International perspective for the development of geothermal energy and Enhanced Geothermal Systems in Europe

Engine Final Conference 2008
Vilnius, Lithuania, 12-15 February 2008

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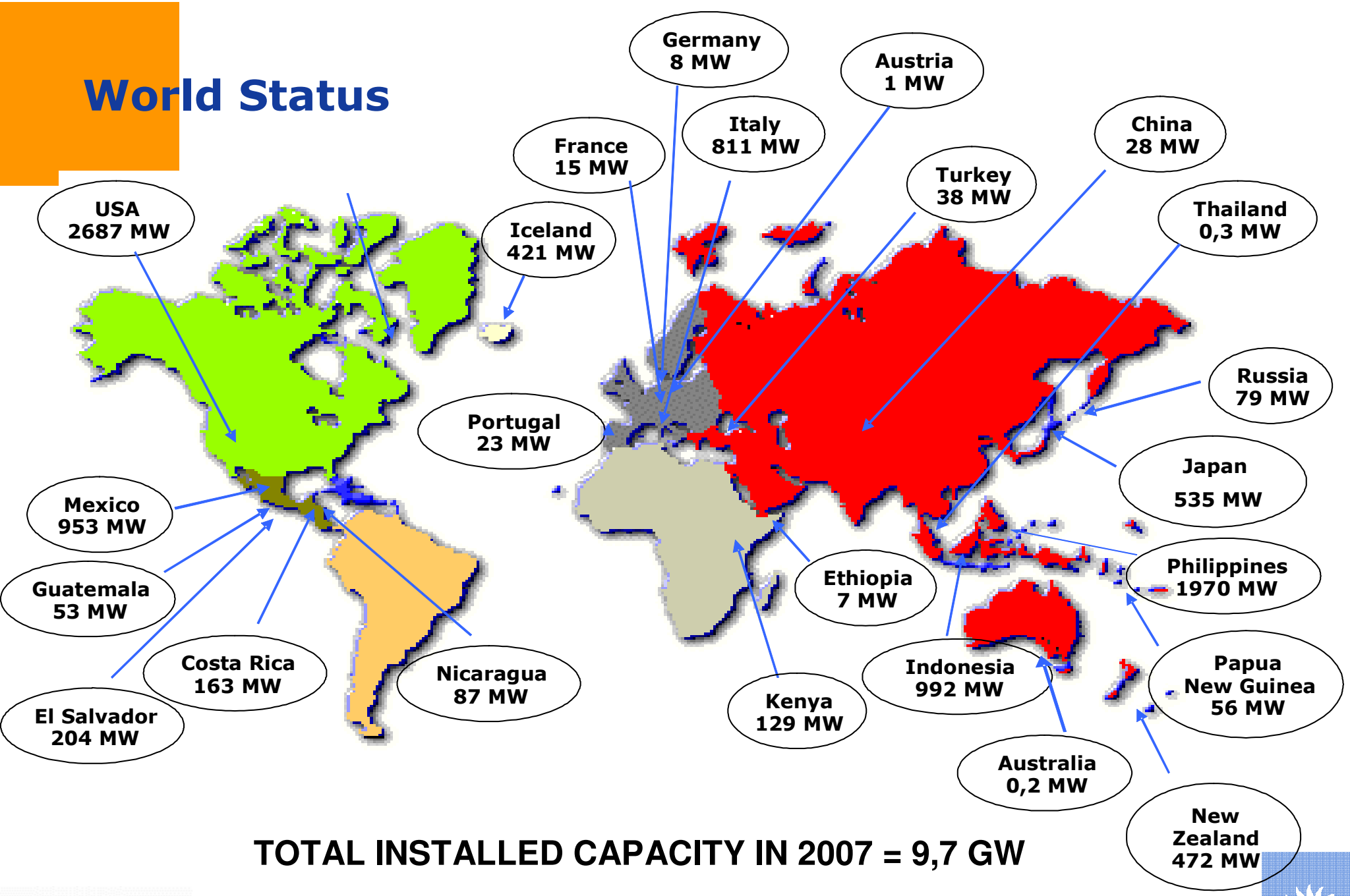
Summary and Acknowledgement

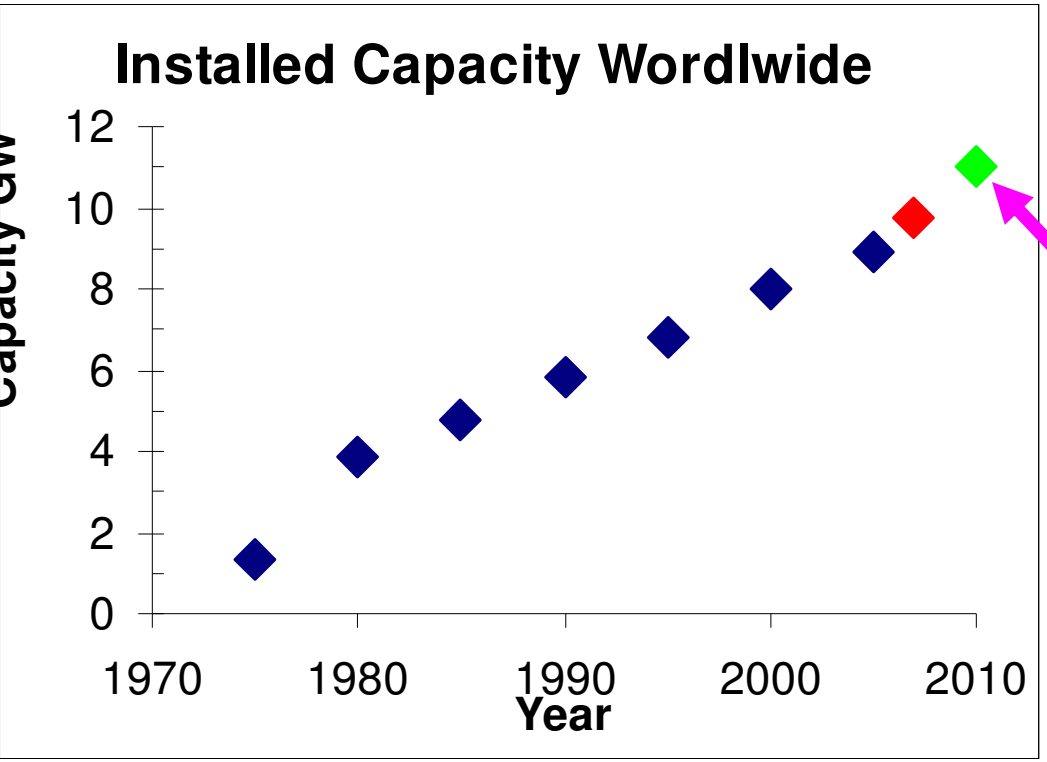
This paper will give an update of the situation of geothermal energy in Europe, as at EGC2007, and will present part of the result collected in an IGA working group for the 2008 IPCC geothermal panel.

World Status



TOTAL INSTALLED CAPACITY IN 2007 = 9,7 GW

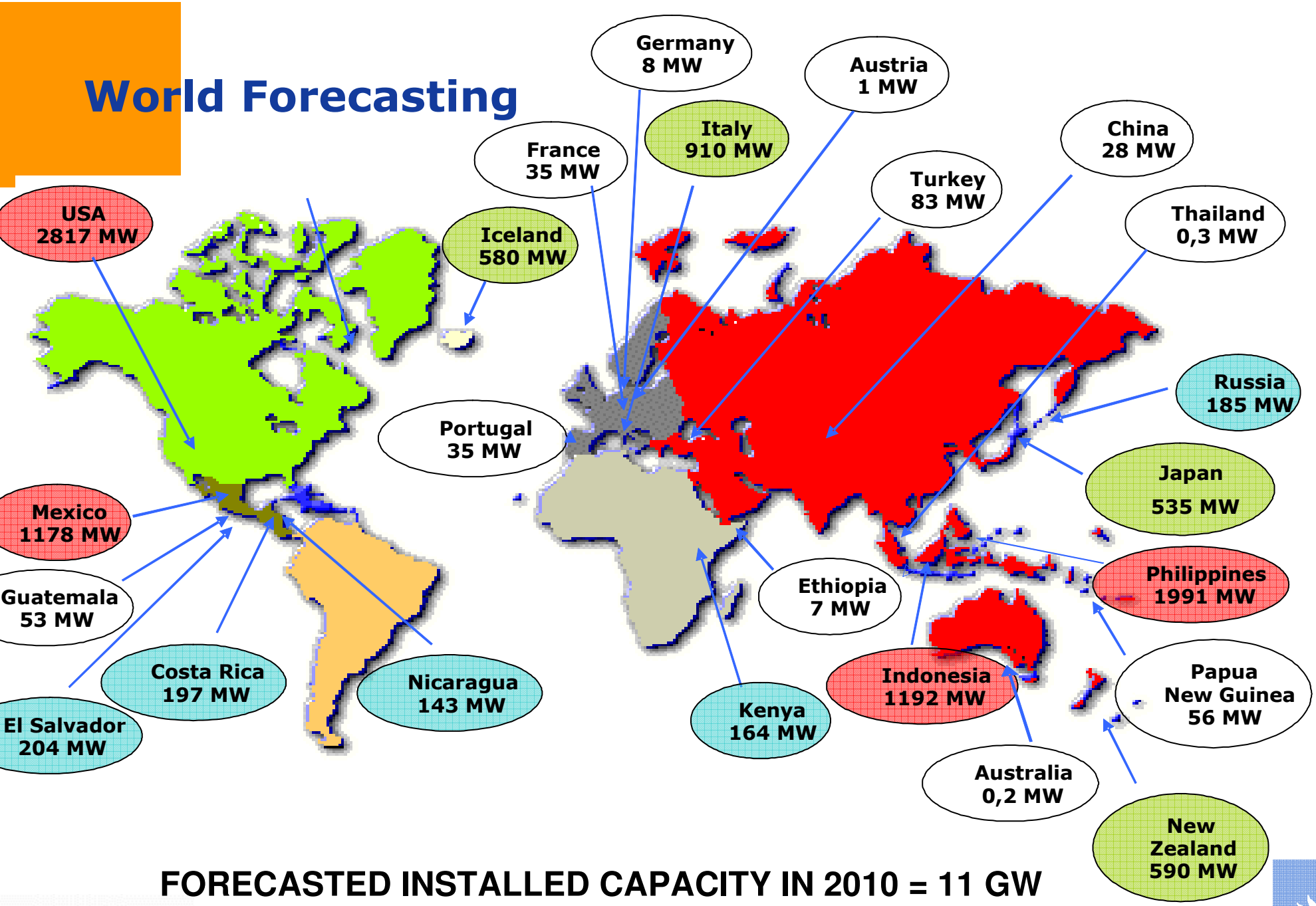
Growing Trend



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**

The geothermal electricity installed capacity is approaching the **10,000 MW threshold**, which can be reached before the next WGC2010 in Indonesia.

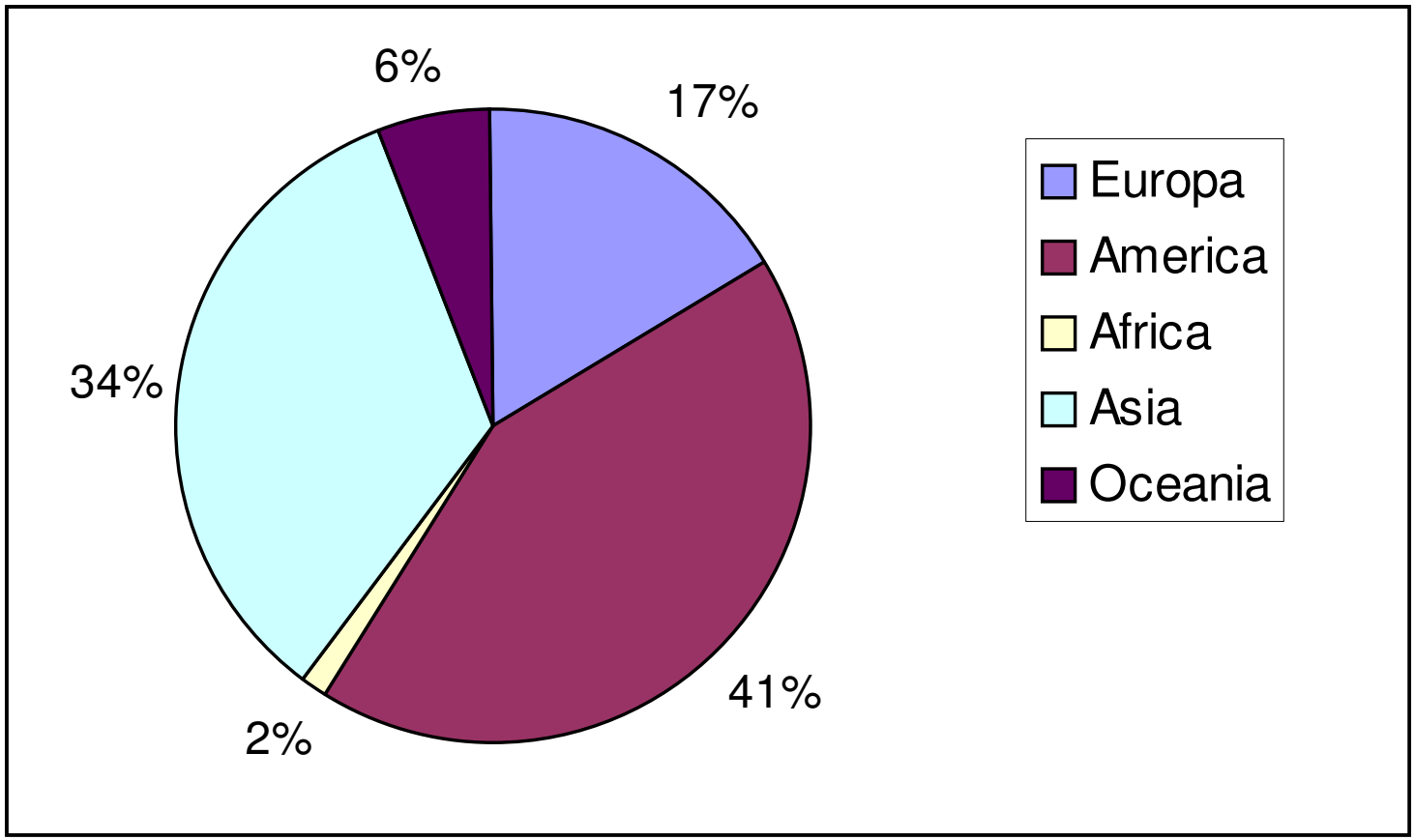
World Forecasting



FORECASTED INSTALLED CAPACITY IN 2010 = 11 GW

World Status

Installed capacity sharing among the continents



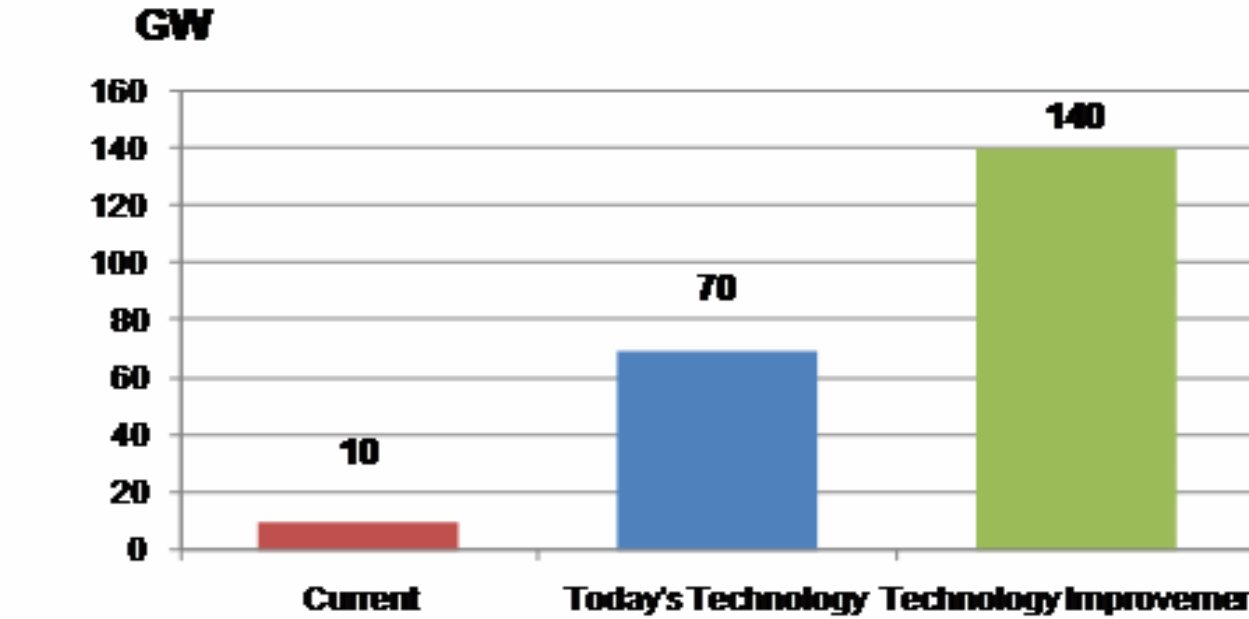
New frontiers?

World Forecasting

It's difficult to estimate the overall world-wide potential, due to the presence of too many uncertainties. Nevertheless, it is possible to identify a range of estimations, taking into consideration the possibility of new technologies:

permeability enhancements, drilling improvements, enhanced geothermal system, low temperature production supercritical fluid.

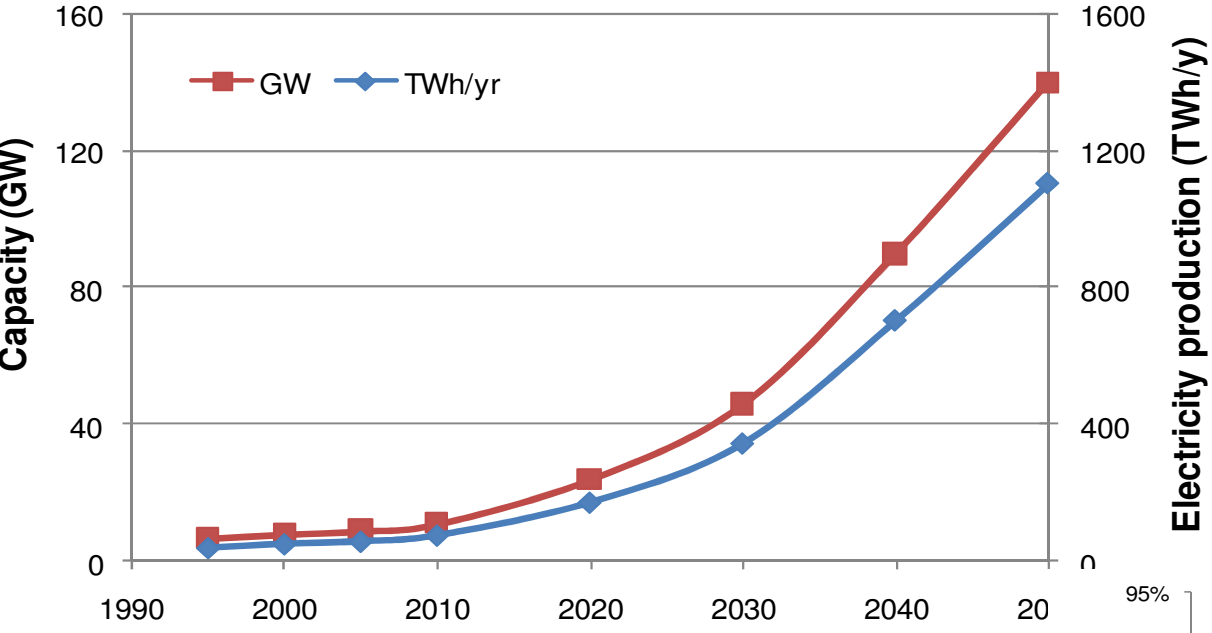
Standard: 70 GW
Improved: 140 GW



It is possible to produce up **8.3%** of total world electricity production, serving **17%** of world population.

39 countries (located mostly in Africa, Central/South America, Pacific) can be **100%** geothermal powered.

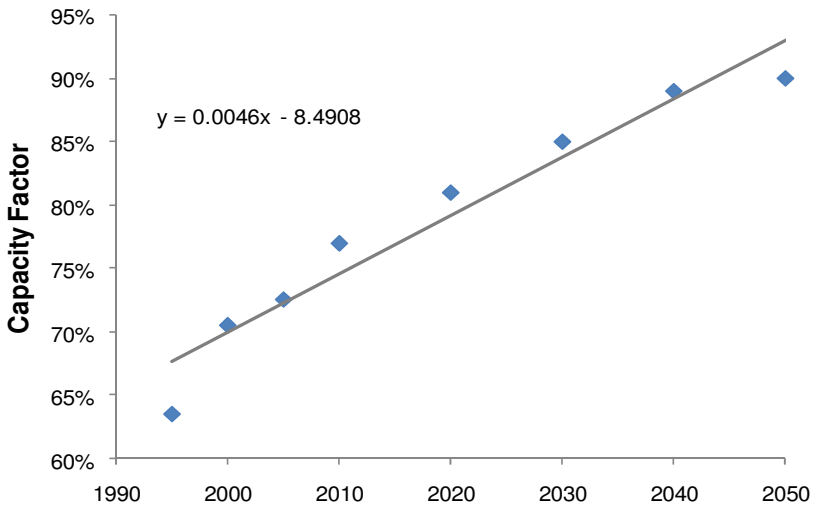
World Forecasting



It is expected that the next generation will see the implementation of **Enhanced Geothermal System** (EGS) and an intensive increase in low-to-medium temperature applications through **binary cycles** and **cascade utilisations**, expanding its availability on a worldwide basis Geothermal energy is not so considerable, but its **base-load capability** is a very important factor for its success.

Long-Term Forecasting of

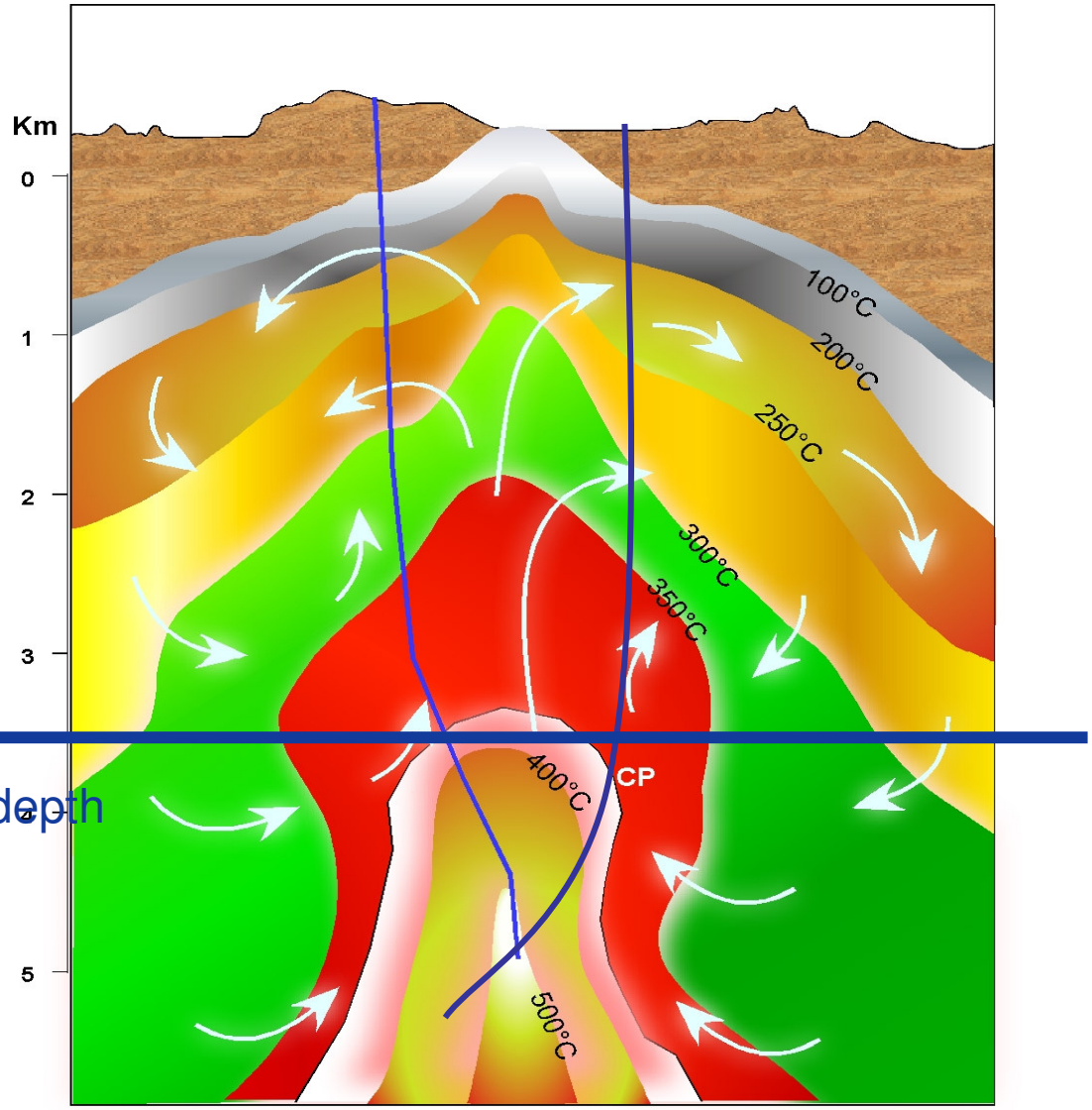
Electricity Production
Installed Capacity
Capacity factor



New technologies

Icelandic Deep Drilling project

Its aim is to produce electricity from natural supercritical hydrous fluids from drillable depths. Producing supercritical fluids will require drilling wells and sampling fluids and rocks to depths of 3.5 to 5 km, and at temperatures of 450-600°C.



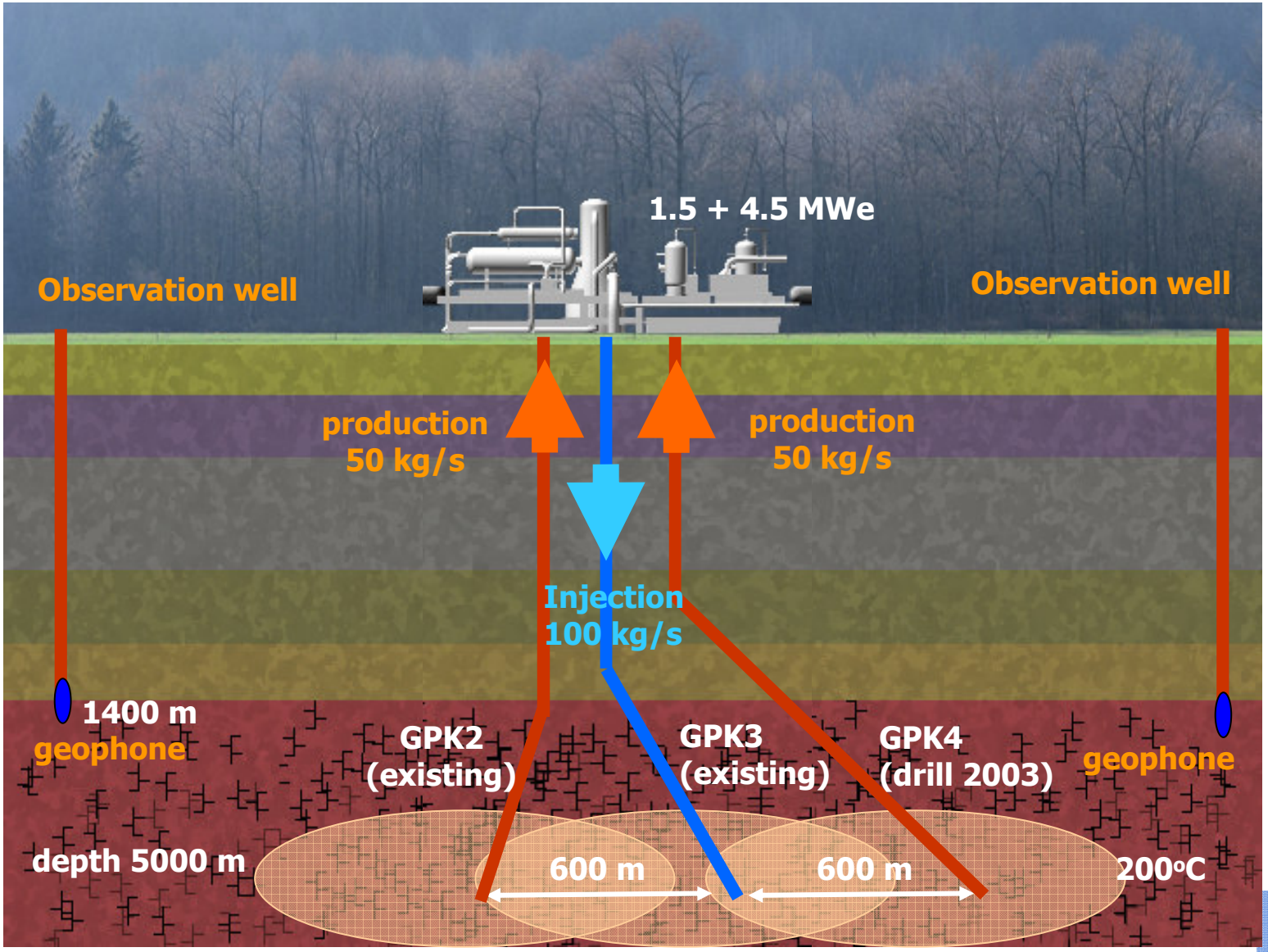
New technologies

The current plan is to drill and test at least three 3.5-5 km deep boreholes in Iceland within the next few years (one in each of the Krafla, Hengill, and Reykjanes high-temperature geothermal systems). Beneath these three developed drill fields temperatures should exceed 550-650°C, and the occurrence of frequent seismic activity below 5 km, indicates that the rocks are brittle and therefore likely to be permeable. Modelling indicates that if the wellhead enthalpy is to exceed that of conventionally produced geothermal steam, the reservoir temperature must be higher than 450°C.

A deep well producing 2500 m^3/h of steam from a reservoir with a temperature significantly above 450°C could yield enough high-enthalpy steam to generate **40-50 MW** of electric power.
This exceeds by an order of magnitude the power typically obtained from conventional geothermal wells. This would mean that much more energy could be obtained from presently exploited high-temperature geothermal fields from a smaller number of wells.

New technologies

Enhanced Geothermal System: **European Soultz project**



New technologies

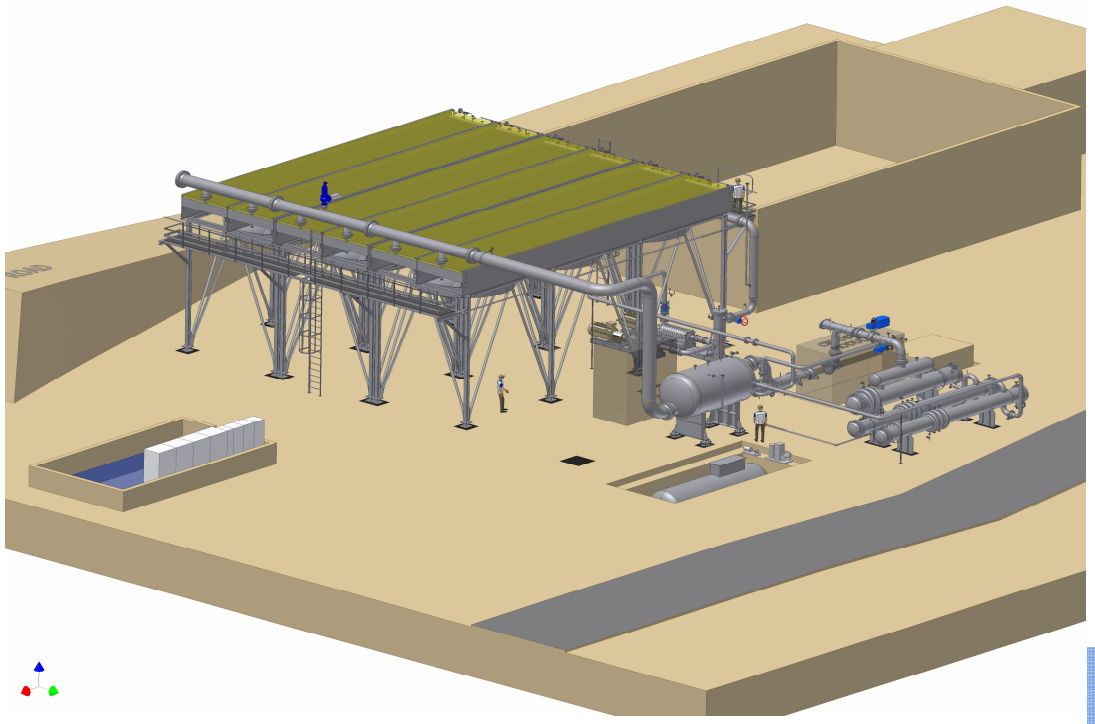
First EGS Power Plant

(J.V. Turboden- Cryostar - start up expected in early 2008)

Heat source: Geothermal fluid at 175°C (return at 70°C)

Cooling: air

Total electric power: 1.5 MW



New technologies

There are several places where targeted EGS R&D is underway:

• **Australia** can claim a large-scale activity: a real boom can be observed: currently there are 19 companies active in 140 leases (a total of 67,000 km^2 in four states), with an investment volume of **650 million USD**. The project developers plan to establish the first power plants (with a few MWe capacity) in the coming years

•The EU project "**EGS Pilot Plant**" in Soultz-sous-Forêts/France, active since 1985, finally ordered a power plant (1.5 MWe) to utilise the 200°C resource that was encountered.

Enhanced Geothermal Systems, which are still at the experimental level, have enormous potential for primary energy recovery using new heat-exploitation technology to extract and utilise the **Earth's stored thermal energy**

New technologies

Drilling technology:
both evolutionary improvements
and conventional approaches
to drilling such as

- more robust drill bits,
- innovative casing methods,
- better cementing techniques for high temperature,
- improved sensors,
- electronic capable of operating
at higher temperature in downhole tools,
- revolutionary improvements utilizing
new methods of rock penetration.

It will result in reducing the drilling cost and it will allow to access deeper and hottest regions.

New technologies

- **Power conversion technology**: improving heat-transfer performance for low temperature fluid, developing plant design with high efficiency and low parasitic losses. It will increase the available resource basis to the huge low-temperature regions, not bounded to the plate boundary.

- **Reservoir technology**: increasing production flow rate by targeting specific zones for stimulation and improving downhole lift systems for higher temperature, improving heat-removal efficiency in fractured rock system. It will lead to an immediate cost reduction increasing the output per well and extending reservoir operating life.

Binary Plants

Geothermal Electricity Production reached the value of **9,700 MW in 24 countries**;

The economics of electricity production is influenced by the drilling costs and resource development;

The productivity of electricity per well is a function of reservoir fluid thermodynamic characteristics (phase and temperature);

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:

Utilization of low temperature resource can be achieved only with binary plant.

Binary plant can be an efficient way for recovering the energy content of the reservoir fluid after its primary utilization in standard flash plant, achieving a better energy efficiency of the overall system.

Binary Plants

OPTIMIZATION

Bottoming cycle technique is widely used worldwide, as shown in the attached table;

his electricity is produced using the waste water from the separated brine: it can be considered s an un-expensive and rich of value by-product of the primary flash power plant;

The total installed capacity of such binary plants is about 160 MW worldwide.

BINARY PLANTS FOR OPTIMIZATION

Country	Plant	Capacity (MW)
Iceland	Svartsenegi	8
El Salvador	Berlin	9
Mexico	Los Azufres	3
New Zealand	Kawerau	6
New Zealand	Mokai	27
New Zealand	Rotokawa	13
New Zealand	Wairakei	14
Nicaragua	Momotombo	7
Philippines	Mak-Ban	16
Philippines	Tongonang	19
Philippines	Mahandong	19
Philippines	Mahiaio	5
Philippines	Malitbog	12
TOTAL		**160**

Binary Plants

LOW TEMPERATURE

For temperature below 150°C, the conventional flash is not able to reach satisfactory efficiency: at this temperature, only **10%** of steam can be produced at about 1 bar of separation pressure; the steam will have a very low efficiency, due to its low pressure and temperature: for producing 20 MW it is necessary to mine up to **3,000 t/h** of fluid; on the other hand, with a binary process, **only 1,800 t/h** are necessary (from 300°C liquid reservoir for flash plant only 500 t/h).

The unique way to exploit the geothermal energy for producing electricity is the use of a binary plant on the pressurized fluid, which will be handled through a closed loop from production and reinjection;
it is a zero emission cycle.

The total installed capacity of such binary plants is about 600 MW worldwide.

Geothermal and Other Renewables

	Installed capacity		Production per year		Capacity factor (%)
	GWe	%	TWh/yr	%	
Hydro	778	87.5	2,837	89	42
Biomass	40	4.5	183	5.7	52
Wind	59	6.6	106	3.3	21
Geothermal	9	1.0	57	1.8	72
Solar	4	0.4	5	0.2	14
Total	890	100	3,188	100	41**

Geothermal energy is available day and night every day of the year and can thus serve as a partner with energy sources available intermittently:

1,0% Capacity ➔1,8% Energy
CF 72% ➔90%

Geothermal power stations serve as base load throughout the year. This applies both to electricity production and direct utilisation

Geothermal and Other Renewables

	GWh	%
Coal	6.944.328	39,61
Gas	3.418.676	19,50
Nuclear	2.738.012	15,62
Oil	1.170.152	6,67
Other sources	2.292	0,01
Non-renewables total	**14.273.460**	**81,42**
Hydro	2.889.094	16,48
Biomass	149.811	0,85
Waste	77.471	0,44
Wind	82.259	0,47
Geothermal	55.896	0,32
Solar thermal	1.608	0,01
Solar PV	840	0,00
Tide, Wave, Ocean	551	0,00
Renewables total	**3.257.530**	**18,58**
Total world generation	**17.530.990**	**100,00**

The overall CO_2 saving from geothermal electricity can be in the range 1000 (coal) 500 (gas) million tons per year,

if the target of 140 GW will be reached

Geothermal Perspectives

Geothermal Energy provides approximately 0,3% of the world global power generation, with a stable long term growth rate of 5%.

Future developments are limited to certain areas, particularly under current technologies.

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 Meuro/MW,** and with very attractive generation costs, **from 40 to 100 euro/MWh**.

It is a resource suitable for base load power.

Europe

For **geothermal electricity**, 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.

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.

Geothermal Perspectives

Europe

There are many geothermal prospects with high temperature but lacking fluid in the formation or the rock permeability too low for permitting fluid circulation.

These systems can be enhanced by engineering the reservoir through stimulation activities: acidizing, hydraulic fracturing. The best results have been obtained from the **Soultz project**.

The critical aspects 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.

Geothermal Advantage

Geothermal Energy Advantage

It can produce **HEAT** which can be
used extensively
for many applications:

district heating,
heating & cooling,
heat&cold storage,
desalination,
snow melting,
shallow geothermal resource utilization,
geothermal heat pumps.

Geothermal Advantage

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 GEO & WIND 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.

Geothermal Advantage

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 so present, 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 a possible future developments) can expand its availability on a worldwide basis.

Geothermal Advantage

The geothermal exploitation techniques are under a rapid development and the understanding of the reservoirs has been improved considerably.

Combined heat and power plants are gaining increased popularity, improving the overall efficiency of the geothermal utilisation.

Also, **low-temperature power generation** with binary plants has opened the possibilities of producing electricity in countries without high-temperature fields.

Enhanced Geothermal Systems that extract heat from deeper parts of the reservoir than conventional systems are under development.

A project for drilling down to 5 km into a reservoir with **supercritical fluids** at 450-600°C is under preparation. If this project will be a success, the power from geothermal fields can be increased by an order of magnitude.

Conclusion

he maximum reduction of CO_2 will be **1000-500** million of tons for electricity and **200** million tons for direct utilizations

- Total geothermal electricity is reaching the value of **9,7 GW** in 24 countries, with 800 MW of increase since 2005; the forecasting for 2010 is about **11 GW**.
- Geothermal energy is not widely diffuse, but its base-load capability and its high availability are key elements for its penetration into the energy market
- Binary plant technology is playing a very important role in the modern geothermal electricity market.
- The possibility of production from enhanced geothermal systems (to be considered as a possible future developments) can expand its availability on a worldwide basis.
- The expected potential for geothermal electricity is about **140 GW**, corresponding to 8% of the world electricity