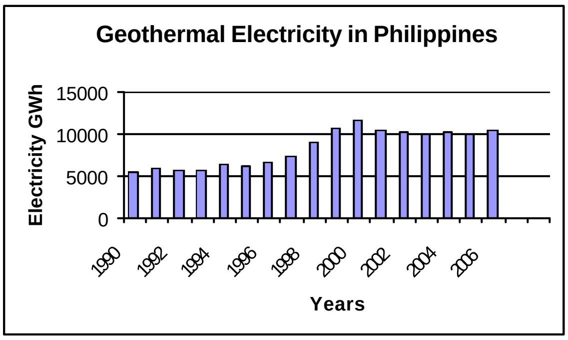

Figure 54: Geothermal Electricity production since 1990 (from UN statistic division web site).

2.27 Portugal (Cabeças and Carvalho, 2010)

In the Portugal, exploitation of geothermal resources for electric power generation has been developed successfully on the largest and most populous Azores island, São Miguel by Electricidade dos Açores.

The Ribeira Grande field (about 250°C) has been expanded to a total capacity of 28 MW, through a second binary unit at Pico Vermelho of 13 MW in 2006, covering about 40% of the electricity need of the island (23 MW net). It is expected to double the contribution of geothermal electricity in the coming years (figure 55).

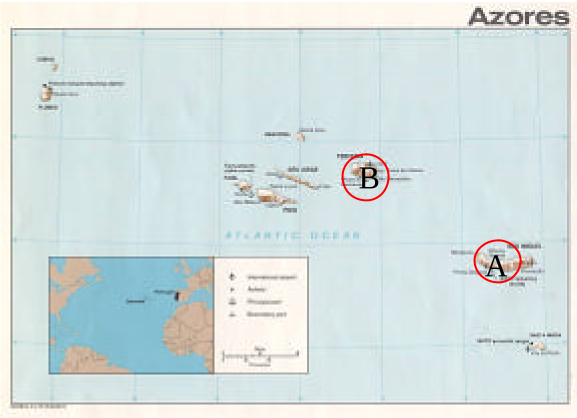

Figure 55: Location of Ribeira Grande [A, 28 MW] and Terceira [B].

On Terceira island a project for installing 12 MW is ongoing (Pico Alto field, where temperature of above 300°C have been recorded), as well as additional expansion of Ribeira Grande, with a forecasted investment of about 200 MEuro in the next years. Unfortunately, the lake of request on the other small island will not allow the realization of any important development, despite the presence of a good resource (figure 56).

The increase of 13 MW from year 2005 has a very important percentage value: 78%, reaching one of the highest score.

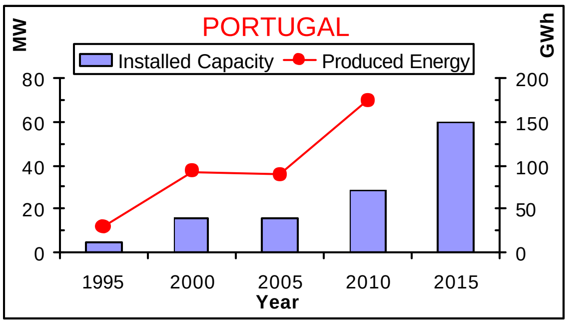

Figure 56: Installed Capacity and Electricity.

2.28 Romania (Rosca et al., 2010)

The geothermal electricity potential of the country is not very important; however, in the Oradea medium-temperature reservoir (about 120°C) project for a pilot binary units have been done in the recent past (figure 57), and unfortunately it did not reach the construction stage. The possibility of some minor development is still under evaluation.

2.29 Russia (Povarov and Svalova, 2010)

No new addition has been realized since 2005. The geothermal resources of the country are located in Kamchatka and some small plants on the Kurili islands. However, projects for construction of binary Verkhne-Mutnovsky (6.5 MW) and the second 100 MW stage of Mutnovsky are under development (figure 58).

The two geothermal areas of Pauzhetsky and Mutnovsky are the main production zones of the Kamchatka peninsula, operated by SC Geoterm: the first field is the oldest in operation (since 1967), with 14 MW and a bottom binary cycle under construction; the second one is the most promising, with a steam zone on the shallow depth and a liquid reservoir (250-310°C) between 1,000 and 2,000 m depth. Its installed capacity is 62 MW, and additional 100 MW are under construction, as well as a bottom binary cycle of 6.5 MW in Verkhne-Mutnovsky.

An intensive exploitation of the huge potential of Kamchatka region is expected in the coming years (figure 59).

Figure 57: Location of Oradea.

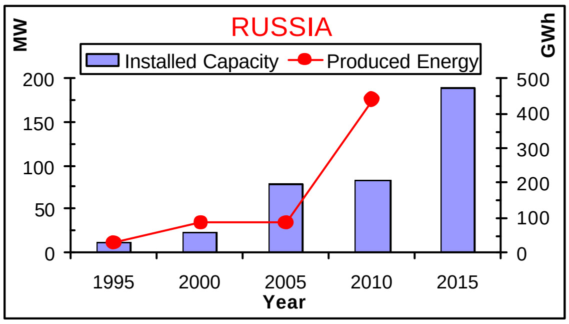

Figure 58: Installed Capacity and Electricity.

2.30 Slovakia (Fendek and Fendekova, 2010)

In the country the low temperature geothermal potential is located in the south-eastern region of Kosice, where a 5 MW binary project is under evaluation (figure 60).

2.31 Spain (Sanchez-Guzma and Garcia de la Noceda, 2010)

In the country the volcanic resources of the Canary islands are still unexploited, despite several researches and advanced studies. Two 20 MW projects in Tenerife and Gran Canaria are under evaluation (figure 61).

2.32 Thailand

A small (300 kW) binary-cycle power plant has been commissioning in 1989 in Fang. This plant has operated successfully, with an 85-90% availability factor. In addition, the Electricity Generating Authority of Thailand (EGAT) is using the 80°C exhaust from the power plant to demonstrate direct heat uses to the local population (figure 62).

Figure 59: Location of Pauzhetsky [A, 14 MW], Mutnovsky [B, 62 MW], Iturup [C, 4 MW], and Kunashir [D, 2 MW].

Figure 60: Location of Kosice.

2.33 The Netherlands (Van Heekeren and Koenders 2010)

Dutch interest in geothermal energy is something quite new, practically starting from scratch since 2005. The Oil&Gas industry is very active in the country, bringing drilling and geological expertise in the local geothermal sector. A pilot binary project is under feasibility study.

Figure 61: Location of Tenerife [A] and Gran Canaria [B].

2.34 Turkey (Mertoglu et al., 2010)

Since 2005 several construction activities have been carried out. Three new binary units of about 8 MW each has been realized, two for exploiting medium enthalpy reservoir (Dora - MB group, in Aydin-Salavatli area, at 167°C and Tuzla - Dardanel Energy, at Canakkale, still under construction) and one on the downstream of the separated brine (140°C) from the Kizildere plant, before its use for district heating, operated by Bereket (figure 63).

Figure 62: Location of Fang.

Figure 63: Location of Germencik [A, 47 MW], Kizildere [B, 27 MW], Salavatli[C, 7 MW] and Tuzla [D].

The old plant of Kizildere, after the privatization, now owned by Zorlu group, has been refurbished and it is operating at full capacity (15 MW as the generator capacity, while the turbine is 20 MW), and a new 60 MW plant is under construction. The reservoir temperature is about 240°C. The plant is producing also 120,000 ton/year of pure CO_2 for the food industry.

A new 47 MW double flash unit has been commissioned in 2009 at Germencik, by the Gurmis group, with the option of a further 47 MW as potential expansion. It is one of the biggest plant in Europe, following only the Italian standard 60 MW units. The brine temperature is 230°C.

Several additional areas have been allocated to private companies for further surface and deep exploration (figure 64). Since 2005 an increase of 60 MW, corresponding to an impressive 300%, has been achieved.

The target for about 200 MW in year 2015 is solid and achievable.

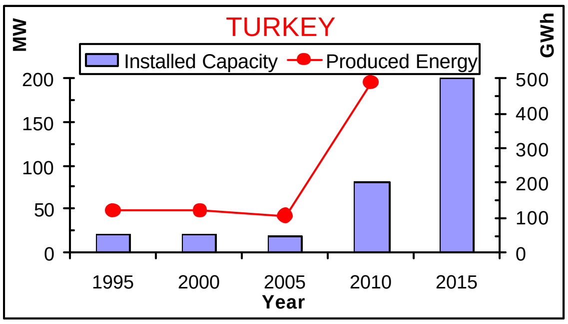

Figure 64: Installed Capacity and Electricity.

2.35 USA (Lund et al., 2010)

Geothermal electric power plants are located (or planned) in Alaska, California, Florida, Hawaii, Idaho, Nevada, New Mexico, Oregon, Utah and Wyoming.

The total installed capacity of the country is around 3 GW, but with only about 2 GW actually running, with an important increase on year 2005 of 12% (about 500 MW of new plants, see figure 65). A total of new projects for 2.4 GW are currently under construction or in advanced planning stage (figure 65).

The total geothermal electricity of about 17 GWh is equivalent to 4% of the entire renewable energy production of the country.

Table III: USA installed capacity per state.

STATE	2005 MW	2010 MW	2015 MW
ALASKA	0	0.7	30
CALIFORNIA	2,239	2,553	3,400
FLORIDA	0	0	0.2
HAWAII	30	35	60
IDAHO	0	16	130
NEVADA	239	442	1,300
NEW MEXICO	0	0.2	20
OREGON	0	0.3	200
UTAH	26	46	240
WYOMING	0	0.2	0.2
USA TOTAL	**2,534**	**3,093**	**5,400**

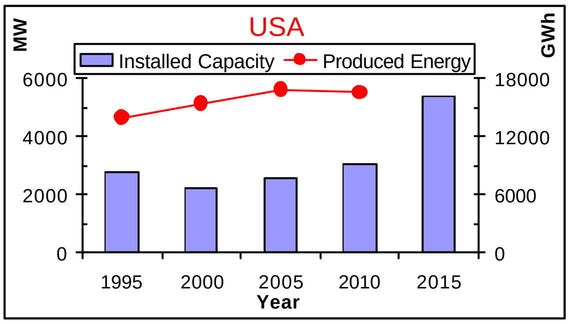

Figure 65: Installed Capacity and Electricity.

<u>Alaska</u>

The first geothermal power plant in this state was installed in 2006, at Chena Hot Springs (figure 66). It is a binary plant, producing 225 kW from the coldest geothermal resource worldwide: only 74°C. A second twin unit has been added, and a third one of 280 kW is under commissioning phase reaching the total installed capacity of 730 kW, which is quite relevant for the local economy of such off-grid remote location.

Figure 66: Location of Chena.

California

Since 2005, the following new plants have been realized in California: 10 MW (Gould), 10 MW (Heber South), 49 MW (North Brawley) binary units in Heber field (Imperial Valley), and the new unit Bottle Rock 2 for 55 MW dry steam at The Geyser. However in California the geothermal capacity of about 2.5 GW is contributing to 4.5% at the electricity generation of the state, with an electricity production of about 12 TWh. Several new projects are in advanced stage of realization. The relevant geothermal power plants are listed as following (figure 67).

Figure 67: Location of The Geyser [A, 1,585 MW], East Mesa [B, 120 MW], Salton Sea [C, 329 MW],COSO [D, 270 MW], Heber [E, 205 MW], Honey Lake [F, 4 MW] and Mammoth [G, 40 MW].

The Geyser (Calpine and Northern California Power Agency): 26 dry steam units, for a total of about 1.6 GW installed capacity (but only 900 MW running), with new units under advanced realization stage. Its newest addition is Bottle Rock 2, 55 MW in 2007. The Geysers Geothermal field, the largest geothermal field in the world, is about 100 km north of San Francisco, California. The field started production in 1960, and by 1987 the production peaked 1,500 MW (installed capacity 2,043 MW). Unfortunately, a rapid decline in production started.

An unique public-private collaboration began from several municipalities, constructing a 42 km long pipeline to transport treated effluent to The Geysers for injection in 1997. By the end of 2003, another pipeline was completed. The current mass replacement from both pipelines and other sources is about 85% of production. This has resulted in sustained steam production, a decrease in non-condensable gases, improved electric generation efficiency, and lower air emissions. The additional electricity generated as a result of these two pipelines is about 155 MW per year (figure 68).

Imperial Valley-East Mesa, with 6 units for 120 MW of installed capacity, in operation since 1986-1989, by Ormat.

Imperial Valley-Heber, 205 MW of installed capacity with 25 units; and an intense planned activity by Ormat, with a short term target of 270 MW. In this field the new plants of Gould (2x5 MW binary, in 2006), Heber South (10 MW binary, in 2008) and the recent North Brawley (7x7 MW binary, in 2009) have been commissioned.

Imperial Valley-Salton Sea, with 13 units for 333 MW, operated by CalEnergy, and new units planned for a total of 330 MW, after the last additions in year 2000.

COSO (Terra Gen), nine unites for an installed capacity of 270 MW, without any further planned development, in operation since 1987-1989.

Mammoth, 10 units for 40 MW operated by a consortium Constellation/Ormat, commissioned in 1984 and 1990.

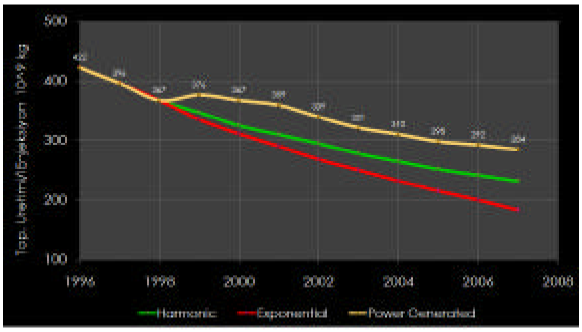

Figure 68: Reinjection effect in The Geyser (from Khan, 2010).

Honey Lake: only three small binary units are operating since 1988 (Amedee) and 1985 (Wineagle). The geothermal contribution from the hybrid HL Power, which uses geothermal as a wood chip dryer and a boiler preheat for 36 MW biomass unit, can be accounted as 1.5 MW, even if recent information are indicating the strong reduction in well flow rate, and probably the geothermal electricity production is not operative anymore, but only the heat is used for boiler preheat and wood chip drying.

Enel Green Power is launching a 20 MW green field project in Surprise Valley.

Florida

A small binary unit of 200 kW will be installed (Jay/Mobile ORC project).

Hawaii

No new addition at the existing ten binary units of 35 MW installed capacity (30 MW running, after rehabilitation and work over) has been done since 2005. This power plant, commissioned in 1993, supplies approximately 20% of the total electricity need of the Big Island (160,000 inhabitants). A further 25 MW of expansion is also planned by Ormat, with the target of 60 MW in the near future (figure 69).

Idaho

In 2007 the construction of the first geothermal power plant in Idaho was finished at Raft River by US Geothermal: a binary plant with a nameplate production capacity of 15.8 MW. Currently, net electrical power output is between 10.5 and 11.5 MW.

The facility is using existing wells of the decommissioned 5 MW binary plant (operated from 1974 to 1982). An expansion to this plant is underway, as well as several other projects in the state (figure 70).

Figure 69: Location of Puna [35 MW].

Figure 70: Location of Raft River [13 MW].

Nevada

Several companies are actively involved in geothermal development in Nevada: Enel Green Power, Ormat, TerraGen, Magma and Nevada Geothermal Power (figure 71).

Several new binary plants have been commissioned since 2005: 50 MW at Blue Mountain (Faulkner) in 2009, 23 MW at Desert Peak II in 2006, the new Enel Green Power plants at Salt Wells (24 MW) and Stillwater (2x24 MW) in 2009, Galena II in 2007, III in 2008 and Burdett in 2005 at Steamboat (5 units for 75 MW).

No changes for Beowave (17 MW, in operation since 1985, Beowawe Power), Brady Hot Spring (three units on 9 MW each since 1992, Ormat), Dixie Valley (62 MW in an unit installed in 1988, Terra Gen), 5 MW in S. Emidio (four units since 1987, US Geothermal) and Wabuska, with two small binary units.

In Soda Lake, ten units installed in 1987 and 1991 for a total 26 MW, no specific development is foreseen by Magma Energy.

At Steamboat Hills (Ormat) a new 12 MW binary plant is planned, in addition at the present 20 MW flash unit, commissioned in 1988.

A new 30 MW binary plant at Galena (Steamboat field) has been commissioned in 2008, with further two units planned by Ormat, with additional 35 MW. Refurbishment of the old Steamboat II has been completed. Moreover, 13 MW at Galena II in 2007 and 2x15 MW at Burdett plant in 2005 started their operative lives. The total capacity of Steamboat complex is 135 MW.

Further additions are foreseen for Desert Peak (30 MW, after the commissioning of unit II of 23 MW in 2006) by Ormat.

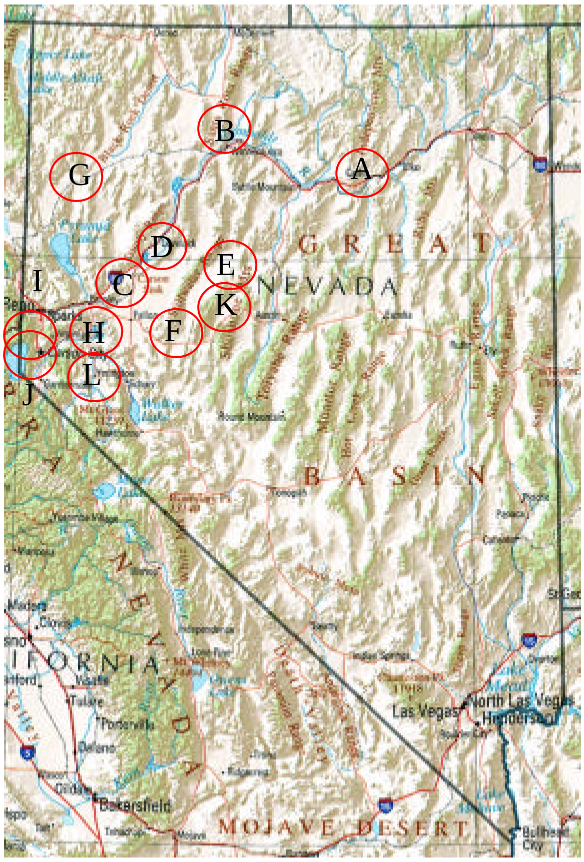

Figure 71: Location of Beowave [A, 17 MW], Blue Mountain [B, 50 MW], Brady Hot Spring [C, 26 MW], Desert Peak [D, 23 MW], Dixie Valley [E, 67 MW], Salt Wells [F, 24 MW], S. Emidio [G, 5 MW], Soda Lake [H, 26 MW], Steamboat [I, 140 MW], Steamboat Hills [J, 14 MW], Stillwater [K, 48 MW] and Wabuska [L, 2 MW].

Another important realization has been commissioned by Enel Green Power, with 24+48 MW at Salt Wells and Stillwater, after the decommissioning of the old binary units (13 MW, operative at Stillwater since 1989).

In 2009 Nevada Geothermal Power commissioned its 50 MW binary plant Faulkner 1 at Blue Mountain.

After the recent BLM tender for several geothermal leases in Nevada, it is expected an intense construction activity in the near future.

New Mexico

Raser Technologies installed a pilot binary unit of 240 kW. The full project, Lightning Dock, is designed to produce 10 MW of electrical power and it is expected to go online in the coming years (figure 72).

Oregon

No private investors have been done any project in this state. However, the Oregon Institute of Technology completed for its campus the installation of a small 280 kW binary unit, which will be on line in 2010 (figure 73).

Two major project at Newberry and Crump Geyser are in advanced stage of realization, for an aggregate capacity of 160 MW.

Figure 72: Location of Lightning Dock.

Utah

The Fort Cove plant has been shut down; the only existing unit in the state is Roosevelt, with 36 MW of installed capacity, from two binary units: 25 MW and a new 11 MW commissioned in 2007; it is operated by Pacific Corporation.

Utah got its second power plant in 2008, when Thermo Hot Springs went online, with 50 small binary units for an aggregate capacity of 10 MW (Raser Technologies).

Enel Green Power is launching a two step project of installing binary units at Fort Cove, with an initial 20 MW projects and an additional one for a total of 40 MW (figure 74).

Wyoming

The Rocky Mountain Oilfield Testing Center (RMOTC) is located at the Teapot Dome oil field, also known as the Naval Petroleum Reserve, operated by the Department of Energy as a test site for oil and gas and renewable energy related technologies.

A small binary unit of 250 kW has been installed in 2009 (figure 75).

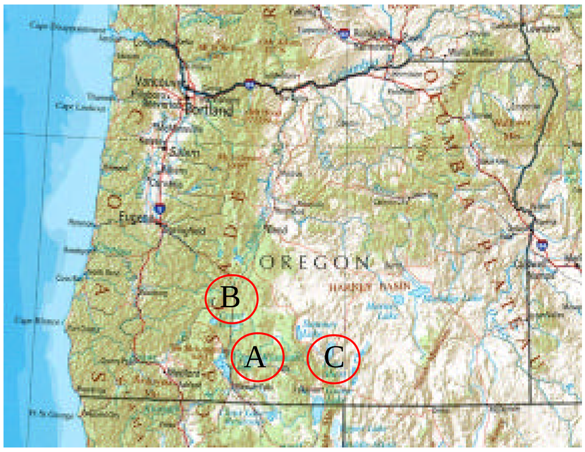

Figure 73: Location of OIT [A], Newberry [B] and Crump Geyser[C].

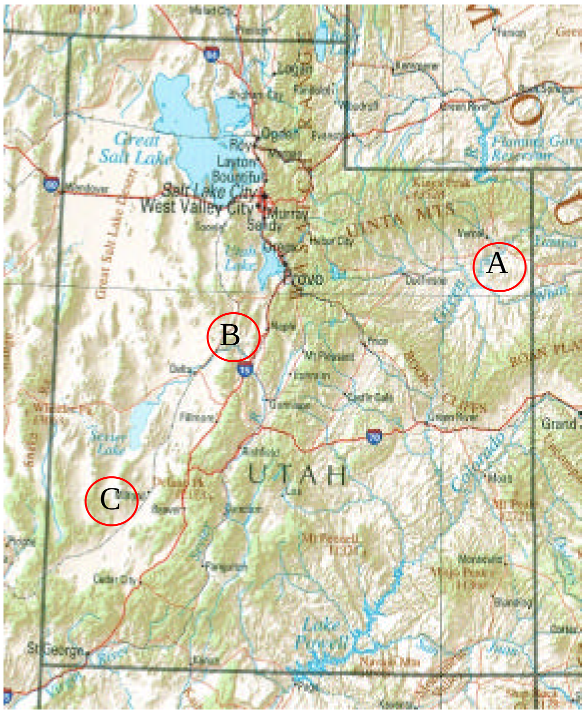

Figure 74: Location of Roosevelt [A, 36 MW], Cove Fort [B] and Thermo Hot Spring[C, 10 MW].

USA Conclusion

In total, in the USA there are about 2 million km^2 of geothermal areas, with an estimated potential of 9 GW, which can be generated by the known geothermal resources, mainly in the western states, where Nevada and California represent more than 80% of all the planned projects (figure 76). Only a strong effort, in term of legislative support and assistance in reducing the duration from the beginning of a geothermal project (lease acquisition) and the effective starting of electricity generation, which can sum up to 5-8 years, can be a key driver for reaching the ambitious target of an exponential increase in the geothermal electricity in the US (and in the world!).

Figure 75: Location of RMOTC.

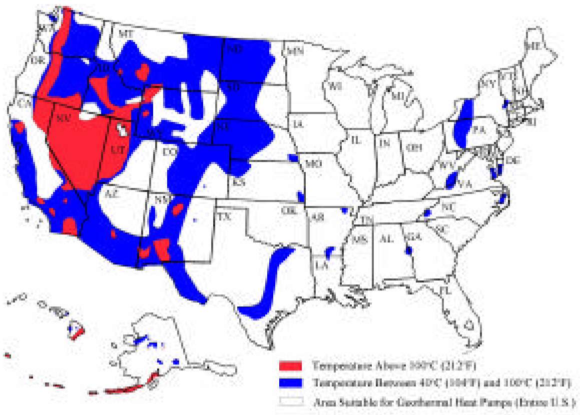

Figure 76: Geothermal potential of the USA (Lund et al., 2010).

3. LONG TERM FORECASTING

Table IV shows the recently observed rapid expansion in the utilization of geothermal energy for 18 world regions (figure 77) as from the classification of Global Energy Assessment (GEA), operated by International Institute for Applied Systems Analysis (IIASA), Austria, under the UN and World Energy Conference (WEC) organizing committee sponsorship (UNDP, 2004; WEA, 2004; WEC, 2007; IEA, 2007).

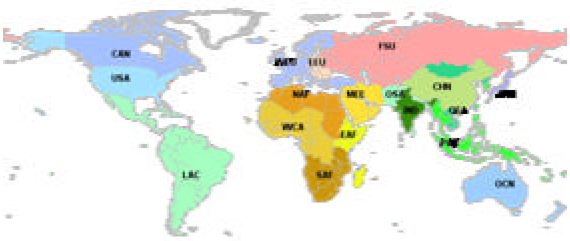

Figure 77: Proposed detailed GEA Regions (18 regions).

Table IV: Utilization of geothermal energy in the 18 GEA regions.

GEA Region	ELECTRICITY TWh/year				
	2000	**2005**	**2010**	**2015**	**2050**
USA	14.0	16.8	16.6	34.1	508
Canada	0.0	0.0	0.0	0.1	8.3
West Europe	3.9	7.1	10.9	13.3	125
Cen/East Eur.	0.0	0.0	0.0	0.1	25
ex URSS	0.0	0.1	0.4	1.2	67
North. Africa	0.0	0.0	0.0	0.0	0.0
East Africa	0.4	1.1	1.4	3.7	25
West/Cen Africa	0.0	0.0	0.0	0.0	0.0
South Africa	0.0	0.0	0.0	0.0	0.0
Middle East	0.0	0.0	0.0	0.0	17
China	0.1	0.1	0.2	0.4	42
East Asia	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	17
South Asia	0.0	0.0	0.0	0.0	0.0
Japan	1.7	3.5	3.1	3.4	17
Pacific Asia	8.3	15.4	20.4	37.8	166
Oceania	2.4	2.8	4.1	8.0	25
Latin Amer.	7.3	8.9	10.2	14.0	125
World	**38**	**56**	**67**	**116**	**1,167**

Growth rates in many regions have been in the two digit range. At the end of 2010, geothermal energy supplied 67 TWh/year of electricity the forecasting for 2015 indicate a short term trend of 116 TWh/year and the expected maximum achievable for year 2050 of about 1,200 TWh/year.

Different authors (Bertani, 2003; Muffler and Cataldi, 1978; Fridleifsson et al., 2008; Fridleifsson and Ragnarsson, 2007) have come up with different quantifications of the global geothermal potentials.

The estimated potentials differ by orders of magnitude depending if these are based on enhanced geothermal systems (EGS) technology and on the type and performance of utilization technologies or both. For example, low-temperature power generation with binary plants has opened up the possibilities of producing electricity in countries which do not have high-temperature fields. EGS technologies are still under development. If EGS can be proven economical at commercial scales, the development potential of geothermal energy will be enormous in many countries of the world.

The geothermal exploitation techniques are being rapidly developed and the understanding of the reservoirs has improved considerably over the past years.

In its broadest sense, the notion geothermal resources refers all of the thermal energy stored between the Earth's surface. Globally the energy stored in the Earth's crust up to a depth of 5,000 meters is estimated at 140 10^6 EJ (WEC, 1994 and 1998) an enormous theoretical resource base.

A very detailed estimation of the heat stored inside the first 3 km under the continents dates back to 1978 (EPRI, 1978).

The study applied an average geothermal temperature gradient of 25ºC/km depth for normal geological conditions and accounted separately for diffuse geothermal anomalies and high enthalpy regions located nearby plate boundaries or recent volcanism. The high enthalpy regions cover about ten percent of the Earth's surface. The total amount of available heat is huge, about 42 10^6 EJ. With the present world energy consumption of 500 EJ/year, the geothermal heat can be fulfill the world need for about 100,000 years.

3.1 Theoretical Potential

This value can be assumed as the theoretical potential**.** It is practically impossible to extract all the heat from underground, both for technical difficulties in using the lowest temperature fraction, and for the inaccessibility of the majority of the bulk of the rock at the fluid, which act as a carrier for cooling down the geothermal resources and bringing the heat energy up to the surface.

The rate at which the heat is continuously replenished from the higher temperature regimes below the 3-5 km depth is estimated at 65 mW/m^2 which corresponds to an average thermal energy recharge rate of about 315 EJ/yr (Stefansson, 2005). This value should be considered only as a rough approximation of the expected geothermal potential, due to the very high uncertainness and the contribution of the volcanic system, which are not considered. However, from this evaluation the expected value of 10 TW_{th} of thermal energy can be used per year as an indication of the overall technical potential of the geothermal energy utilization.

Of interest, however, is the resource base that may be accessible over the next several decades with current or future technology, i.e., technical potential.

From the theoretical to the effective technical potential it is necessary to exclude the heat which cannot be accessed through natural or artificial circulation, the surface of the continents which are remote, unreachable or non-connectable with any user of heat and electricity, as well as all that part of heat which, in a drillable depth down to 5 km, will not reach an economical temperature level. The missing information are far too much for reaching an acceptable valued from the theoretical potential. For these reasons we did not followed this way.

3.2 Technical Potential

The technical potential has been evaluated recently (Stefansson, 2005), starting from a general correlation between the existing geothermal high temperature resources and the number of volcanoes inferring a total electricity generation potential of 200 GW. This value is considering only the traditional hydrothermal resources. The consideration of the distribution between wet and dry system and the recent statistical analysis of the lognormal heat distribution (Goldstein, 2009), will consider the 70% probability of adding up to 1,000 GW of EGS system to the technical potential, with the total value of 1,200 GW.

According to the effective efficiency in the transformation from heat to electricity for different temperature classes (10% for 120-180°C, 20% for temperature 180-300°C, 5% for EGS system, considering for this technology an efficiency reduction from the available heat to the accessible one of a factor two in comparison with a standard binary plant in an hydrothermal system), it is possible to evaluate the temperature weighted average of the amount of equivalent heat extracted per year from the heart of about 660 EJ/yr.

From the distribution of the geothermal resources over different temperature regimes, it is possible to estimate the low temperature potential (for direct utilization or low-temperature electricity cycles) using a empirical function (Stefansson, 2005).

The value of 61 EJ/yr, corresponding to a thermal capacity of 5,000 GW_{th} has been assumed (corresponding to a capacity factor of 40%), and it has been split among the different regions accordingly to the amount of low temperature areas. The technical potential (about 700 EJ/y) is approximately the same order of magnitude of the natural heat recharge of the underground resources, proving that geothermal energy can be an important resource for the world energy needs, exploitable in a sustainable way.

3.3 Economic Potential: 2050 target

For policy and investment decisions, it is the economic potential that matters: that part of the technical resource base that could be extracted economically in a competitive market setting at some specified time in the future (up to 2050 and beyond). Over the short-to-medium run the economic potential are geothermal sites that are known and characterized by drilling or by geochemical, geophysical and geological evidence. The effective hydrothermal economic potential for year 2050 is about 70 GW.

For considering the contribution of EGS to the economical potential, it is necessary to highlight the very important aspect of the lack of any commercial experience to-date for any EGS system in any place of the world. This technology is still in the experimental phase, and it is still to be proven as economical viable in the short term. In particular, it is important to reach a minimum heat exchange surface (some million square meters of heat exchange surfaces, preferably uniformly distributed; several cubic kilometer of reservoir volume, maximum flow impedance of a few MPa per liter/sec, water loss < 10%).

To spread out EGS installations widely a technology would be needed to establish such EGS reservoirs independent of local ground conditions. This technology is far from being developed (Tester et al., 2006): a large number of problems that still remain to be solved in this respect. Even in reservoirs created with the required characteristics some further, not yet clear effects could appear like hydraulic short-circuiting, leading to rapid thermal drawdown.

However, again we can make the hypothesis that the EGS will become in the coming years a leading technology and the way for disseminating geothermal electricity all around the world, where it would be possible to reach at least 200°C in an affordable depth and where it would be possible to achieves enough artificial permeability for ensuring the necessary circulation among the wells.

It would be possible to use the aforesaid statistical analysis of the lognormal distribution of the underground heat (Goldstein, 2009), and assuming for year 2050 the exploitation of at least additional 70 GW from EGS, which could be possible with an acceptable probability (about 85%, but within the condition of the success of the medium/long term experimentation of the present EGS pilot plants). The final value of 140 GW for year 2050 has been evaluated, corresponding to 66 EJ/yr, using the same heat/electricity conversion ratio (figure 78); the expected production in TWh/year is calculated assuming 95% capacity facto.

The economic potential of direct geothermal heat utilization depends to a large part on the technology associated with its utilization (heat pumps, binary cycles, etc). By 2050 the global potential is estimated at 800 GW_{th}, corresponding at 10 EJ/yr. The results of the geothermal potentials (theoretical, technical and economic) are presented in table V and figure 79. The relative weights for each GEA region are taken from the heat classes of the EPRI (1978) report in order to estimate the technical potential for each region.

It would be possible to produce up **8.3%** of total world electricity production (IPCC, 2000 and 2007), serving **17%** of world population; **40** countries (located mostly in Africa, Central/South America, Pacific) can be 100% geothermal powered. The overall CO_2 saving from geothermal electricity can be in the range **1,000 million tons per year**, if the target of 140 GW will be reached.

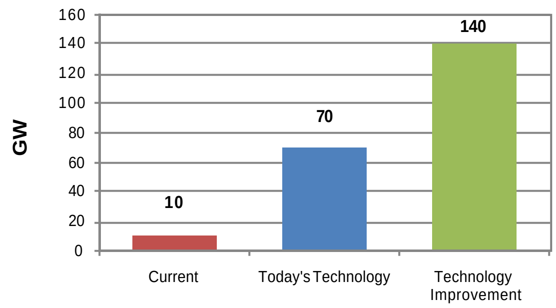

Figure 78: Present value (red), estimated potential with present technology (blue) and with EGS (green).

Table V: Geothermal potentials for the 18 GEA regions. The values are referring to the underground heat available for direct utilization or electricity, with the exception of the expected electricity production, calculated using the weighted average conversion efficiency (about 17 joule of heat for each joule of electricity) and 95% of capacity factor. For the direct utilization, the thermal capacity is calculated with an average 40% of capacity factor.

GEA Region	Theoretical potential	Technical Potential		Economic Potential		
		Heat for Direct utilization	Heat for Electricity	Heat for Direct utilization	Heat for Electricity	Produced Electricity
	10^6 EJ	EJ/year	EJ/year	EJ/year	EJ/year	TWh/year
USA	4.738	7.0	75	1.215	34.9	508
Canada	3.287	4.8	52	0.099	0.307	8.3
Western Europe	2.019	3.0	32	4.311	6.216	125
Cent.East Europe	0.323	0.5	5.1	0.852	1.243	25
ex Soviet Union	6.607	9.9	104	0.508	3.097	67
Northern Africa	1.845	2.8	29	0.103	0.0	0.0
Eastern Africa	0.902	1.3	14	0.004	0.918	25
West.Cent. Africa	2.103	3.2	33	0.0	0.0	0.0
Southern Africa	1.233	1.8	19	0.0	0.0	0.0
Middle East	1.355	2.0	21	0.175	0.612	17
China	3.288	4.7	52	1.764	1.856	42
Other East Asia	0.216	0.3	3.4	0.018	0.0	0.0
India	0.938	1.4	15	0.062	0.613	17
Other South Asia	2.424	3.7	38	0.002	0.0	0.0
Japan	0.182	0.2	2.9	0.201	0.612	17
Other Pacific Asia	1.092	1.4	17	0.004	7.424	166
Oceania	2.304	3.5	36	0.391	1.568	25
Latin America	6.886	9.9	109	0.383	6.216	125
World	**41.743**	**61.4**	**657**	**10.092**	**65.582**	**1,167**
Equivalent Capacity		**5,000 GW_{th}**	**1,200 GW_{el}**	**800 GW_{th}**	**140 GW_{el}**	

4. STATISTICAL HIGHLIGTHS

4.1 Some Ranking

Top Five

The "Top Five Countries" for capacity and produced energy are in the following table VI:

Table VI: Top five countries (total).

COUNTRY	2005 MW	2005 GWh	2010 MW	2010 GWh
USA	2,564	16,840	3,060	14,533
PHILIPPINES	1,930	9,253	1,904	10,311
INDONESIA	797	6,085	1,197	9,600
MEXICO	953	6,282	958	7,047
ITALY	791	5,340	843	5,520

It should be mentioned the important change of ranking of Indonesia, (now 3rd), with in impressive increase both in capacity and in energy. Italy is stable at 5th position.

The "Top Five Countries" for absolute value increase are highlighted as follows in table VII:

Table VII: Top five countries (increase).

COUNTRY	MW	GWh	%MW	%GWh
USA	496	-2,307	19%	-14%
INDONESIA	400	3,515	50%	58%
ICELAND	373	3,114	184%	210%
NEW ZEALAND	193	1,281	44%	46%
TURKEY	62	385	308%	368%

Four countries realized plants for more than 100 MW: USA, Indonesia, Iceland and New Zealand. This is an important signal: even in countries where the geothermal development started more than 50 year ago, still the industry is presently proactive in launching new projects, and the economical environment is strongly positive in terms of incentives and supporting measures. Turkey is not a newcomer, but after a first plant (Kizildere) no new activities has been carried out since the very recent years, following the privatization of existing assets and taking the advantage of the new geothermal law. The perspectives for the country are very promising.

The "Top Five Countries" for percentage increase are the following (table VIII):

Table VIII: Top five countries (percentage).

COUNTRY	MW	GWh	%MW	%GWh
GERMANY	6	49	2,774%	3,249%
PAPUA-NEW GUINEA	50	433	833%	2,547%
AUSTRALIA	1	0	633%	-5%
TURKEY	62	385	308%	368%
ICELAND	373	3114	184%	210%
PORTUGAL	29	175	78%	94%
GUATEMALA	52	289	58%	36%
INDONESIA	1,197	9,600	50%	58%

The value of Germany and Australia are meaningless, due to their very small installed capacity. On the other hand, Papua – New Guinea, with the important value of 56 MW in operation, can be proud of its 833% of increase since 2005. But two already ranked countries should be highlighted: Turkey and Iceland, with in increase of 300% and 200% approximately, must be considered among the most actives geothermal countries in the past five years.

A corrected percentage "Top Six Countries" ranking, excluding the two small players of Germany and Australia, will add at 4th and 5th two well known geothermal countries: Portugal (78%) and Guatemala (58%), followed by the Indonesian giant, with 50% in the 6th position.

Biggest plants (>55 MW)

The biggest plant are not very often utilized in the geothermal field, even if their economy of scale is quite important: the need of feeding them with enough fluid is a critical point, and it can be afforded only where the resource is abundant and well known.

In the following table IX the list of plants with installed capacity higher than 55 MW is presented. It should be highlighted that the average geothermal capacity on the entire 526 units in operation is 20.6 MW, where for the 48 units presented in the table the average is 79.5 MW.

Smallest plants (<10 MW)

It is almost impossible to present a similar list of the small plants, with capacity less than 10 MW: there are about 259 units in operation, with an average capacity of 3.2 MW.

The majority of them is binary (196 units), 22 are back pressure, 22 are single flash and 17 double flash.

Most important plant commissioned since 2005: New plants

Since WGC2005, 139 new units have been commissioned, having COD 2005-today.

Restricting only to units having capacity greater than 1 MW, and collecting together different units of the same plant, the "New Plants" list can be presented in table X.

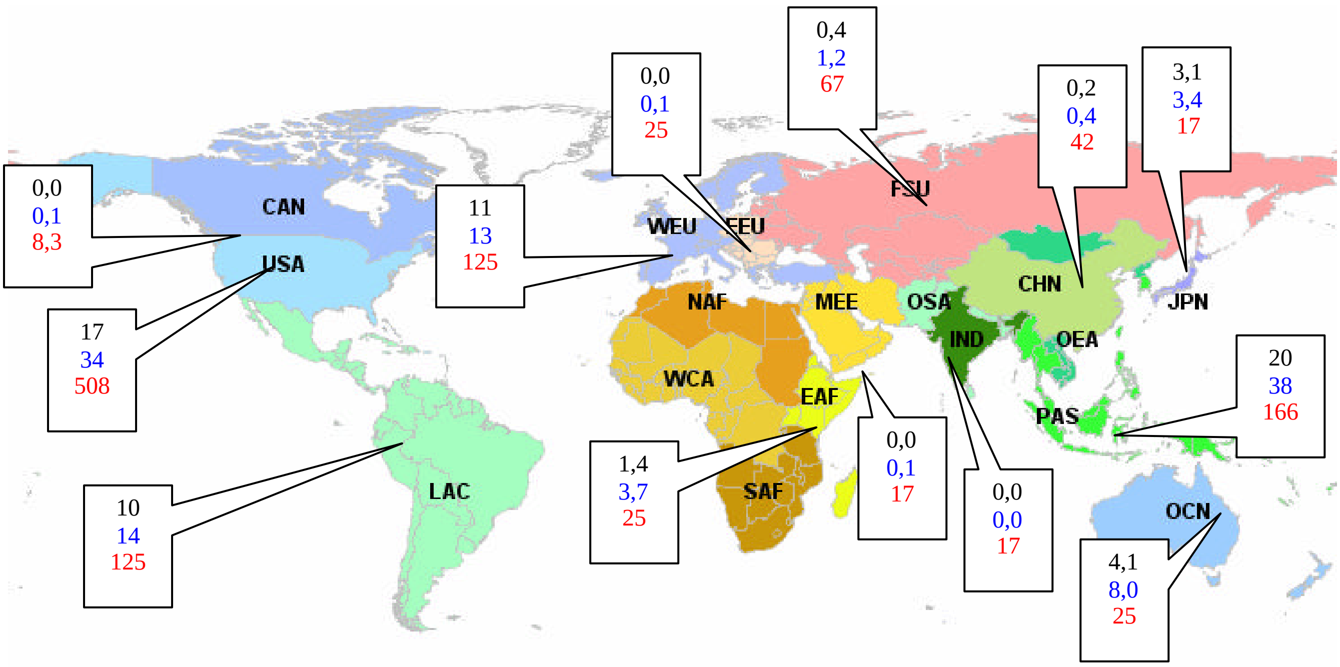

Figure 79. World forecasting for the 18 GEA regions, in TWh/year: Today, 2015 (in blue) and 2050 (in red). The energy quoted in the figure is corresponding to the effective capacity of 10.7 GW for 2010, 18.4 GW for 2015 and 140 GW for 2050 (the EGS contribution of 70 GW is considered).

4.2 Plant Classification

We followed the standard plant classification with the classical definitions of binary, back pressure, single/double flash and dry steam plant. In the pie charts of figures 80, 81 and 82 the installed capacity in MW, the produced energy in GWh and the total number of units for each category is presented.

We can classify three major families: small (binary, back pressure) about 5 MW per unit, medium (flash plants, around 30 MW per unit) and big (dry steam, 45 MW per unit).

The subdivision per country of each category is given in table XI.

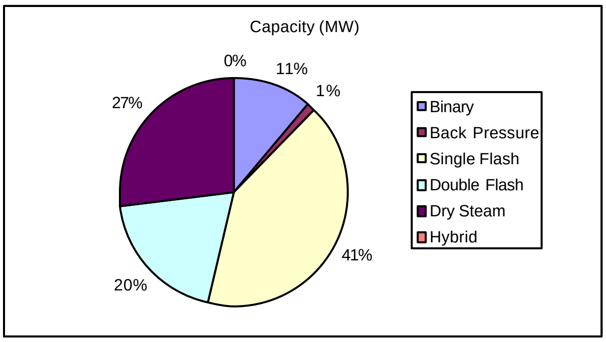

Figure 80: Installed capacity.

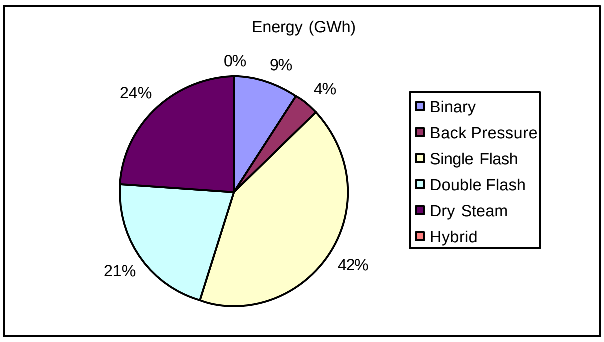

Figure 81: Produced energy.

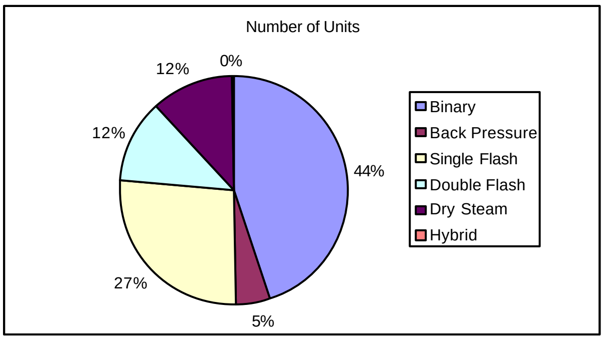

Figure 82: Number of units.

The average values per unit of the installed capacity and the produced energy is given in table XII.

Table IX: The biggest plants list.

Country:	Plant	Unit	COD	Capacity	Type	Operator	Manufacturer
Indonesia	Wayang Windu	2	2009	117	Single Flash	Star Energy Ltd	Fuji
USA	Socrates	1	1983	113	Dry Steam	Calpine	Toshiba
USA	Quicksilver	1	1985	113	Dry Steam	Calpine	Toshiba
USA	Lake View	1	1985	113	Dry Steam	Calpine	Toshiba
USA	Grant	1	1985	113	Dry Steam	Calpine	Toshiba
México	Cerro Prieto III	1	1986	110	Double Flash	CFE	Toshiba
USA	Cobb Creek	1	1979	110	Dry Steam	Calpine	Toshiba
USA	Eagle Rock	1	1975	110	Dry Steam	Calpine	Toshiba
México	Cerro Prieto II	2	1987	110	Double Flash	CFE	Toshiba
México	Cerro Prieto II	1	1986	110	Double Flash	CFE	Toshiba
Indonesia	Darajat	3	2008	110	Dry Steam	Chevron	Mitsubishi
Indonesia	Wayang Windu	1	2000	110	Single Flash	Star Energy Ltd	Fuji
México	Cerro Prieto III	2	1986	110	Double Flash	CFE	Toshiba
USA	Sulphur Spring	1	1980	109	Dry Steam	Calpine	Toshiba
New Zealand	Kawerau	1	2008	100	Double Flash	Mighty River Power	Fuji
USA	Big Geyser	1	1980	97	Dry Steam	Calpine	GE/Nuovo Pignone
Indonesia	Darajat	2	1999	90	Dry Steam	Chevron	Mitsubishi
USA	Calistoga	1	1984	80	Dry Steam	Calpine	Toshiba
Philippines	Malitbog	1	1997	78	Single Flash	EDC	Fuji
Philippines	Malitbog	2	1997	78	Single Flash	EDC	Fuji
Philippines	Malitbog	3	1997	78	Single Flash	EDC	Fuji
USA	Sonoma	1	1983	72	Dry Steam	Calpine	Mitsubishi
Indonesia	Gunung Salak-IPP	1	1997	65	Single Flash	Chevron	Fuji
Indonesia	Gunung Salak-IPP	3	1997	65	Single Flash	Chevron	Fuji
Japan	Yanaizu-Nishiyama	1	1995	65	Single Flash	Tohoku Electric Power	Toshiba
Indonesia	Gunung Salak-IPP	2	1997	65	Single Flash	Chevron	Fuji
Philippines	Mak-Ban A	1	1979	63	Double Flash	Chevron	Mitsubishi
Philippines	Mak-Ban B	2	1980	63	Double Flash	Chevron	Mitsubishi
Philippines	Mak-Ban A	2	1979	63	Double Flash	Chevron	Mitsubishi
Philippines	Mak-Ban B	1	1980	63	Double Flash	Chevron	Mitsubishi
USA	Dixie Valley	1	1988	62	Double Flash	Terra Gen	Fuji
Indonesia	Gunung Salak	3	1997	62	Single Flash	PLN	Fuji
Indonesia	Gunung Salak	1	1994	60	Single Flash	PLN	Ansaldo/Tosi
Indonesia	Gunung Salak	2	1994	60	Single Flash	PLN	Ansaldo/Tosi
Indonesia	Dieng	1	1998	60	Single Flash	PLN	
Italy	Nuova Serrazzano	1	2002	60	Dry Steam	Enel Green Power	Ansaldo/Tosi
Italy	Farinello	1	1995	60	Dry Steam	Enel Green Power	Ansaldo/Tosi
Italy	Valle Secolo	2	1991	60	Dry Steam	Enel Green Power	Ansaldo/Tosi
Indonesia	Darajat	1	1994	60	Dry Steam	PLN	Mitsubishi
Philippines	Tiwi A	1	1979	60	Single Flash	Chevron	Toshiba
Indonesia	Kamojang	4	2007	60	Dry Steam	PLN	Fuji
Philippines	Tiwi A	2	1979	60	Single Flash	Chevron	Toshiba
Italy	Valle Secolo	1	1991	60	Dry Steam	Enel Green Power	Ansaldo/Tosi
Philippines	Mahanagdong B	1	1997	59	Single Flash	EDC	Toshiba
Philippines	Mahanagdong A	1	1997	59	Single Flash	EDC	Toshiba
Philippines	Mahanagdong A	2	1997	59	Single Flash	EDC	Toshiba
Philippines	Tiwi C	2	1982	57	Single Flash	Chevron	Toshiba
Philippines	Tiwi C	1	1982	57	Single Flash	Chevron	Toshiba

Table X: The new plants list.

Country:	Plant	Unit	COD	Capacity	Type	Operator	Manufacturer
Indonesia	Wayang Windu	2	2009	117	Single	Star Energy Ltd	Fuji
USA	Faulkner	1	2009	50	Binary	Nevada Geothermal	ORMAT
Turkey	Germencik	1	2009	47	Double	GURMAT	Mitsubishi
Italy	Sasso 2	1	2009	20	Dry Steam	Enel Green Power	General
Italy	Nuova Lagoni Rossi	1	2009	20	Dry Steam	Enel Green Power	General
Indonesia	Lahendong	3	2009	20	Single	PLN	Fuji
USA	Stillwater	1-2	2009	48	Binary	Enel Green Power	Mafi Trench
USA	Salt Wells	1	2009	24	Binary	Enel Green Power	Mafi Trench
USA	North Brawley	1-7	2009	49	Binary	ORMAT	ORMAT
USA	Thermo Hot Spring	1-50	2009	10	Binary	Raser Technologies	UTC/Turboden
Indonesia	Darajat	3	2008	110	Dry Steam	Chevron	Mitsubishi
New Zealand	Kawerau	1	2008	100	Double	Mighty River Power	Fuji
Iceland	Hellisheidi III	1-2	2008	90	Single	Orkuveita Reykjavikur	Mitsubishi
Kenya	Olkaria III	3	2008	36	Single	ORMAT	Mitsubishi
USA	Galena III	1	2008	30	Binary	ORMAT	ORMAT
Indonesia	Lahendong	2	2008	20	Single	PLN	Fuji
New Zealand	Ngawha 2	1	2008	15	Binary	Top Energy	ORMAT
USA	Raft River	1	2008	13	Binary	US Geothermal	ORMAT
USA	Heber South	1	2008	10	Binary	ORMAT	ORMAT
El Salvador	Berlin	4	2008	9.4	Binary	LaGeo/Enel Green Power	Enex
New Zealand	KA24	1	2008	8.3	Binary	ORMAT	ORMAT
Turkey	Kizildere Binary	1	2008	6.8	Binary	BEREKET	ORMAT
Germany	Unterhaching	1	2008	3.4	Binary	Municipality	Siemens
Germany	Landau	1	2008	3	Binary	Municipality	ORMAT
France	Soultz-sous-Forêts	1	2008	1.5	Binary	European EGS Interest	UTC/Turboden
Indonesia	Kamojang	4	2007	60	Dry Steam	PLN	Fuji
USA	Bottle Rock	2	2007	55	Dry Steam	US Renewables	Fuji
Philippines	Mambucal	1	2007	49	Single	National Power	Fuji
Iceland	Hellisheidi II	1	2007	33	Single	Orkuveita Reykjavikur	Toshiba
Guatemala	Amatitlán	1	2007	24	Binary	ORMAT	ORMAT
Papua New Guinea	Lihir	3	2007	20	Single	Lihir Gold Ltd mine	General
New Zealand	Mokai 1A	1	2007	17	Binary	Tuaropaki Power Co	ORMAT
USA	Galena II	1	2007	13	Binary	ORMAT	ORMAT
USA	Blundell I	2	2007	11	Binary	Pacific Corporation	ORMAT
Indonesia	Sibayak	2-3	2007	11	Single	Pertamina Geothermal	Harbin
México	Los Humeros	8	2007	5	Back	Comisión Federal de	Mitsubishi
Kenya	Oserian	2	2007	2	Single	Oserian Flower co	Elliot
Nicaragua	San Jacinto-Tizate	1-2	2007	10	Back	Polaris	Alstom
Russia	Okeanskaya	1-2	2007	3.6	Single	SC Geoterm	Kaluga Turbine
Russia	Mendeleevskaya	1	2007	1.8	Single	SC Geoterm	Kaluga Turbine
Iceland	Reykjanes	2	2006	50	Single	Hitaveita Sudurnesja	Fuji
Iceland	Hellisheidi I	1-2	2006	90	Single	Orkuveita Reykjavikur	Mitsubishi
El Salvador	Berlin	3	2006	44	Single	LaGeo/Enel Green Power	General
USA	Desert Peak II	1	2006	23	Binary	ORMAT	ORMAT
Portugal	Pico Vermelho	1	2006	13	Binary	Electricidade dos Açores	ORMAT
Turkey	Dora	1	2006	7.4	Binary	MB	ORMAT
USA	Gould	1-2	2006	10	Binary	ORMAT	ORMAT
Japan	Hatchobaru	3	2006	2	Binary	Kyushu Electric Power	ORMAT
Iceland	Reykjanes	1	2005	50	Single	Hitaveita Sudurnesja	Fuji
Italy	Nuova San Martino	1	2005	40	Dry Steam	Enel Green Power	General
Papua New Guinea	Lihir	2	2005	30	Single	Lihir Gold Ltd mine	General
Iceland	Svartsengi	2	2005	30	Single	Hitaveita Sudurnesja	Fuji
Iceland	Nesjavellir	4	2005	30	Single	Orkuveita Reykjavikur	Mitsubishi
Italy	Nuova Larderello	1	2005	20	Dry Steam	Enel Green Power	Ansaldo/Tosi
USA	Richard Burdett	1-2	2005	30	Binary	ORMAT	ORMAT
New Zealand	Mokai 2	1	2005	19	Single	Tuaropaki Power Co	Mitsubishi
New Zealand	Mokai 2	1-5	2005	20	Binary	Tuaropaki Power Co	ORMAT
New Zealand	Wairakei Binary	15-17	2005	14	Binary	Contact Energy	ORMAT

Table XI: Plant category per country (hybrid excluded).

	Back Pressure		Binary		Single Flash		Double Flash		Dry Steam		TOTAL	
Country	MW	Unit	MW	Unit	MW	Unit	MW	Unit	MW	Unit	MW	Unit
Australia			1	2							1	2
Austria			1	3							1	3
China							24	8			24	8
Costa Rica	5	1	21	2	140	3					166	6
El Salvador			9	1	160	5	35	1			204	7
Ethiopia			7	2							7	2
France			2	1	10	1	5	1			16	3
Germany			7	3							7	3
Guatemala			52	8							52	8
Iceland			10	8	474	14	90	3			575	25
Indonesia	2	1			735	14			460	7	1197	22
Italy					88	5			755	28	843	33
Japan			2	2	349	14	160	3	24	1	535	20
Kenya			14	3	153	7					167	10
México	75	15	3	2	410	15	470	5			958	37
New Zealand	47	5	137	24	290	12	100	1	55	1	628	43
Nicaragua	10	2	8	1	70	2					88	5
Papua New Guinea	6	1			50	2					56	3
Philippines			209	18	1330	31	365	7			1904	56
Portugal			29	5							29	5
Russia					82	11					82	11
Thailand							0	1			0	1
Turkey			14	2	20	1	47	1			82	4
USA			653	149	59	4	795	30	1585	25	3094	209
TOTAL	**145**	**25**	**1178**	**236**	**4421**	**141**	**2092**	**61**	**2878**	**62**	**10715**	**526**

Table XII: Average capacity and energy per each plant category (hybrid excluded).

TYPE	Average Energy (GWh/per unit)	Average Capacity (MW/unit)
Binary	27	5
Back Pressure	96	6
Single Flash	199	31
Double Flash	236	34
Dry Steam	260	46

4.3 Commissioning Date

The geothermal power plant development history can be easily read from the commissioning date of each individual power plant as stated from operators.

The following figure 83 is the cumulated capacity, on yearly basis. It is not the effective 2010 installed capacity, because decommissioned plant are still considered. There was an initial exponential phase from 1946 to 1990, and after a smooth linear growing, with a more evident (but still linear) increase in the slope after 2005.

The average since 1990 is about 300 MW/year. In the last five years, however, this slope is slightly increased up to 350 MW/year.

The different type of power plant had their individual history, and some categories were more popular and used in the past. The figure 84 shows the installed capacity per category per year.

The first Double Flash has been installed in 1977, with the Japan Hatchobaru 1 of 55 MW (Mitsubishi), whereas only in 1984 an important installation of binary plants started, with the four 2.5 MW Ormat units of Mammoth I in California, USA.

From 1980 and 1990 there was an impressive series of new plants, but the "geothermal year" can be considered 1997, with 680 MW commissioned, all Single Flash. The most important installation of Binary plants, 183 MW was in 2009, for Double Flash in 1986, with 368 MW, for Dry Steam in 1985, with 489 MW. It is possible to arrange the plant commissioning data accordingly the individual countries, as in figure 85. In the following table XIII the starting date with at least 5 MW for each country is presented.

Table XIII: Initial geothermal electricity development per country.

COUNTRY	DATE
Italy	1916/1946
New Zealand	1958
USA	1960
Japan	1966
Russia	1966
México	1973
El Salvador	1975
Iceland	1978
Philippines	1979
China	1981
Kenya	1981
Indonesia	1983
Nicaragua	1983
France	1984
Turkey	1984
Costa Rica	1994
Portugal	1994
Guatemala	1998
Ethiopia	1999
Papua New Guinea	2001
Germany	2008

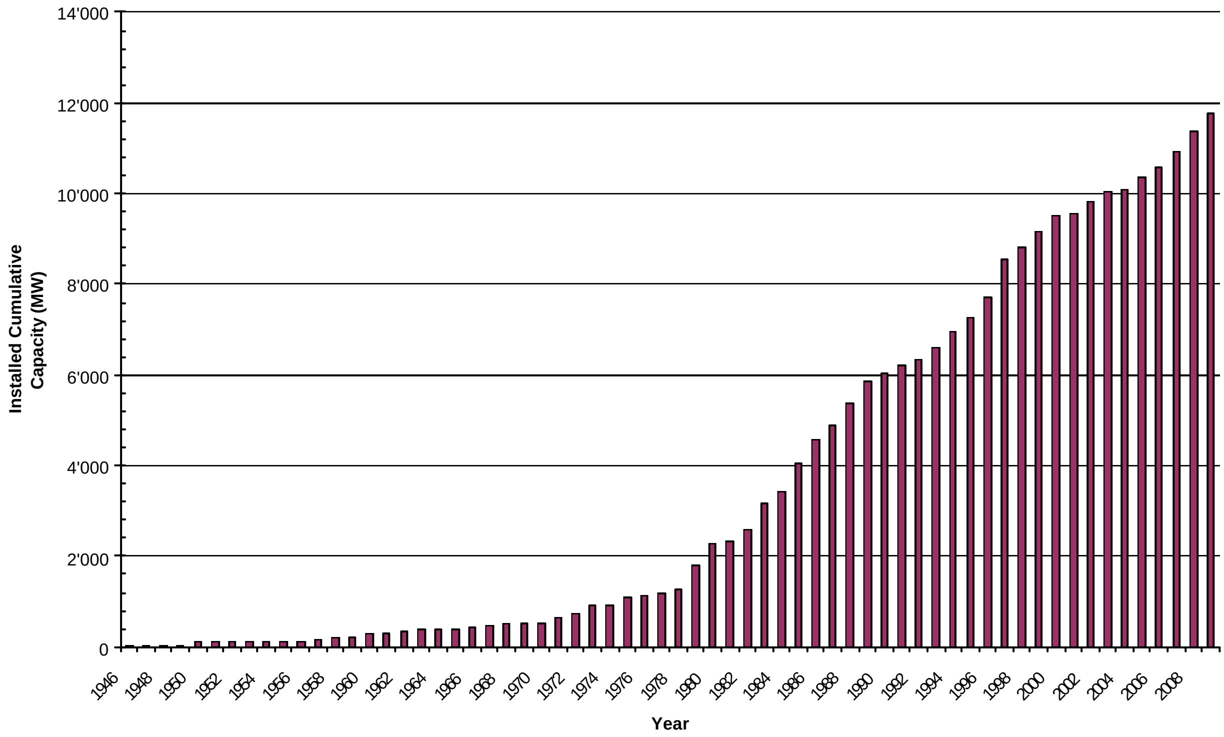

Figure 83: Cumulated capacity from Second World War.

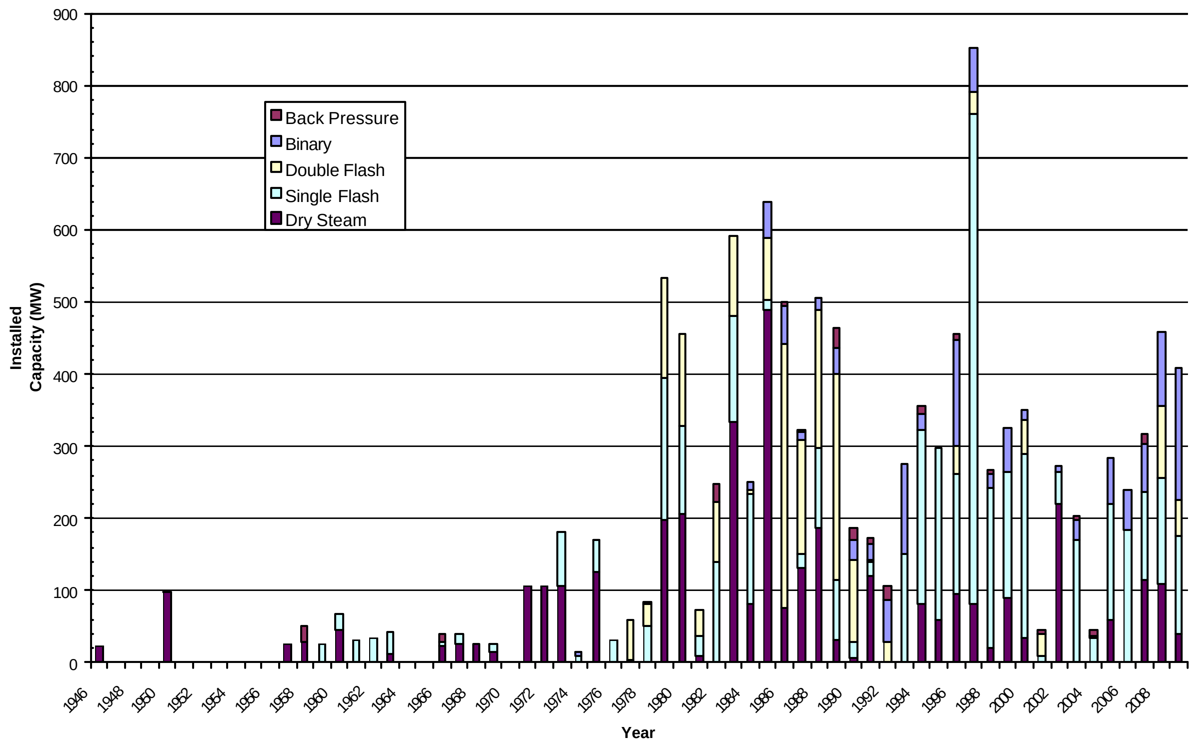

Figure 84: Installed capacity from Second World War per each category of plants.

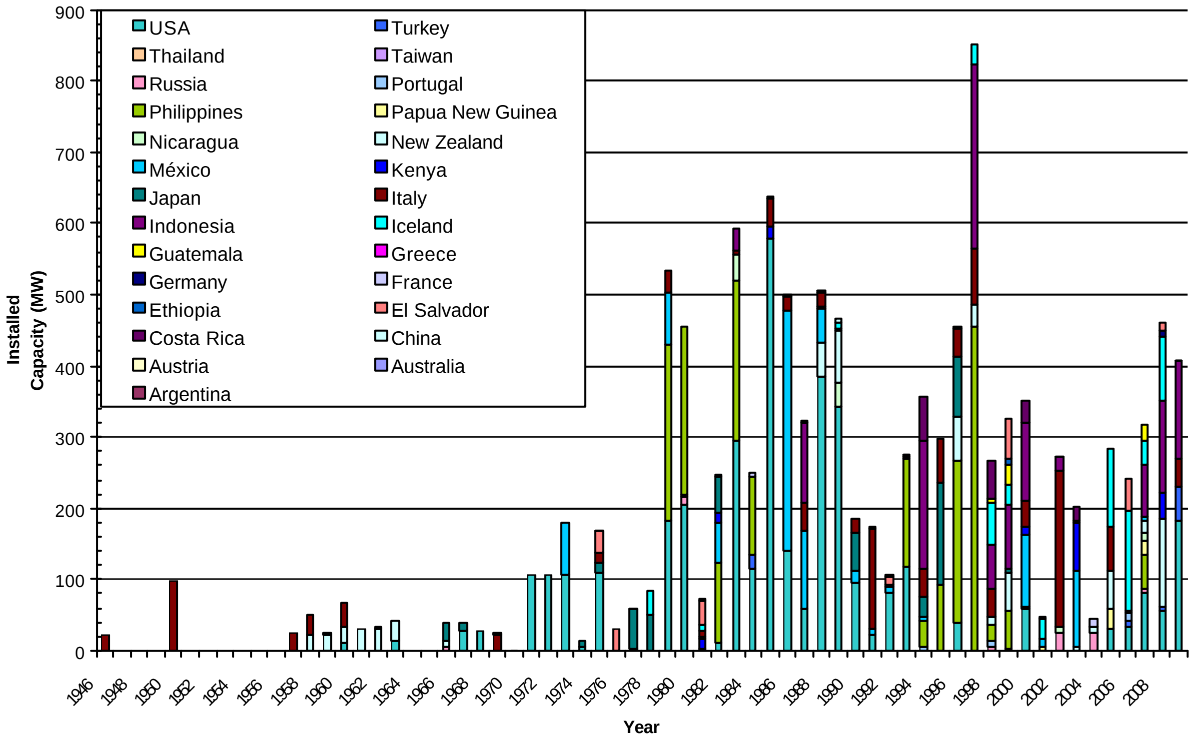

Figure 85: Installed capacity from Second World War per each country.

4.4 Companies Ranking

Field Owners

The companies currently operating geothermal fields are presented in figure 86, with their installed capacity and produced energy.

The first five are Chevron (USA, but operative in the Philippines and Indonesia), EDC/Firstgen (Philippines), Comisión Federal de Electricidad (México), Calpine (USA) and Enel Green Power (Italy, with presently operative field in USA).

Plant Operators

The companies currently operating geothermal fields are presented in figure 87, with their installed capacity and produced energy.

The first five are Comisión Federal de Electricidad (México), Calpine (USA), Enel Green Power (Italy), EDC/Firstgen (Philippines) and Chevron (USA).

In table XIV and figure 88 only the integrated operators, active both for field management and power plant operations are presented, ranked for their cumulative capacity.

4.5 Field Ranking

The list of all the geothermal field with a production of at least 100 GWh is presented in table XV.

The data are presented also in figure 89, on the world map, for the top twelve fields.

4.6 Manufacturer Ranking

The Turbine manufacturer for the plant currently in operation are presented in table XVI and figure 90. It is surprisingly to have at the first position Japanese companies, whereas in Japan construction of geothermal plants is practically halted.

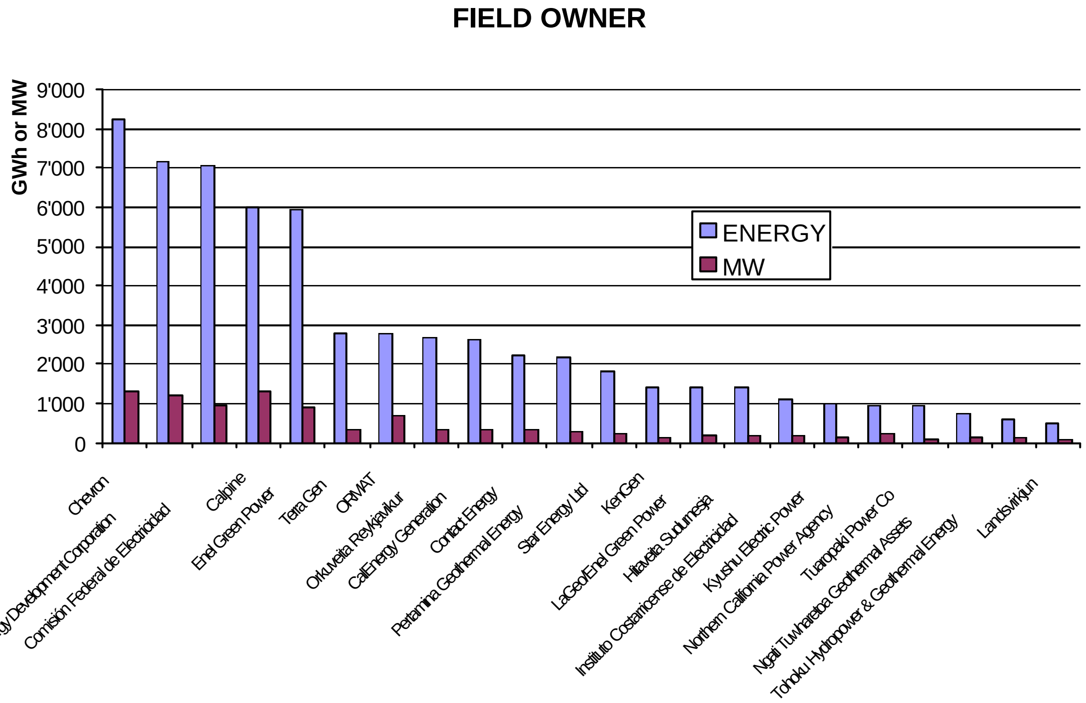

Figure 86: The most important geothermal field operators.

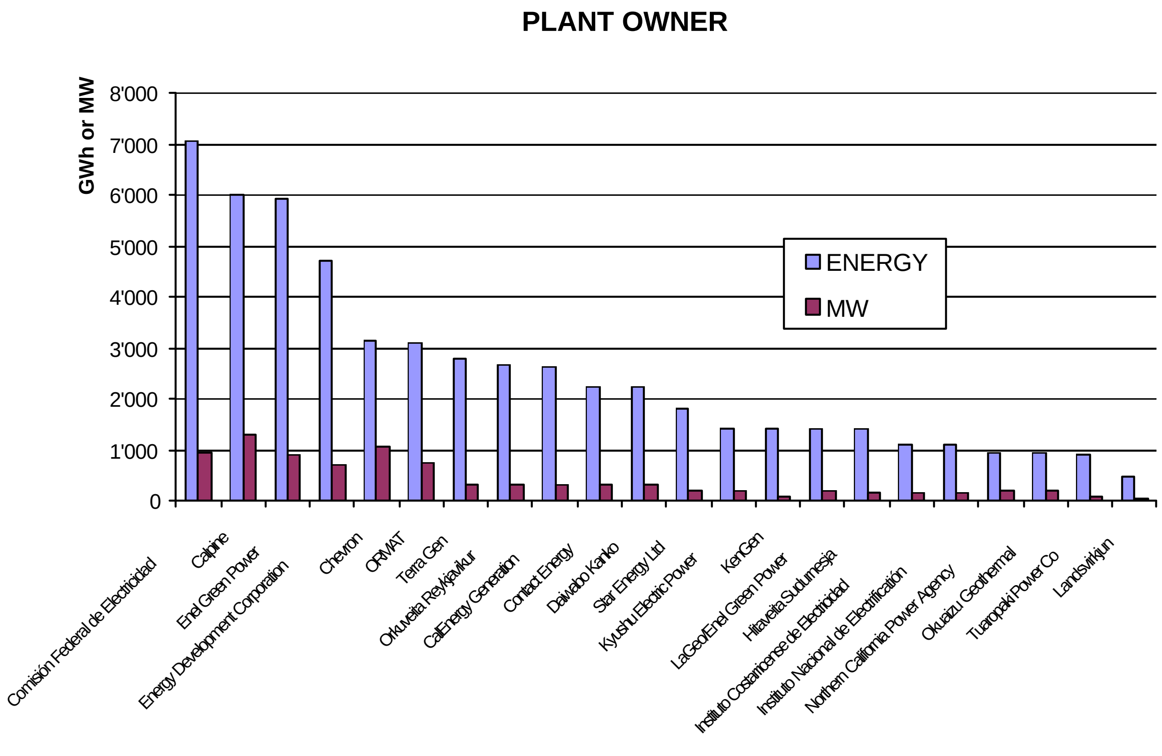

Figure 87: The most important geothermal power plant operators.

Table XIV: Integrated field and plant geothermal operators.

COUNTRY	COMPANY	FIELD (MW)	PLANT (MW)
USA	Calpine	1'310	1'310
USA	Chevron	1'329	1'087
Philippines	Energy Development Corporation	1'212	707
México	Comisión Federal de Electricidad	958	958
Italy	Enel Green Power	915	915
Israel	ORMAT	689	749
USA	Terra Gen	337	337
New Zealand	Contact Energy	335	335
Iceland	Orkuveita Reykjavikur	333	333
USA	CalEnergy Generation	329	329
Indonesia	Star Energy Ltd	227	227
USA	Northern California Power Agency	220	220
El Salvador	LaGeo/Enel Green Power	204	204
Japan	Kyushu Electric Power	155	210
Iceland	Hitaveita Sudurnesja	176	176
Costa Rica	Instituto Costarricense de Electricidad	166	166
Kenya	KenGen	115	115
New Zealand	Tuaropaki Power Co	111	111
Guatemala	Instituto Nacional de Electrificatión	52	166
New Zealand	Ngati Tuwharetoa Geothermal Assets	157	50
Russia	SC Geoterm	82	82
Iceland	Landsvirkjun	63	63
Papua-New Guinea	Lihir Gold Ltd mine	56	56
USA	Nevada Geothermal Power	50	50
Turkey	GURMAT	47	47
USA	Constellation Energy/Ormat	40	40
Japan	Nittetsu Kagoshima Geothermal	30	50
USA	Pacific Corporation	36	36
Portugal	Electricidade dos Açores	29	29
China	Electric Power Tibet	24	24

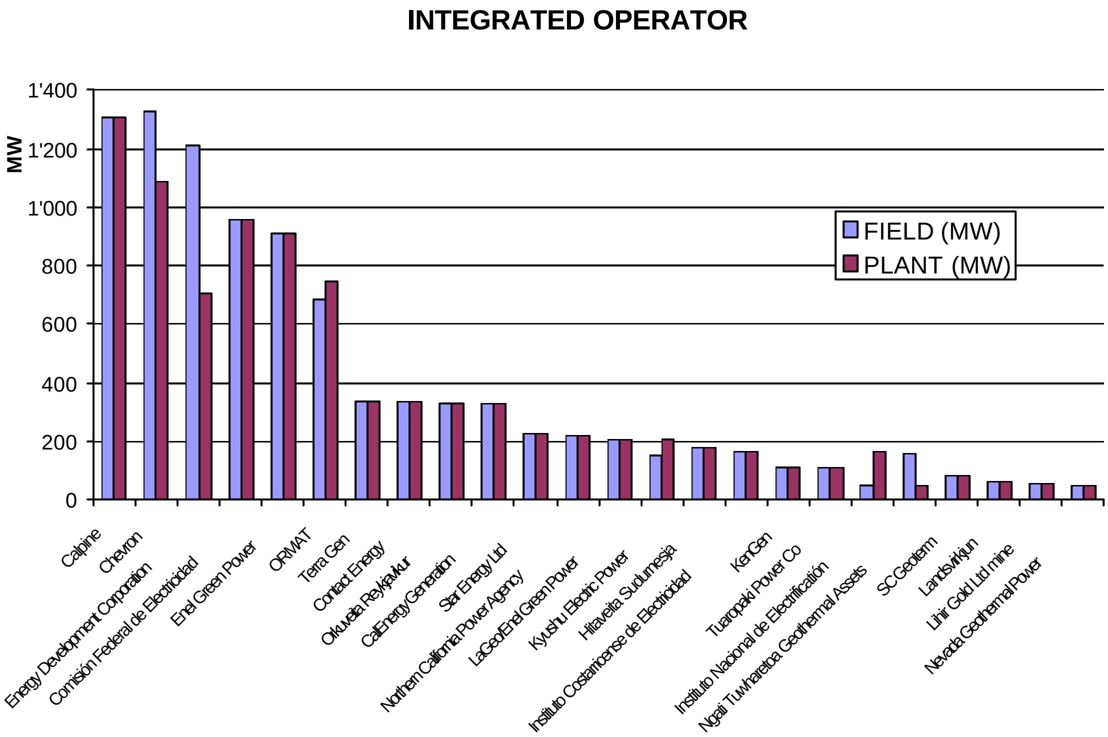

Figure 88: The most important integrated geothermal operators.

Table XV: List of the geothermal fields with production >100 GWh/year.

FIELD	COUNTRY	MW	GWh
CA-The Geysers	USA	1585	7062
Cerro Prieto	México	720	5176
Tongonan/Leyte	Philippines	716	4746
Larderello	Italy	595	3666
Java - Gunung Salak	Indonesia	377	3024
CA-Salton Sea	USA	329	2634
CA-Coso	USA	270	2381
Mak-Ban/Laguna	Philippines	458	2144
Java - Darajat	Indonesia	260	2085
Java - Wayang Windu	Indonesia	227	1821
Hellisheidi	Iceland	213	1704
Wairakei	New Zealand	232	1693
Java - Kamojang	Indonesia	200	1604
Los Azufres	México	188	1517
Olkaria	Kenya	167	1430
Palinpinon/Negros Oriental	Philippines	193	1257
Travale-Radicondoli	Italy	160	1209
Miravalles	Costa Rica	166	1131
Oita	Japan	152	1106
Tiwi/Albany	Philippines	234	1007
Nesjavellir	Iceland	120	960
Mokai	New Zealand	111	927
Reykjanes	Iceland	100	800
Berlin	El Salvador	109	753
Mindanao/Mount Apo	Philippines	103	751
CA-Heber	USA	205	708
NV-Steamboat	USA	140	696
Ahuachapan	El Salvador	95	669
Svartsengi	Iceland	76	611
Akita	Japan	88	568
CA-East Mesa	USA	120	556
Reporoa	New Zealand	103	549
Java - Dieng	Indonesia	60	481
Sulawesi - Lahendong	Indonesia	60	481
Krafla	Iceland	60	480
Mt. Amiata-Piancastagnaio	Italy	68	475
Kawerau	New Zealand	122	473
Lihir Island	Papua New Guinea	56	450
Iwate	Japan	104	447
NV-Dixie Valley	USA	67	426
Bacon-Manito/Sorsogon/Albany	Philippines	152	390
Severo-Mutnovsky	Russia	62	381
Fukushima	Japan	65	363
Aydin-Germencik	Turkey	47	360
Kagoshima	Japan	60	347
UT-Roosvelt	USA	36	328
NV-Stillwater	USA	48	314
Los Humeros	México	40	313
Momotombo	Nicaragua	78	275
Rotokawa	New Zealand	35	273
HI-Puna	USA	35	237
CA-Mammoth	USA	40	236
NV-Blue Mountain	USA	50	177
Ribeira Grande	Portugal	29	175
Mt. Amiata-Bagnore	Italy	20	170
Amatitlán	Guatemala	24	158
Yangbajain	China	24	150
Northland	New Zealand	25	140
Zunil	Guatemala	28	131
NV-Beowawe	USA	17	129
NV-Brady Hot Spring	USA	26	122
Hokkaido	Japan	50	115
NV-Desert Peak	USA	23	106
Miyagi	Japan	13	104
Sumatra - Sibayak	Indonesia	13	104

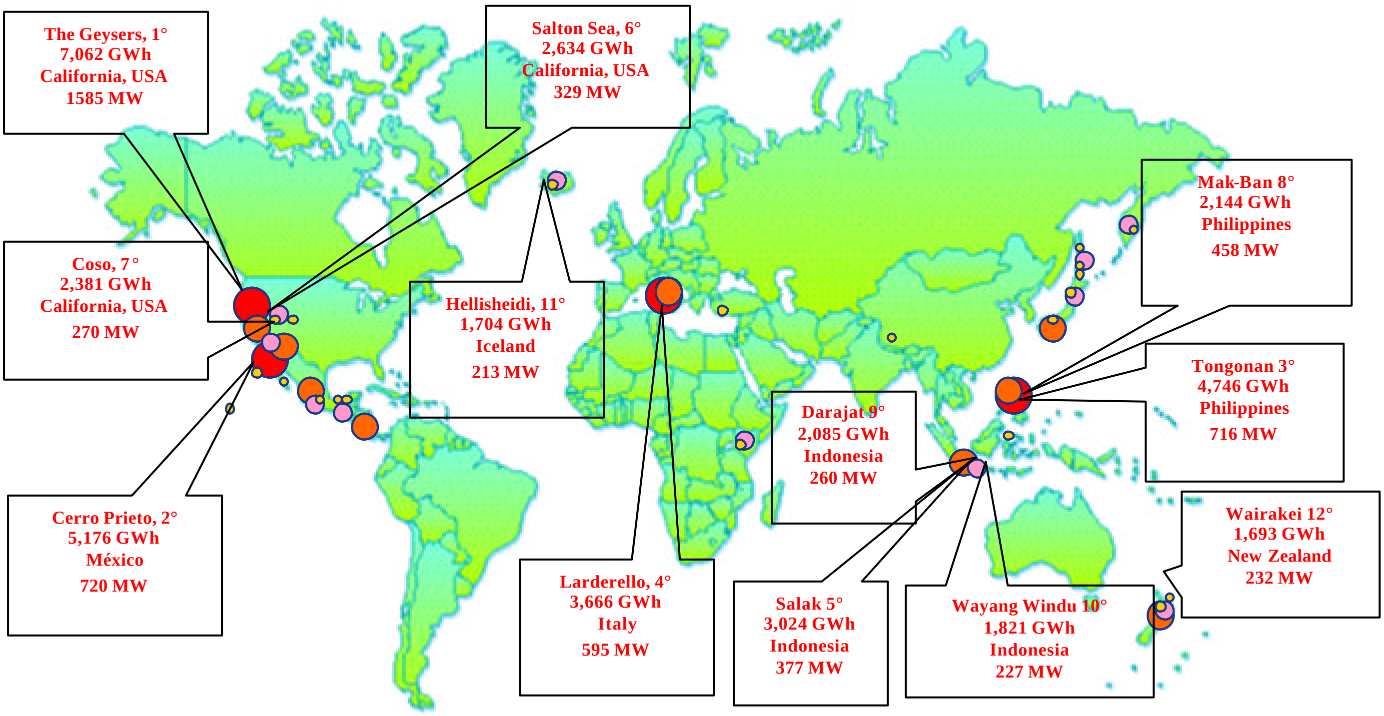

Figure 89: World Map of the top 12 geothermal fields. The dots are proportional to the field size.

Table XVI: List of the geothermal turbine manufacturer.

MANUFACTURER	COUNTRY	Back Pressure	Binary	Single Flash	Double Flash	Dry Steam	TOTAL
Mitsubishi	Japan	30	0	1'211	869	520	**2'630**
Toshiba	Japan	5	0	823	490	1'207	**2'524**
Fuji	Japan	0	0	1'238	608	300	**2'147**
Ansaldo/Tosi	Italy	40	0	523	0	575	**1'138**
ORMAT	Israel	0	1'074	0	26	0	**1'100**
General Electrics/Nuovo Pignone	USA/Italy	6	0	213	54	277	**550**
Alstom	France	10	0	140	5	0	**155**
Associated Electrical Industries	New Zealand	0	0	90	0	0	**90**
Kaluga Turbine Works	Russia	0	0	82	0	0	**82**
British Thompson Houston	UK	34	0	48	0	0	**82**
Mafi Trench	USA	0	72	0	0	0	**72**
Qingdao Jieneng	China	0	0	0	21	0	**21**
Westinghouse	USA	0	0	14	0	0	**14**
Kawasaki	Japan	2	0	13	0	0	**15**
UTC/Turboden	USA/Italy	0	13	0	0	0	**13**
Enex	Iceland	0	11	0	0	0	**11**
Harbin	China	0	0	11	0	0	**11**
Elliot	New Zealand	8	0	2	0	0	**10**
Makrotek	México	5	0	0	0	0	**5**
Parsons	New Zealand	5	0	0	0	0	**5**
Siemens	Germany	0	4	0	0	0	**4**
Barber-Nichols Inc.	USA	0	2	0	0	0	**2**
Peter Brotherhood	UK	0	1	0	0	0	**1**
TOTAL		**145**	**1'178**	**4'409**	**2'074**	**2'878**	**10'683**

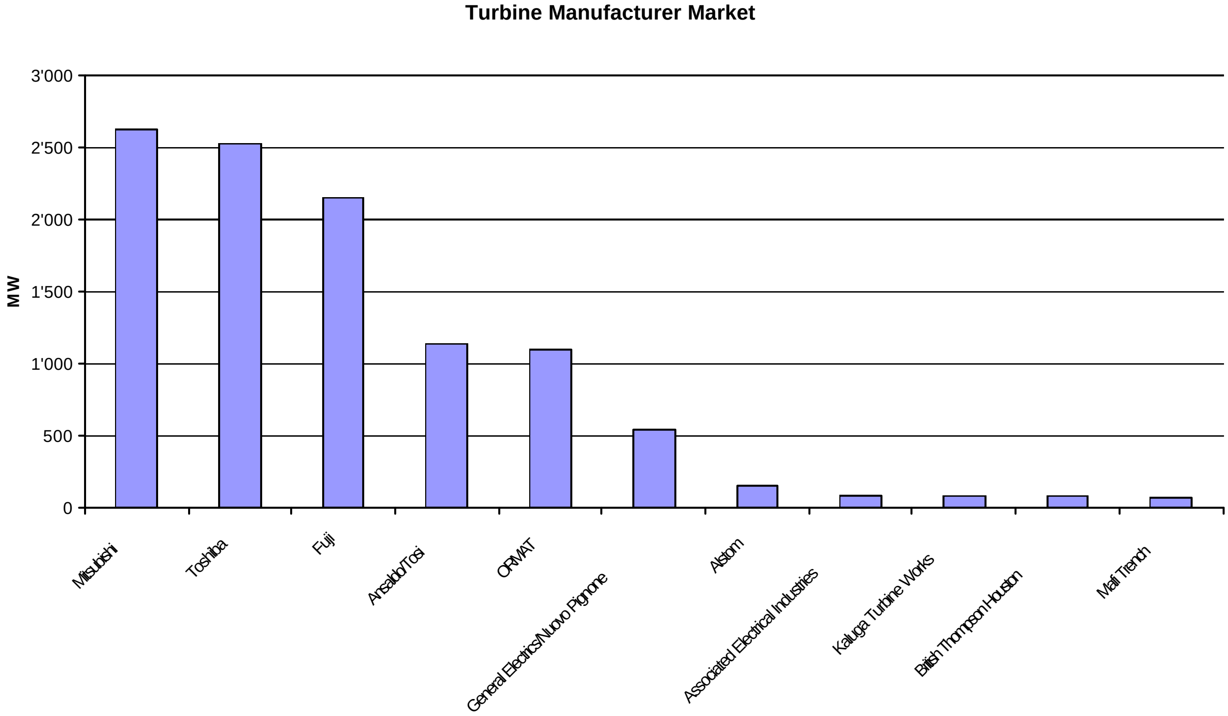

Figure 90: Top geothermal turbine manufacturer.

5. CONCLUSION

The present value of 10.7 GW is an important result, breaking the 10 GW threshold.

The average geothermal capacity on the entire 526 unit in operation is 20.6 MW. Present typical unit values for each plant category are:

- Small (binary, back pressure) about 5 MW,
- Medium (Flash plants), around 30 MW,
- Big (Dry Steam), 45 MW per unit.

Four countries realized plants for more than 100 MW of increase since 2005: USA, Indonesia, Iceland and New Zealand. This is an important signal: even in countries where the geothermal development started more than 50 year ago, still the industry is presently proactive in launching new projects, and the economical environment is strongly positive in terms of incentives and supporting measures.

The first three companies operating geothermal power plant, accordingly to the produced electricity, are: Comisión Federal de Electricidad (México), Calpine (USA) and Enel Green Power (Italy).

The expected target from hydrothermal resources of 70 GW for year 2050 is very ambitious, as can be seen from figure 91 (EGS contribution is not considered).

It would be necessary to abandon the present linear trend and jump over the exponential increase, mainly from the increasing in the medium-low temperature development projects through binary plants, and an important effort in realizing all the economically viable projects worldwide. The short term forecasting for 2015 is an hope: the expected 18 GW is on the exponential behavior forecasting. Now it would be important to transform 7 GW of paper-projects in real plants in five years. This challenge will be able to give to the entire geothermal community a clear signal of the possibility and the willingness of being one of the most important renewable energy player in the future electricity market.

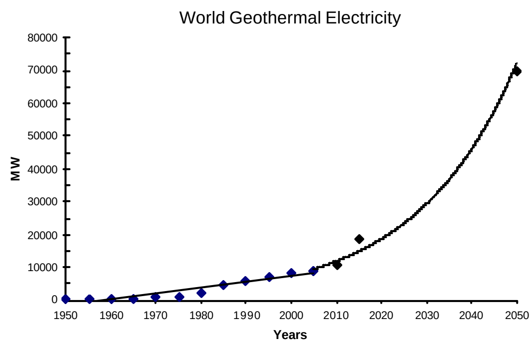

Figure 91: Forecasting up to year 2050.

If the target of 140 GW will be reached (with EGS), it would be possible to produce from geothermal up 8.3% of total world electricity production, serving 17% of world population. Moreover, 40 countries (located mostly in Africa, Central/South America, Pacific) can be 100% geothermal powered.

The overall CO_2 saving from geothermal electricity can be in around 1,000 million tons per year.

We can hope to see in the coming years another "geothermal year" as in 1997, with 680 MW commissioned: so let us close this paper with the following question:

Is it possible to have another year like 1997 in geothermal electricity development in the world?

All the geothermal community, operators, manufacturer, authorities, regulation bodies, and general public should work for reaching such very ambitious goal.

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