WORLD GEOTHERMAL GENERATION IN 2007

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BACKGROUND

The major activities carried out for geothermal electricity generation since WGC2005 are analyzed in this paper.

Data are presented for the countries where some new addition to the existing capacity has been realized, with exception for the European countries, which is presented with some updated information, even in cases where there has been no new addition. Reference is made to WGC2005 world update papers (Bertani, 2005a, 2005b and 2006) for further details and analytical description of the existing geothermal fields and on the relevant on-going activity.

New data has been taken from private communications from IGA members and Affiliated Organizations, and the author would like to acknowledge all IGA (international Geothermal Association) 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 2007, are included in the installed capacity.

An increase of about 800 MW in the three year term 2005-2007 has been achieved, following the rough standard linear trend of approximately 200/250 MW per year.

INTRODUCTION

The total installed capacity from worldwide geothermal power plant is given in Table 1 and Figure 1.

Table 1: Total worldwide installed capacity from 1975 up to end of 2007 (estimated).

Year	Installed Capacity MW
1975	1,300
1980	3,887
1985	4,764
1990	5,832
1995	6,833
2000	7,972
2005	8,933
2007	9,732

Binary plant technology is playing a very important role in the modern geothermal electricity market. The economics of electricity production are influenced by the drilling costs and resource development (typical CAPEX (Capital Expense) quota is 30% for reservoir and 70% plant); the productivity of electricity per well is a function of reservoir fluid thermodynamic characteristics (phase and temperature), and the higher the energy content of the reservoir fluid, the lesser is the number of required wells and as a consequence the reservoir CAPEX quota is reduced.

Moreover, a binary plant can be an efficient way for recovering the energy content of the reservoir fluid after its primary utilization in a standard flash plant, achieving a better energy efficiency of the overall system. Whereas in the dry steam reservoir (Larderello-Italy, The Geyser-USA) the exploited energy of the fluid can be fully utilized, in all other situation worldwide the majority of the thermal energy from the extracted fluid is lost, being reinjected at high temperature and practically not used and wasted. The binary plants on the reinjection stream could be a very effective way of producing cheap energy, because there will not be any additional exploitation costs associated with this extra production. Utilization of low temperature resource can be achieved only with binary plant, increasing the overall exploitable potential worldwide. The author has included in this paper a selection of public domain pictures of existing (old and new) binary plants worldwide.

In Table 2 data from all the countries currently generating geothermal electricity are presented, with data for 2000 and 2005, 2007, and the present running capacity, as well as the increment since 2005 both in absolute terms and as a percentage. A forecast for 2010, considering the existing project in advanced stage of development, is also presented. In Figure 2, a world map of the year 2007 installed capacity is presented.

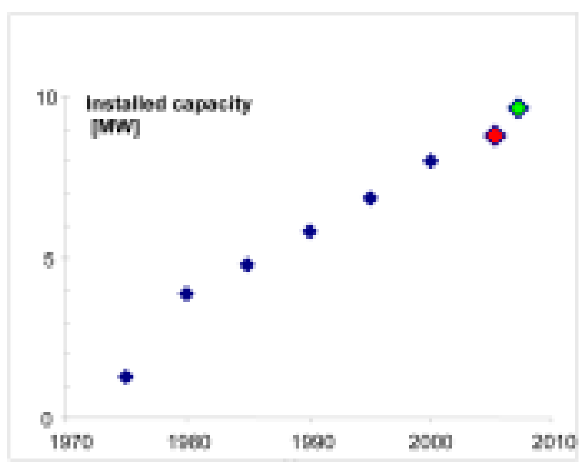

Figure 1: Installed capacity from 1975 up to end of 2007 and estimated to 2010.

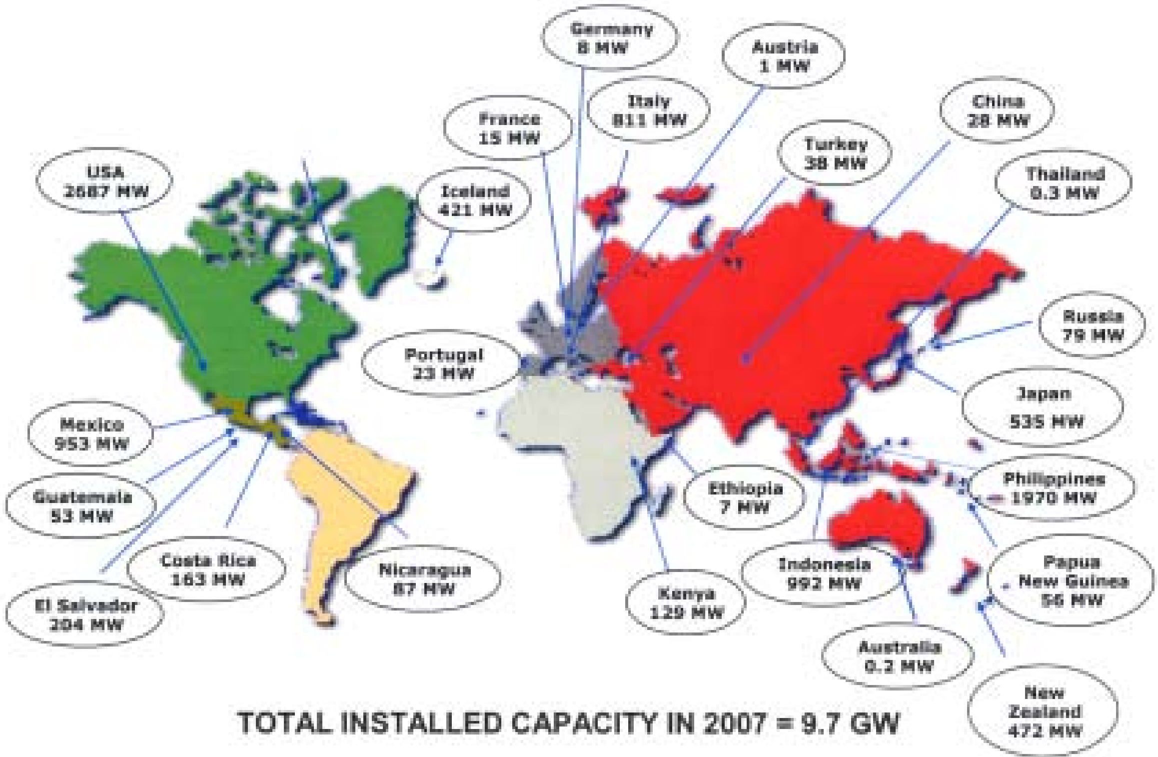

Figure 2: Installed capacity in 2007 worldwide.

Table 2: 2000, 2005 and 2007 installed capacity and forecast to 2010.

COUNTRY	**Installed Capacity in 2000 (MW)**	**Installed Capacity in 2005 (MW)**	**Installed Capacity in 2007 (MW)**	**Running Capacity in 2007 (MW)**	**Increment (MW)**	**Increment (%)**	**Forecasting for 2010 (MW)**
AUSTRALIA	0.2	0.2	0.2	0.1			0,2
AUSTRIA	0.0	1.1	1.1	0.7			1
CHINA	29.2	27.8	27.8	18.9			28
COSTA RICA	142.5	163.0	162.5	162.5			197
El SALVADOR	161.0	151.0	204.2	189.0	53	35%	204
ETHIOPIA	7.3	7.3	7.3	7.3			7
FRANCE	4.2	14.7	14.7	14.7			35
GERMANIA	0.0	0.2	8.4	8.4	8		8
GUATEMALA	33.4	33.0	53.0	49.0	20	61%	53
ICELAND	170.0	202.0	421.2	420.9	219	109%	580
INDONESIA	589.5	797.0	992.0	991.8	195	24%	1192
ITALY	785.0	791.0	810.5	711.0	20	2%	910
JAPAN	546.9	535.0	535.2	530.2			535
KENYA	45.0	129.0	128.8	128.8			164
MEXICO	755.0	953.0	953.0	953.0			1178
NEW ZEALAND	437.0	435.0	471.6	373.1	37	8%	590
NICARAGUA	70.0	77.0	87.4	52.5	10	14%	143
PAPUA-NEW GUINEA	0.0	6.0	56.0	56.0	50	833%	56
PHILIPPINES	1909.0	1930.0	1969.7	1855.6	40	2%	1991
PORTUGAL	16.0	16.0	23.0	23.0	7	44%	35
RUSSIA	23.0	79.0	79.0	79.0			185
THAILAND	0.3	0.3	0.3	0.3			0,3
TURKEY	20.4	20.0	38.0	29.5	18	90%	83
USA	2228.0	2564.0	2687.0	1935.0	123	5%	2817
TOTAL	**7973**	**8933**	**9732**	**8590**	**800**		**10993**

GEOTHERMAL POWER GENERATION STATUS SUMMARIES

Austria

In the country two small binary plants are installed: Altheim and Bad Blumau.

In Altheim a 106°C fluid is utilized both for district heating and for electricity production using a binary plant (Figure 3). The net output is 500 kW, after accounting for the 350 kW for submersible pump parasitic load, selling to the grid 1.1 GWh in 2006.

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

The RES-E (renewable energy sources – electricity) target to be achieved in Austria by 2010 is 78% of gross electricity consumption. In 2004, the share of renewable energy in gross electricity consumption reached 62% (it was 70% in 1994); the geothermal installed capacity of 1.1 MW (0.7 MW net) plays a marginal role.

Figure 3: Altheim Binary Plant.

Costa Rica

No new power plant has been added to the country geothermal capacity, which is 163 MW at Miravalles. A 35 MW plant is planned in Rincon de la Vieja.

El Salvador

There are two major geothermal fields in this country: Ahuachapán and Berlín.

In the Ahuachapán area two 30 MW single flash and one 35 MW double flash are currently online; due to the reservoir decline, only 78 MW of net capacity are currently in operation. A project for reaching the full capacity loading of the units (Ahuachapán optimization) is under study. The possibility of further increase of the residual heat exploitation through a 3.5 MW binary plant is also under consideration.

In Berlín two 28 MW single flash units have been installed before 2005; two major additions have been placed online up to today: a bottoming cycle binary unit for 9.2 MW (Figure 4) and a single flash 44 MW unit, built by Enel (Italy) under a shareholder agreement with LaGeo (El Salvador, ownership and developer of the geothermal resources of the country).

The total installed capacity of the country is raised to 204 MW (189 MW running), with an increase of 35% from 2005.

Figure 4: Berlin Binary Plant.

France

The high enthalpy utilization for electricity production in France is only in the French Overseas Department, at Bouillante on Guadeloupe Island. The total capacity of 15 MW, which has not increased since 2005, produces 95.3 GWh, corresponding to 8% of the local consumption (Figure 5). The activity for the third unit of 20 MW is ongoing.

On the islands of La Martinique and La Réunion, geothermal exploration programs are planned in the near future.

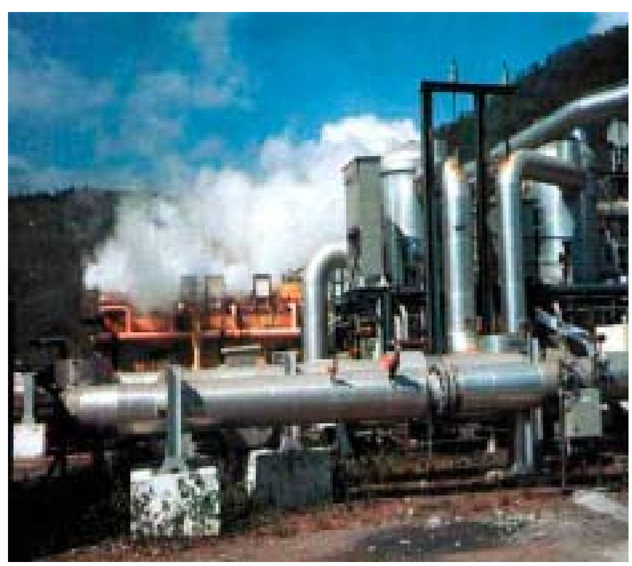

Figure 5: Bouillante Binary Plant.

The Hot Dry Rock (HDR) project at Soultz-sous-Forêts is now constructing a scientific pilot plant module of 1.5 MW. The enhanced geothermal system, exploited with a three-well system bored through granite to a depth of 5000 m, is expected to come into operation during 2008.

The RES-E target from the EU Directive for France is 21% RES-E share of gross electricity consumption in 2010. France's share of RES-E was 13% in 2004 (it was 15% in 1997). Geothermal electricity is not available on the mainland, but in the Caribbean islands it can reach up to 20% of electricity needs. HDR electricity will not be available at industrial level before year 2010.

Germany

The first geothermal plant for electrical power generation in Germany is at Neustadt-Glewe (Figure 6), with an installed capacity of about 230 kW with a binary cycle using 98°C geothermal fluid. In addition 10.7 MWt are used for district and space heating. The energy production is about 1.5 GWh per year.

Currently more than 150 permits for prospecting geothermal energy for power production have been given to companies by the German state mining authorities. Three new plants will start their operation in 2007: Landau/Pfalz (3.8 MW), Bruchsal (1 MW), Unterhaching (3.2 MW). The total installed capacity is foreseen about 8 MW.

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

The RES-E targets set for Germany are 12.5% of gross electricity consumption in 2010, and 20% in 2020. Substantial progress has already been made towards the 2010 RES-E target. Germany's RES-E share in 2004 is 9%, whereas in 1997 it was only 4%. The 2010 target is scheduled to break even this year.

Figure 6: Neustadt GleweBinary Plant.

Guatemala

In this country the geothermal resource is present in two fields, Zunil and Amatitlan.

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 , has an estimated capacity of 50 MW whereas the second one, with 240°C has an estimated capacity of 50 MW (28 MW installed).

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 old 5 MW backpressure unit, a new 20 MW binary plant at Amatitlan has been commissioning this year, bringing the total installed capacity of the country to 53 MW, with an increase of 61% on the value of 2005. An exploration of the Tecuamburro area, aimed to a 40 MW project, is currently under preliminary stage of permitting.

Iceland

The geothermal electricity production in Iceland has increased significantly since 2005, with the installation of new plants in Nesjavellir, Hellisheidi and Reykjanes. The total installed capacity is as follows:

- Bjarnarflag, with a small 3.2 MW unit (the first plant in Iceland) and 40 additional MW under construction, in combination with an outdoor swimming pool, sauna and tourist center, following the "Blue Lagoon" model;
- Hellisheidi: 90 MW are on-line, and 120 MW are currently under construction, for a final total of 210 MW and 400 MWt of thermal output for district heating; the electricity is supplied mainly to local aluminum refineries;
- Husavik, with the first geothermal Kalina power plant in operation for 2 MW (Figure 7), using geothermal water at 124°C; the discharged fluid at 80°C is used for the district heating of the town, satisfying 75% of the heat demand;
- Krafla: two 30 MW double flash turbines for 60 MW total;
- Nesjavellir: four 30 MW units (total 120 MW), combining heat/electricity production with 300 MWt for district heating;
- Reykjanes: two 50 MW units for a total of 100 MW;
- Svarstenegi: two flash units (30 and 8 MW) and an 8 MW binary unit, for a total of 46 MW and hot water production of 150 MWt for district heating and the famous outdoor swimming/spa facilities of Blue Lagoon.

The total installed capacity of the country is 422 MW, and additional 160 MW under construction, with an increase on the 2005 capacity of 108%.

The Icelandic Deep Drilling Project (IDDP) has been moved near the Krafla geothermal area, in the northern part

Figure 7: Husavik Kalina Binary Plant.

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.

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 tonnes 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 tonnes of aluminum. This will be a very efficient way of exporting the surplus of cheap and abundant geothermal electricity production from Iceland.

The Icelandic National Energy Authority has entered into an agreement with the German company Energie Baden-Württemberg (EnBW) to examine whether electricity can be transported from Iceland to Germany via an undersea cable.

The country with 300,000 inhabitants is 100% renewably powered, with 17% of its electricity and 87% of heating needs provided by geothermal energy.

Indonesia

After the economic crisis of the recent past, this country is starting geothermal activity again with important power plant construction and exploration. Only one area is still pending under arbitration after the litigation process due to the heavy local currency depreciation, but it is near to a positive conclusion; in all the other geothermal fields the situation is clarified and companies (local and international) are now investing and there are good perspectives and positive signals from the market, still to be confirmed over the next months.

The new plants commissioned or under very advanced stage of construction are 110 MW in Darajat, 20 MW at Lahendong and 10 MW at Sibayak, reaching the total installed capacity of 992 MW, with an increase of 24% on the 2005 value; its distributions is as follows:

- Darajat: two old units of 55 and 90 MW and a new one of 110 MW for a total of 255 MW; the geothermal resource is vapor dominated;
- Dieng: one unit of 60 MW;
- Kamojang: one 30 MW and two 55 MW units, for a total of 140 MW; 60 additional MW are currently under construction; this field is a dry steam reservoir;
- Lahendong: two 20 MW units, for a total of 40 MW installed and further 20 MW under construction;
- Salak: six similar units for a total of 375 MW;
- Sibayak: one 2 MW and two 5 MW units, for 12 MW in total;
- Wayang Windu: one 110 MW installed, a second 110 MW unit under preparation for construction.

Italy

There are two major geothermal areas in Italy: Larderello-Travale/Radicondoli and Mount Amiata, with a total installed capacity of 810 MW (711 MW running capacity, Buonasorte, et al., 2007).

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. In the Larderello side the exploited area is 250 km^2, with 21 units for 562 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.

Mount Amiata area includes two water dominated geothermal fields: Piancastagnaio and Bagnore. In both the fields a deep resource has been discovered under the shallow one. 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.

The addition since 2005 is a new unit in Larderello for 20 MW, for a modest 3% increase. Projects for further 100 MW are approved and will be realized in the coming years.

Italy has a target of a RES-E share of 25% of gross electricity consumption by 2010. No progress has been made towards this. While Italy's RES-E share amounted to 16% in 1997, it is decreased to 15% in 2004.

Enel Green Projects

Enel has a very important program for the 2007-2011 period, with a four billion euro investment plan for renewable energy generation, aimed at saving 4 million tonnes of CO_2 each year. In particular, 1,700 MW of new capacity will be installed, (1,500 MW wind, 100 MW hydro and geothermal each) for 3.3 billion euro; the investment will be 1.6 billion in Italy, and 1.7 billion abroad. 800 millions euro will be invested in innovative projects for renewable energy generation (thermodynamic solar, photovoltaic research, off-shore wind generation, and other minor projects), energy efficiency and distributed generation, "zero emissions" and hydrogen frontier.

For the "zero-emission in geothermal program", an important investment plan has been approved by Enel, 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 (owner and operator of the geothermal resources in Italy): AMIS plant (Figure 8; 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 8: AMIS Plant.

Kenya

No new addition has been realized since 2005; however, a project for 35 MW at Olkaria has been approved and it is expected to be completed within two years.

Mexico

No new addition has been realized since 2005. However, the projects Cerro Prieto V (100 MW) and Los Humeros II (46 MW) have been approved and it is expected that both will be completed by 2010. The project Cerritos Colorados (75 MW), formerly known as La Primavera, has no programmed date since it must be approved by the environmental authorities first.

New Zealand

All the geothermal projects in this country are in the central North Island or the Northland region (Ngawha). Since 2005 two new plants have been realized: a binary unit of 14 MW at Wairakei and a second stage at Mokai for 39 MW, bringing the total installed capacity of the country to 472 MW (only 373 MW running, due to the fluid supply issues at Ohaaki and to a minor extent at Wairakei, and consent restrictions for the Poihipi station on the Wairakei field), with an increase of 8%. The geothermal areas are as follows:

- Kawerau: 8 MW flash and 6 MW binary, for a total of 14 MW (but with the primary steam supply being directed to the world's largest geothermal industrial direct use application-Tasman); a new dual flash plant is under construction for 90 MW;
- Mokai: two flash units for 30+39 MW and four 4.5 MW binary plants, for a total installed capacity of 96 MW; a further binary plant expansion is under construction;
- Ngawha: two 4.8 binary plants for 9.6 MW; a new 15 MW unit is under construction;
- Ohaaki: four flash units, two of 11 MW (now decommissioned) and two of 43 MW, up to a total of 86 MW, but with only 45 MW running (and output recently reduced below 30 MW);
- Poihipi: one dry steam plant of 55 MW, but running in day-night mode averaging 25 MW normally due to consent restrictions;
- Rotokawa: one flash unit of 15 MW and three 4.5 MW binary plants and a 6 MW binary plant, for a total of 35 MW;
- Wairakei: several plants, flash and binary (Figure 9), for a total of 176 MW (but recently offering 146 MW due to supply restrictions) – there has recently been a suggestion to replace this fifty year old facility.

Figure 9: Wairakei Binary Plant.

Nicaragua

No new addition has been realized since 2005; however, a project for an additional 10 MW and subsequently 46 MW at San Jacinto is on-going, bringing the total installed capacity of this field up to 66 MW. No activities are scheduled for the other geothermal area of Momotombo.

An exploration program at El Hoyo-Monte Galan and 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.

Papua - New Guinea

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.

After an initial 6 MW back-pressure 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 and two 10 MW modules). This lifts the total capacity to 56 MW (Figure 10), with an increase of 833%.

Figure 10: Lihir Back-Pressure Steam Power Station.

Some 75% of the mining operation's current capacity needs are covered by geothermal electricity, with a significant saving estimated at approximately 40 million USD in 2007, replacing heavy fuel oil for power generation. It will also generate revenues of 3 million USD per year from the sale of carbon credits on the global market.

Philippines

The Philippines is the world's second largest producer of geothermal energy for power generation, with an installed capacity of 1,971 MW for a running capacity of 1,856 MW.

There was a minor increase since 2005, with the 49 MW at Northern Negros merchant plant (it will operate with electricity supply contracts between PNOC-EDC and electricity cooperatives and distributors) commissioned in 2007, with an increase of 2%.

The geothermal areas are as follows:

- Bac-Man: 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 151.5 MW;
- Leyte: five flash (661.5 MW), and 3 topping cycle (back pressure turbines), 1 bottoming (flash), and 1 bottom cycle binary plant (total optimization capacity 61 MW, Figure 11), for the optimization of the overall energy recovery from the geothermal system, for a total installed capacity of 723 MW;
- Mak-Ban: ten flash units and a 15.7 binary plant, for a total of 458 MW;
- Mindanao: two flash units (one single and one dual pressure) for 104 MW in total;

Figure 11: Leyte Binary Plant.

- Northern Negros: one flash (dual pressure) unit of 49 MW;
- South Negros: five flash units for 192.5 MW; an optimization project for 20 MW binary is under development;
- Tiwi: five flash units for 289 MW.

An intensive privatization process of the mining operator PNOC/EDC and of some power plants is planned for 2008.

Portugal

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

A second binary unit at Pico Vermelho of 10 MW has been installed, bringing the total island capacity up to 23 MW, with an increase of 44% (Figure 12).

The share of renewable energy generation in São Miguel is now 43%. On Terceira Island a project for installing 12 MW is ongoing.

The RES-E target to be achieved by Portugal in 2010 is 39% of gross electricity consumption. There was a sharp decline between 1997 (38%) and 2004 (24%).

Figure 12: Ribeira Grande Binary Plant.

Russia

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, Figure 13) and the second 100 MW stage of Mutnovsky are under development.

Figure 13: Verkhne-Mutnovsky Binary Plant.

Turkey

Since 2005 several construction activities have been carried out. Three new binary units of 8 MW each has been realized (Figure 14), two for exploiting medium enthalpy reservoir and one on the downstream of the separated brine from the Kizildere plant, before its use for district heating.

A new 45 MW unit is also at an early stage of construction at Germencik, with the option of a further 45 MW as potential expansion.

The total installed capacity (taking into account only Kizildere and the binary units) is 38 MW, with an increase of 90% with respect to the 2005 value.

Figure 14: Salavatli Binary Plant.

USA

Geothermal electric power plants are located in Alaska, California, Nevada, Utah and Hawaii; the total installed capacity of the country is 2,687 MW, but with only 1,935 MW actually running, with a 5% increase on year 2005. A total of 130 MW is currently under construction.

Alaska

The first geothermal power plant in this state was installed in 2006, at Chena Hot Springs. It is a binary plant (Figure 15), producing 200 kW gross from the coldest geothermal resource worldwide: only 74°C.

Figure 15: Chena Binary Plant.

A second unit has been added, reaching the total installed capacity of 400 kW gross. At the end of the construction activity, a total of 1 MW will be installed.

California

No new plant has been realized; since year 2005, some repowering at three units at The Geyser has been performed.

The relevant geothermal power plants are listed as following:

- The Geyser: 22 dry steam units, for a total of 1,531 MW installed capacity (but only 932 MW running);
- Imperial Valley-East Mesa, with 70 units for 100 MW of installed capacity;
- Imperial Valley-Heber, 94 MW of installed capacity with 14 units;
- Imperial Valley-Salton Sea, with 10 units for 327 MW;
- COSO, nine units for an installed capacity of 270 MW;
- Others, with 29 additional MW.

The total installed capacity of the state is 2,351 MW (1,715 MW running). Geothermal supplies 5% of California's electric generation, producing a net-total of 14,000 GWh/year.

Future developments are planned in Northern California, at Glass Mountain: 50 MW approved at Fourmile Hill, and 18 additional MW binary at Heber.

A new unit at Salton Sea for 185 MW has been announced. An exploration program at Surprise Valley, in northeastern California, aimed to a binary project of 45 MW has been launched by Enel.

Hawaii

No new addition at the existing ten flash+binary units of 35 MW installed capacity (30 MW running, after rehabilitation and work over) has been done since 2005. This power plant supplies approximately 20% of the total electricity need of the Big Island (160,000 inhabitants). A further 8 MW of expansion is also planned.

Nevada

A new 30 MW binary plant at Galena (Steamboat field) has been commissioned, with further two units planned by Ormat, for additional 25 MW.

The total installed capacity for the state is 275 MW (240 MW running). At Stillwater and Salt Wells, recently transferred to Enel, additional 40 MW are scheduled. At Steamboat Hills a 12 MW binary plant is also planned. Further additions are foreseen for Desert Peak (30 MW). A 30 MW binary unit is under construction at Fallon Naval Air Station.

Utah

The Cove Fort plant has been shut down; the only existing unit in the state is Roosevelt, with 26 MW of installed capacity. A further 11 MW are planned at this facility. Enel is launching a two step project of installing binary units at Cove Fort, with 25 MW in 2009 and an additional 40 MW in 2011.

GEOTHERMAL ENERGY AND OTHER RENEWABLES

At the world level, the most important renewable energy source is hydro, which represents about 93% of all the installed capacity. This quota is similar for all the continents except Europe, where wind plays a relevant role of 13%, as shown in Figure 16 (IEA, 2006).

Hydropower also has a relevant quota among the total power generation worldwide: 19% of the total electricity generation, with a growing rate of 2-5%; the largest markets are in USA, Canada, Brazil, Norway, and China. No relevant new European resources are being considered.

Wind energy provides 1% of world global power generation, with the most important countries being in Europe (Germany, Spain, Denmark) and USA. A very aggressive growth rate of 15-20% is expected, mainly in UK, China, India and Australia.

Geothermal energy provides approximately 0.4% of the world global power generation, with a stable long term growth rate of 5%. At present the largest markets are in USA, Philippines, Mexico, Indonesia, Italy and Iceland. Future developments are limited to certain areas worldwide, particularly under current technologies.

Solar energy plays a very limited role in global power generation, but it has a very high growth rate of 25-30%, especially in USA, Spain, China, Australia and India.

The growth of developing countries will produce a doubling of the global electricity demand over the next 25 years, from 15,000 TWh for 2005 to 30,000 TWh for 2030. The present renewable energy quota is 21.5% (mainly hydro), and the projected share will be 25.8% in 2030, with the distribution shown in Table 3.

The growth profile will be different for each RES region by region: in Western Europe, given the modest growth in overall electricity demand, renewable will subtract considerable market share to conventional sources.

Wind

From the present installed capacity of 74 GW, it is expected to reach 150 GW in 2010. It is a reliable technology, with attractive costs for onshore applications: the CAPEX is 0.9-1.3 euro/MW for onshore and 1.5-2.5 euro/MW for offshore, with generation costs in the range 30-60 euro/MWh for onshore and almost double for offshore.

The quality of the power and its availability is strongly dependent on the wind resource. The next generation is expected to use high power turbines (>5 MW), vertically rotating machines and dedicated offshore applications.

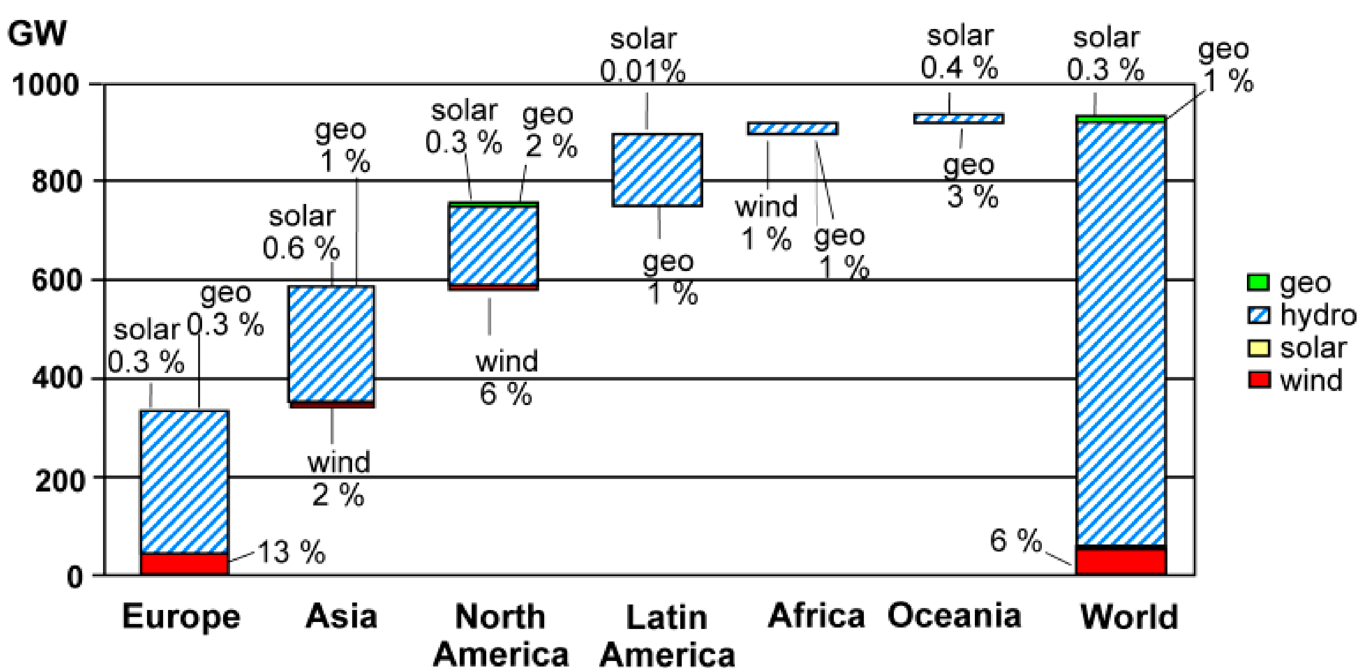

Figure 16: RES distribution by source and continent (source: IEA, 2006 - based on 2004 data).

Geothermal

The present installed capacity of 9.7 GW will increase up to 11 GW in 2010. It has medium investment costs, depending on the quality of the resource (temperature, fluid chemistry and thermodynamics phase, well productivity), ranging approximately from 2 to 4.5 euro/MW, and with very attractive generation costs, from 40 to 100 euro/MWh. It is a resource suitable for base load power.

It can be considered as broadly cost-competitive, despite its relatively high capital costs for the development of the geothermal field (resource evaluation, exploitation risk, drilling and piping) for its very high availability and the stability of the energy production.

Table 3: RES quota today and projection for 2030 (source: IEA).

RES	**2004**	**2030**
Hydro	19. 0%	16. 3%
Biomass	1. 5%	3. 3%
Solar	0. 0%	0. 8%
Wind	0. 6%	4. 8%
Geothermal	0. 4%	0. 6%
Tidal/Wave	0. 0%	0. 1%
Renewable Quota	**21. 5%**	**25. 8%**
Total Demand	**15,000 TWh**	**30,000 TWh**

For the next generation it is expected to see the implementation of the Enhanced Geothermal System (EGS) production and an intensive increasing of the low-to-medium temperature applications through binary cycle and cascade utilizations.

Solar

It is expected to reach 20 GW for 2010 through PV generation, with an increase of 35%. The costs are the least promising, from 4 to 5 euro/MW of CAPEX and 250 to 450 euro/MWh of operation. It is a peak power, non programmable and highly discontinuing. For the future, large scale technologies and cost reduction through thin-film and organic material for PV generation can be foreseen.

Europe

Restricting our analysis to Europe only, the availability of the different RES can be seen in Figure 17, where the level of wind resources at 50 m above ground level, the global solar irradiation, the gross theoretical hydraulic energy potential and the geothermal heat flow density are shown.

For geothermal electricity production, the highest concentration of resource in the continental Europe is located in Italy, Iceland and Turkey; the present exploited value is only 0.3% of all the renewable market.

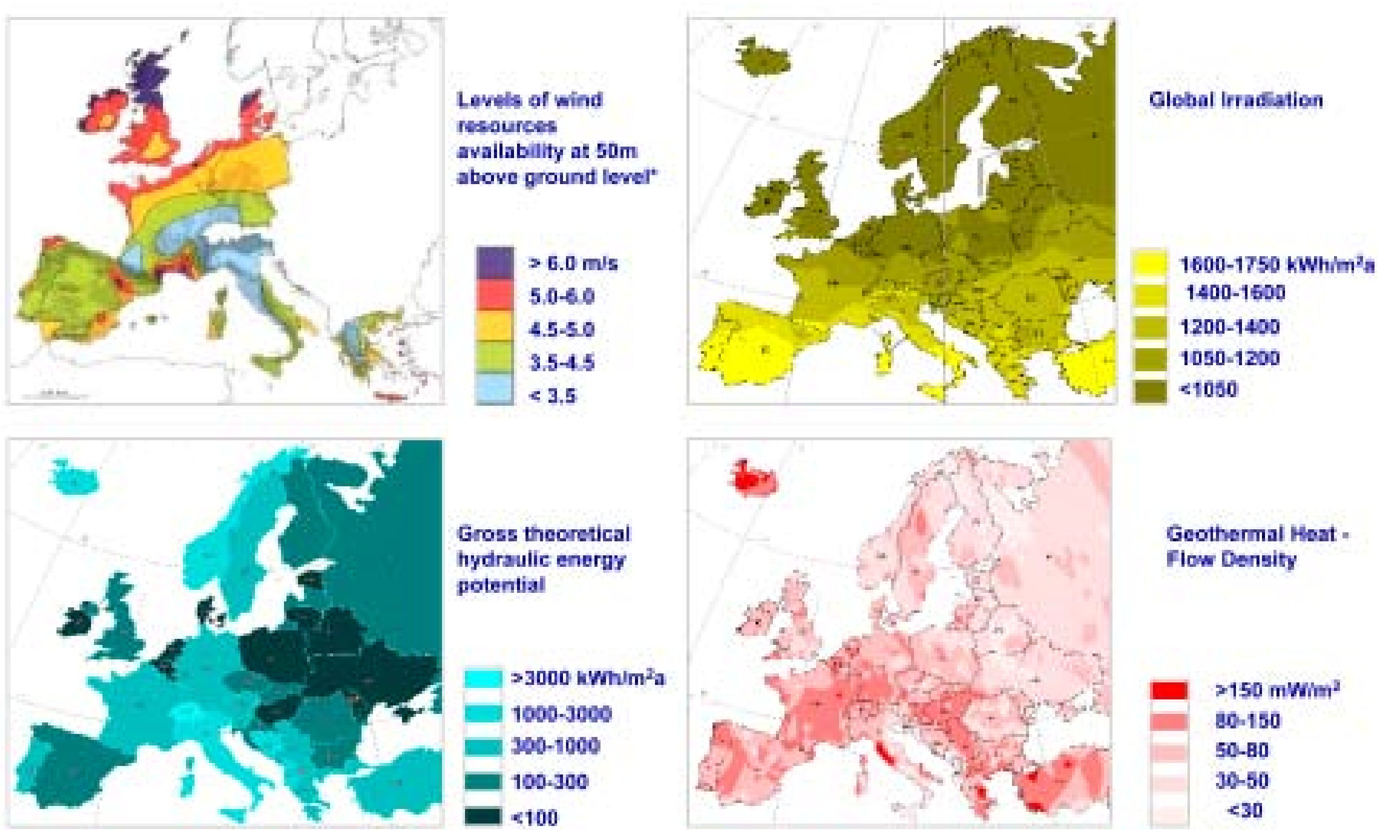

Figure 17: RES availability in Europe.

The possibilities for geothermal energy to expand its penetration in Europe is mainly from the Enhanced Geothermal System (EGS); whereas the drilling technology is already in a mature stage, and efforts can only be done to reduce the drilling costs, the stimulation technologies are still in the pilot stage.

There are many geothermal prospects with high temperature but lacking fluid in the formation or the rock permeability is too low for permitting fluid circulation. These systems can be enhanced by engineering the reservoir through stimulation activities: acidizing, and hydraulic fracturing. The development of these technologies will make a huge geothermal potential available.

The best results worldwide have been obtained from the Soultz project. The critical aspect is the seismic hazard induced by the hydraulic fracturing.

Without the EGS contribution, the expected value of the installed capacity in Europe from geothermal energy will be 1,800 MW in 2010, with an increase of 400 MW approximately.

CONCLUSION

The geothermal electricity installed capacity is approaching the 10,000 GW threshold, which can be reached before the next World Geothermal Congress (WGC2010) in Indonesia.

The most important and active country, both for absolute capacity increase and for the relative percentage value since 2005 can be considered Iceland, with about 220 MW of new plant commissioned and with a 110% increase.

The combined utilization of geothermal energy both for electricity and district heating, the cascade integrated development, the increasing of export of electricity through aluminum manufacturing, the presence of strong and motivated industry, the existence of well developed geothermal culture and expertise could be considered the key elements for the success of the Icelandic geothermal experience; very good prospects are still present for a further increase of their potential.

A special mention should be addressed to the Papua New Guinea: this country reached 56 MW, covering 75% of the electricity needs through geothermal, and realizing an unique integrated example of joint development of a gold mining activity with geothermal electricity generation, using some common infrastructures and taking the maximum advantage of the mining environment and the isolated remote location (no access to grid).

Indonesia, defined in 2005 as the “sleeping beauty”, can be considered now as an “awake giant”, after the closing of the pending arbitrations and the private/public investments for realizing about 200 MW (25% increase from 2005 value) and with very good prospects. If the present economic situation of the country could be considered as stabilized and promising for foreign companies and the regulatory/tariff framework will be considered as attractive, there is no doubt of the realistic possibility of a huge increase in the installed capacity in the country over the coming years, reaching an appreciable quota of its enormous potential of some tens of GW.

Very positive developments from the three Central American countries of El Salvador, Guatemala and Nicaragua, with approximately new 80 MW in total and promising perspectives in the near future.

Turkey, after a long period of standby, initiated an important construction activity, with about 20 new MW and further 50 MW under an advanced stage of development.

The overall geothermal electricity potential of approximately 200 MW could be realistically reached in the next few years, using mainly binary plants from medium enthalpy resources and traditional flash technologies.

The electricity needs of the São Miguel - Azores Islands (Portugal) are now covered 43% from geothermal energy, almost doubled since 2005. There are relatively good perspectives of future developments for some islands of the archipelagos.

A minor but important increase should be highlighted also for New Zealand, Philippines and the USA.

We should consider as very good and positive signals the new binary plants of Austria and Germany (and Alaska), proving the possibility of producing some geothermal electricity also from low temperature resources.

In Italy, after 100 years of continuous development, reaching the relevant value 800 MW, it’s necessary to invest for achieving a better social acceptance of the geothermal development, increasing the emission abatement and reducing the environmental impacts of the geothermal industry, in order to receive more social and political support for the permitting and licensing for the future projects.

Larderello is still alive and productive, and we can consider it as the best example of the renewability and sustainability of the geothermal development and exploitation through a good management of the resources for more than 100 years. Reinjection strategy, deep drilling and well stimulation are the key drivers for keeping this valuable resource as a potential “treasure pot” for future generations and for producing a relevant economical return of the investment.

Among the other renewable energy resources, whereas hydro potential can be considered as already known and utilized; without important growth margin, only wind can be considered as a realistic competitor for geothermal. But they should not be considered to be in opposition: both the resources can be developed where they are more convenient and where their presence is assessed.

Wind is more widely diffused, but it is not generally constant during the day and its production is not easily predictable, especially in consideration with the very fast climate changes worldwide.

Geothermal energy is not present everywhere, but its base-load capability is a very important factor for its success. The utilization of binary plants and the possibility of production from enhanced geothermal systems (to be considered as possible future developments) can expand its availability on a worldwide basis.

Note: 1 Euro = 1.35 US$

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