

STATUS, DEVELOPMENT, AND PROSPECTS OF GEOHERMAL ENERGY

ARGeoC2 Conference, Entebbe/Uganda, 24-24 November 2008

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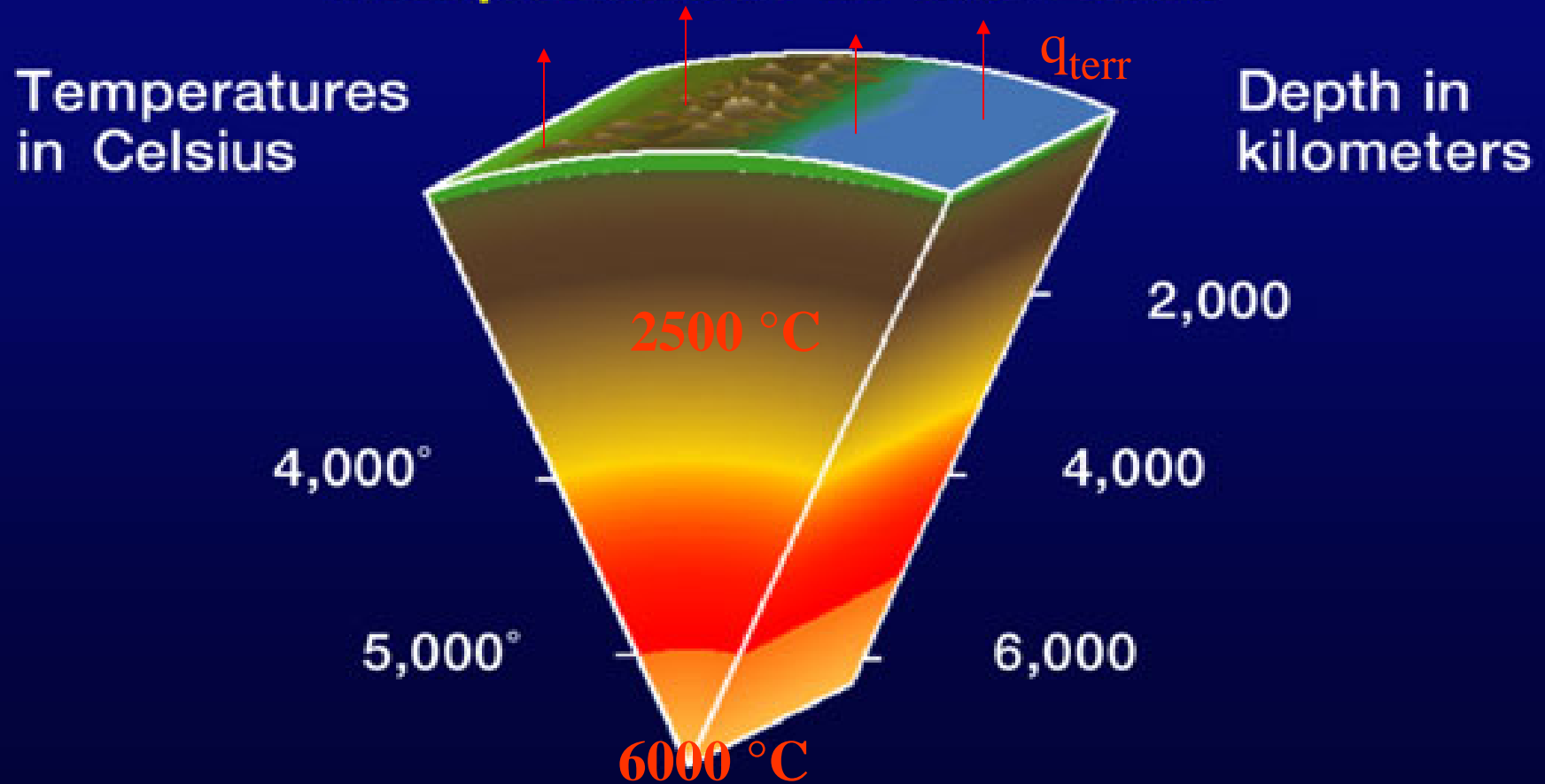
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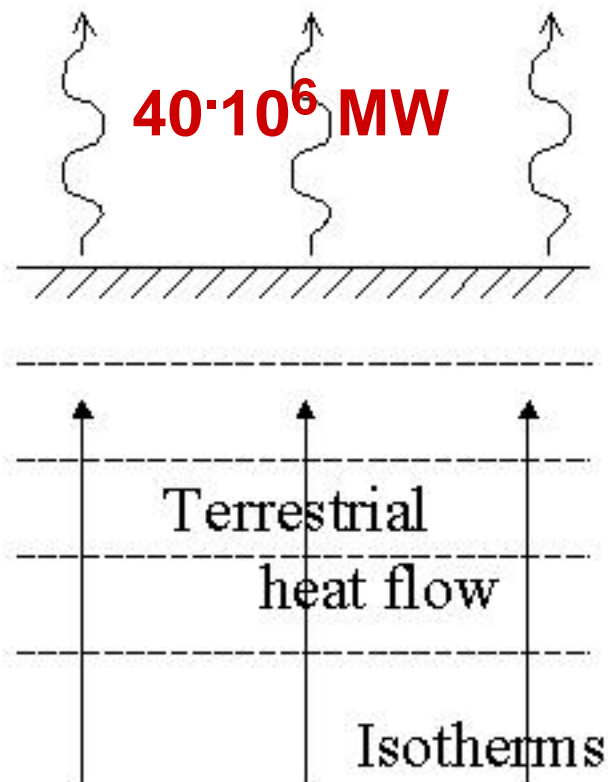
- **Basis of geothermal energy utilization**
- **Geothermal energy within the renewables**
- **Power generation and direct use**
- **Sustainability and economics**
- **Future prospects, combating climate change**



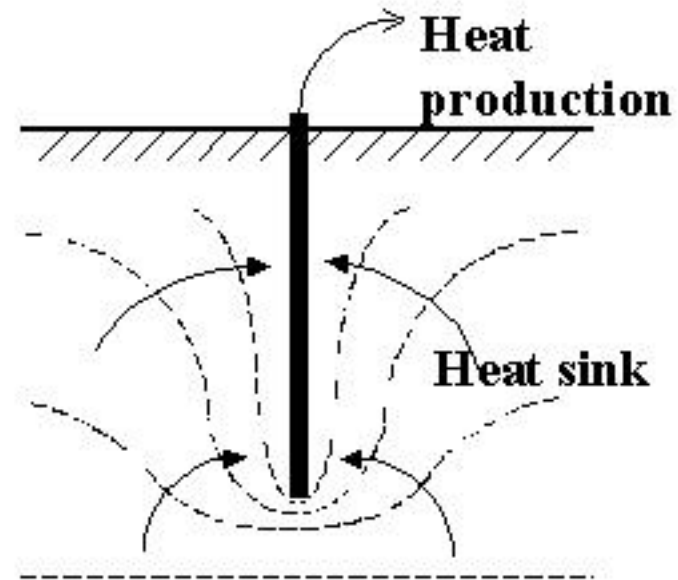
Temperatures in the Earth



99 % of the earth's interior is hotter than 1000°C.
Global heat loss is 40 million MW.



The terrestrial heat flow is lost to the atmosphere



The heat sink captures the heat flow

Principle of geothermal energy utilization: collecting earth's heat.

Potential of renewable energy sources (WEA 2000)

Energy source	Capacity (EJ/yr)*
Geothermal	5000
Solar	1575
Wind	640
Biomass	276
Hydro	50
Total	7541

*) 1 EJ = 10^{18} J

**There are two main lines of geothermal energy utilization:
power generation and direct use.**

Electricity from renewable sources in 2005.

Compiled from Tables in 2007 Survey of Energy Resources (WEC, 2007)

Technology	Installed capacity		Production per year		Availability factor %
	GWe	%	TWh/yr	%	
Hydro	778	87.5	2,837	89	42
Biomass	40	4.5	183	5.7	52
Wind	94* 59	6.6	106	3.3	21
Geothermal	10* 9	1.0	57	1.8	72
Solar	9.1** 4	0.4	5	0.2	14
Total	890	100	3'188	100	41*

*) in 2008

**) new in 2007: 2.8 GW

*) weighted average

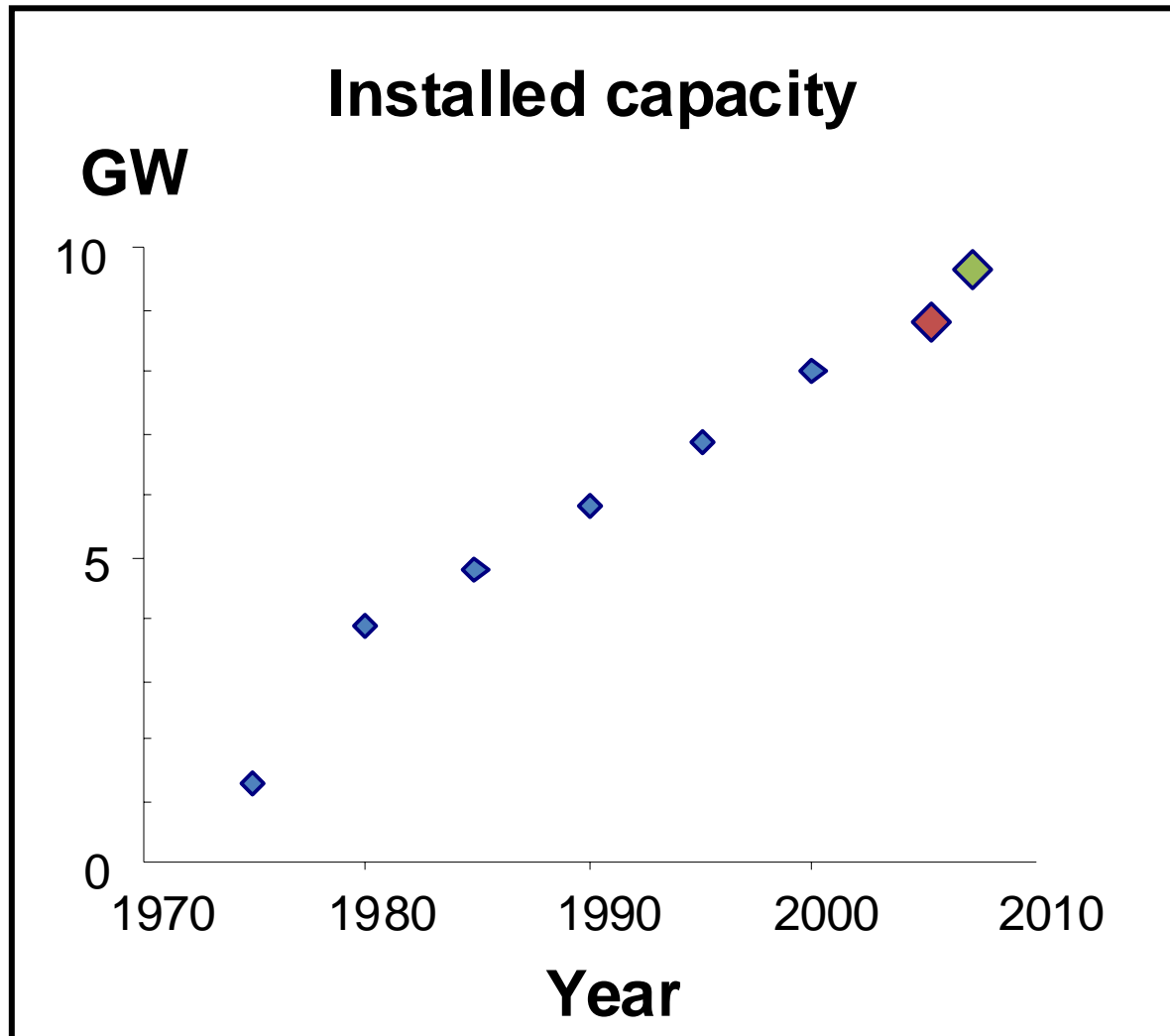
Geothermal energy is available round around the clock all year. Providing 1.8% of global renewable electricity with only 1% of the installed capacity reflects the reliability of geothermal plants, which can be operated at availability factors in excess of 80%,

Geothermal power generation

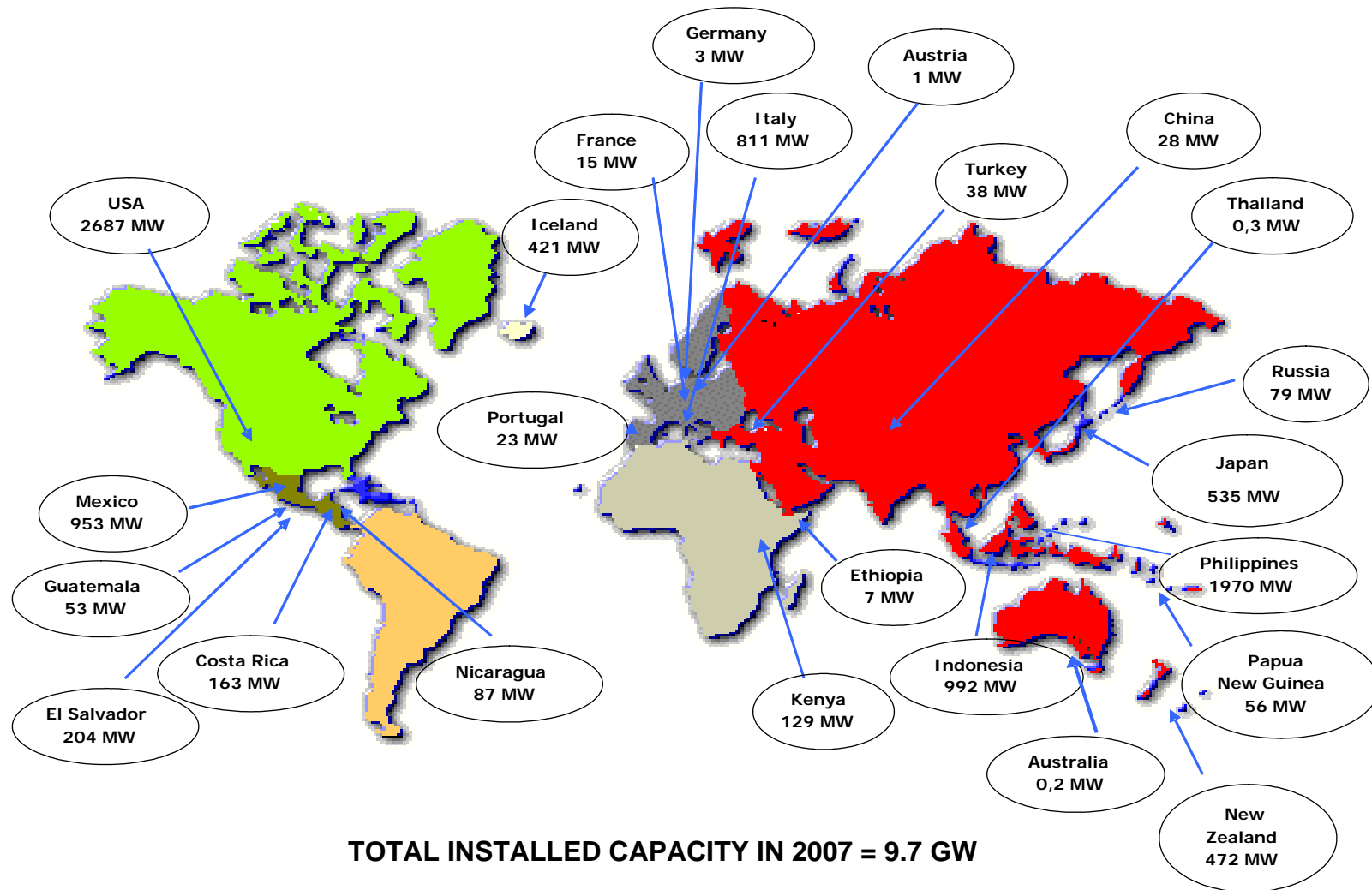
Geothermal electricity generation started in Italy more than 100 years ago.

Today 24 countries generate base-load electricity. Five of these countries obtain 15-22% of their national electricity production from geothermal (Costa Rica, El Salvador, Iceland, Kenya and the Philippines).

In 2007 a world-wide geothermal capacity of 9.7 GWe produced 60 TWh electricity.



Installed capacity for electricity production from 1975 up to end of 2007 (red) and forecast to 2010 (green) (Bertani, 2007).



Geothermal power plant capacities in 2007 in different countries.
(from Bertani, 2007).



12 MWe (3x4) - 1999

**7 plants
73 MWe
By 2010
300 MWe**



1st stage 50 MWe (2x25)



Separators – 50 MWe

**Severe
weather -
unmanned
and remote
controlled
– planned
15 m snow**



Turbines – 50 MWe

Mutnovsky power plant, Kamchatka, Russia

Geothermal direct use

Direct application of geothermal energy is being realized in a wide variety of uses: space heating, industrial and agriculture applications, spas and wellness facilities. Direct use is reported from 72 countries.

The worldwide direct use of geothermal heat is currently about 300 PJ/yr, produced by a total capacity of about 30 GW_{th} .

The usage is distributed as follows: space heating 52% (thereof 32% using heat pumps), bathing and swimming (including balneology) 30%, horticulture (greenhouses and soil heating) 8%, industry 4%, and aquaculture (mainly fish farming) 4% .

Top fifteen countries utilising geothermal energy in 2005.

Data on electricity from Bertani (2005) and on direct use from Lund et al. (2005).

Geothermal electricity production		Geothermal direct use	
	GWh/yr		GWh/yr
USA	17,917	China	12,605
Philippines	9,253	Sweden	10,000
Mexico	6,282	USA	8,678
Indonesia	6,085	Turkey	6,900
Italy	5,340	Iceland	6,806
Japan	3,467	Japan	2,862
New Zealand	2,774	Hungary	2,206
Iceland	1,483	Italy	2,098
Costa Rica	1,145	New Zealand	1,968
Kenya	1,088	Brazil	1,840
El Salvador	967	Georgia	1,752
Nicaragua	271	Russia	1,707
Guatemala	212	France	1,443
Turkey	105	Denmark	1,222
Guadeloupe (France)	102	Switzerland	1,175

Table 1. The world-wide top 15 in geothermal direct use, and ranking in terms of areal density of production capacity. Ranking calculated from data in Fridleifsson et al. (2008).

Country	GWh/yr	Country area 10^3 km^2	GWh/yr per 10^3 km^2	Rank
China	12,605	9571	1.32	12
Sweden	10,000	450	22.2	6
USA	8,678	9809	0.88	13
Turkey	6,900	779	8.86	7
Iceland	6,806	103	66.1	1
Japan	2,862	378	7.57	8
Hungary	2,206	93	23.7	5
Italy	2,098	301	6.97	10
New Zealand	1,968	271	7.26	9
Brazil	1,840	8512	0.22	14
Georgia	1,752	70	25.0	4
Russia	1,707	17075	0.10	15
France	1,443	544	2.65	11
Denmark	1,222	43	28.4	3
Switzerland	1,175	41	28.7	2



Iceland :
88 % of all buildings;

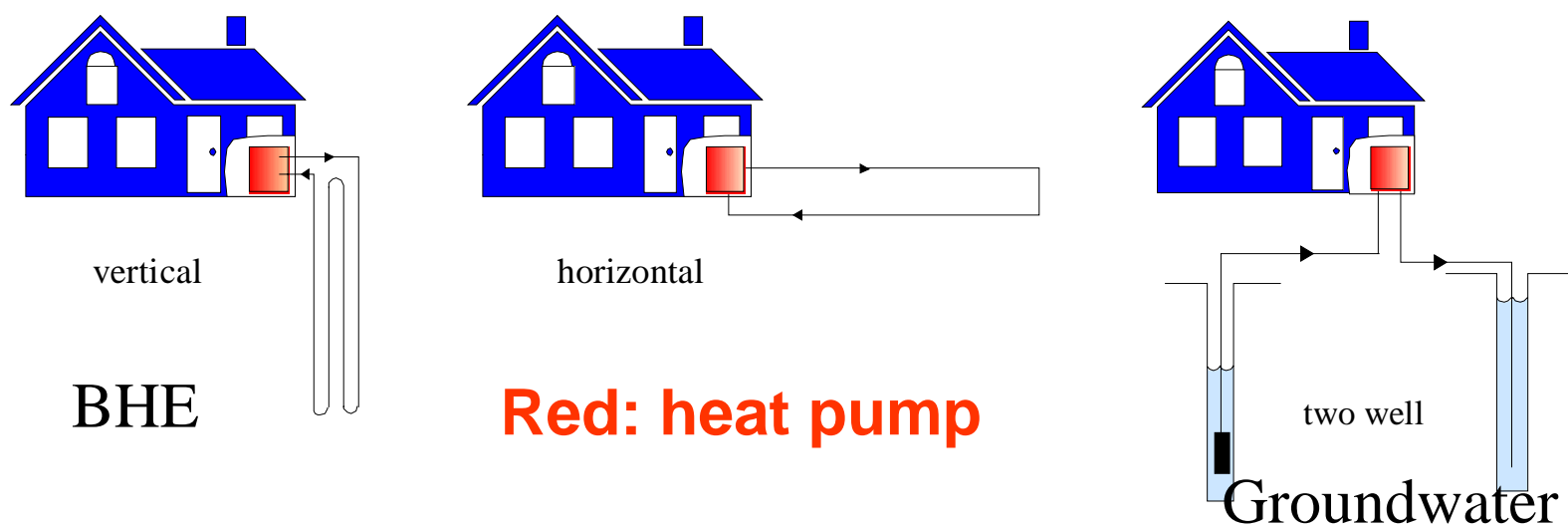
Paris basin :
> 100'000 apartment units

**are supplied by geothermal district
heating networks**

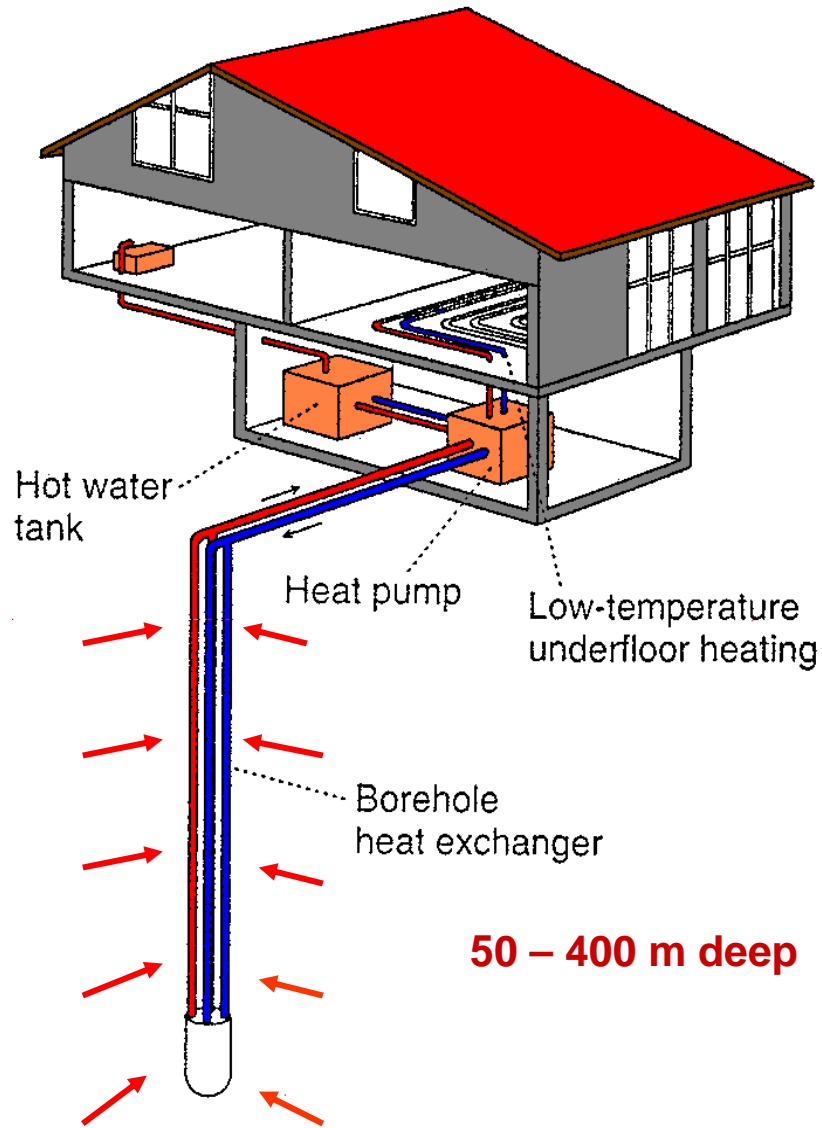
Geothermal heat pumps

The highest growth rate in direct use is with geothermal heat pumps (GHP), one of the fastest growing renewable energy technologies.

World-wide production by GHPs increases (in PJ/yr): 14.6 in 1995, 23.3 in 2000, 87.5 in 2005. GHPs provide space heating, cooling and also domestic hot water.



Geothermal heat pump (with borehole heat exchanger)



BHE drilling and installation

GEOWATT AG
S W I S S
G E O T H E R M A L
E X P E R T
G R O U P

CH - 8050 Zürich

Terminal E, Zurich airport



200'000 m³ construction space
58'000 m² energy supply area

2120 MWh/a heating, 1240 MWh/a cooling load

300 energy piles à 30 m

Geothermal sustainability

Geothermal energy is generally classified as a renewable resource, where “renewable” describes a characteristic of the resource: the energy removed from the resource is continuously replaced on time scales similar to those required for energy removal. Consequently, geothermal production is not a “mining” process.

Geothermal energy can be used in a “sustainable” manner, which means that the production system applied is able to sustain the production level over long times.

The longevity of production can be secured and sustainable production achieved by using moderate production rates, which take into account the local resource characteristics (field size, natural recharge rate, etc.).

Economics

Electricity production cost from renewables (WEA, 2004)

Power plant type	Generation cost (US cent/kWh)
Hydro	2 – 10
Geothermal	2 – 10
Wind	4 – 8
Biomass	3 – 12
Solar PV	25 – 160
Concentrated solar	12 – 34

Currently the installation cost of geothermal power plants is around 3.0 – 4.5 million €/MWe, the production cost 40 – 100 €/MWh. CO₂ taxing and feed-in tariffs will help in the future.

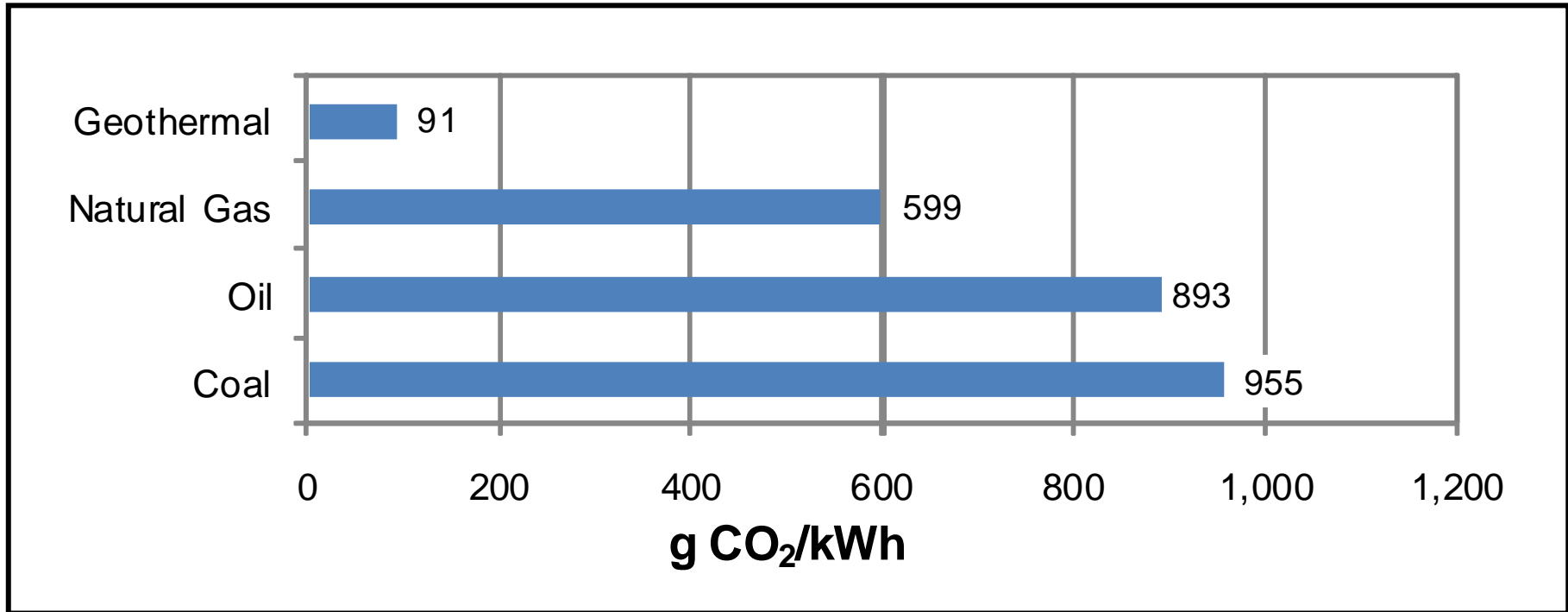
Direct use average unit cost of heat for geothermal district heating is 2.0 €/GJ. For geothermal heat pumps the cost of combined heating/cooling is 16.0 €/J; return of investment time is in 4 – 8 years for GHPs.

Future prospects, combating climate change

Geothermal technologies cause little or no greenhouse gas emissions since no burning processes are involved. Power generation as well as direct use already contribute to the reduction of CO₂ emissions. Further deployment – depending on future growth rates – could reduce CO₂ emissions even more significantly.

Quantitative development trends for coming decades can only be estimated. It is considered possible to increase the installed world geothermal electricity capacity from the current 10 GW to 70 GW with present technology, and to 140 GW with enhanced technology until 2050.

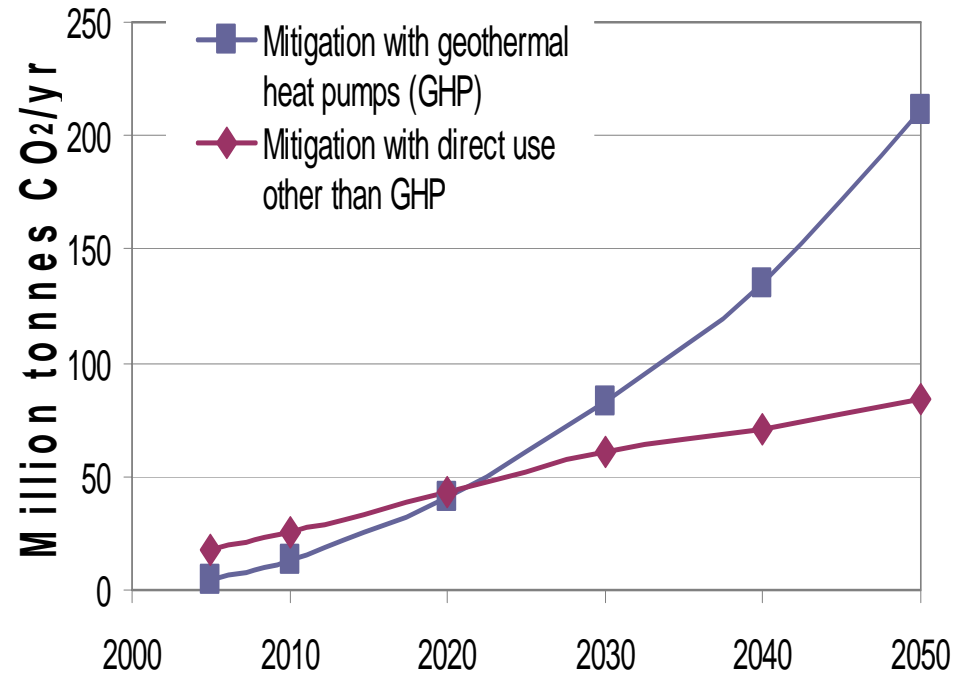
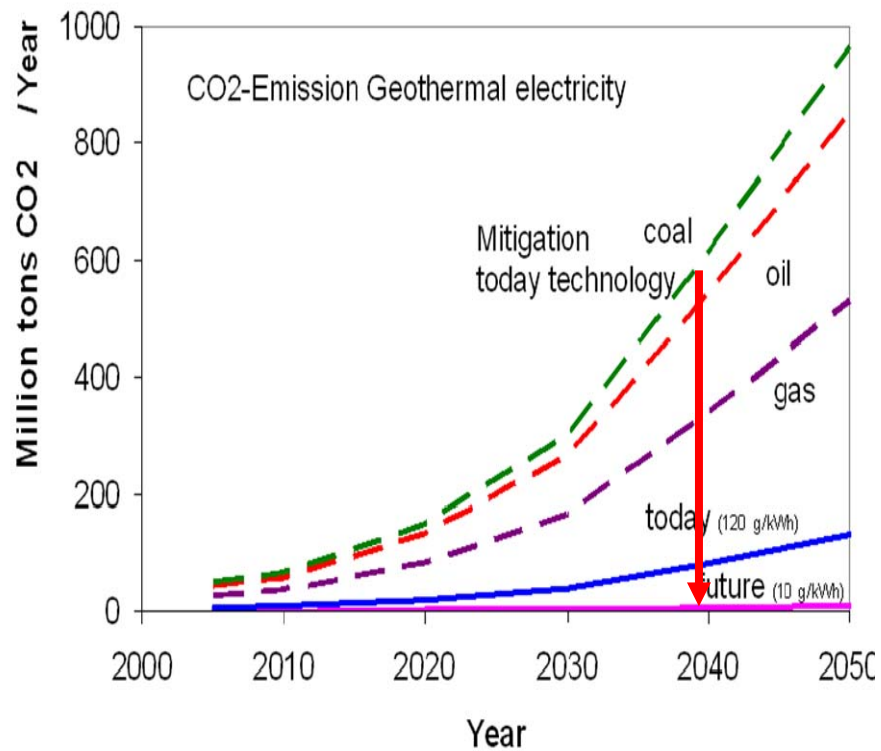
Production from direct use in 2050 has been estimated at 5.1 EJ/yr, with the GHP portion at 4.2 EJ/yr.



Comparison of CO₂ emission from electricity generation from different energy sources in the USA.

Data from Bloomfield et al. (2003).

Geothermal CO₂ emission mitigation potential



Left: Mitigation potential of geothermal power plants in the world –when replacing fossil technologies–

Right: Mitigation potential of geothermal direct heating use in the world, based on the growth estimate data.

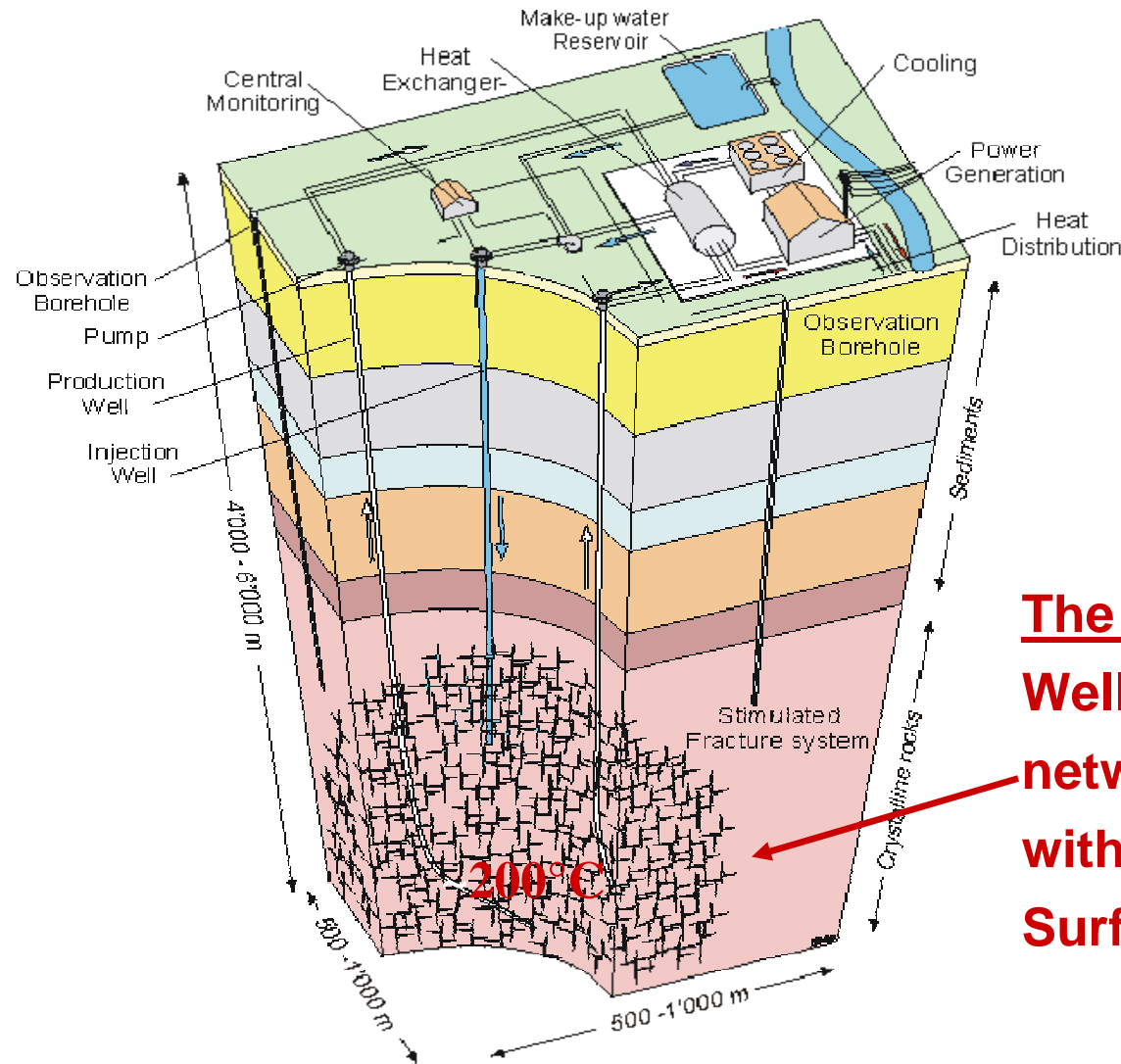
Enhanced Geothermal Systems

The EGS principle is simple: in the deep subsurface where temperatures are high enough for power generation (150-200 °C) an extended fracture network is created and/or enlarged to act as new pathways.

Water from the deep wells and/or cold water from the surface is transported through this deep reservoir using injection and production wells, and recovered as steam/hot water.

Injection and production wells as well as further surface installations complete the circulation system. The extracted heat can be used for district heating and/or for power generation.

The future :EGS for cogeneration (combined heat / power)



The main component:
Well distributed fracture network at several km depth with sufficient heat exchange Surface.

Concept of the Deep Heat Mining System

EGS potential

The EGS potential is huge: A recent study determined for the USA alone recoverable resources > 200,000 EJ, corresponding to 2,000 times the annual primary energy demand.

Current EGS status

After internationally organized EGS research over about 25 years the first EGS power plant is now producing electricity with 1.5 MWe capacity at Soultz-sous-Forêts/France.

In Australia there is a veritable EGS boom (numerous stockmarket-registered enterprises), newly also in the USA. Nevertheless some basic questions still need answers.

Remaining R&D needs

Development of a technology to produce electricity and/or heat from a basically ubiquitous resource, in a manner relatively independent of site conditions.

There is no experience about possible changes of an EGS heat exchanger with time

So far the envisaged electric power capacity of EGS systems is limited at a few MWe. But in order to play a significant role in electricity supply a system capacity of at least several tens of MWe would be essential.

One of the main future R&D goals will be to see whether and how the EGS power plant size could be upscaled,

Conclusions

The basis of geothermal energy is the immense heat content of the earth's interior; since billions of years it is constantly supplied by the decay of natural radioisotopes. Thus the resource is vast and ubiquitous and has a correspondingly large potential for utilization.

The two main lines of geothermal energy utilization, power generation and direct use, are currently producing about 60 TWh_e with 10 GW_e power, and about 300 TJ/yr with 30 GW_{th} and are constantly growing, to 70 GW_e with present technology, and to 140 GW_e with enhanced technology until 2050. Production from direct use in 2050 has been estimated at 5.1 EJ/yr, with the geothermal heat pump portion at 4.2 EJ/yr.

Power generation as well as direct use already contribute to the reduction of CO₂ emissions. Further deployment, – depending on future growth rates – could reduce CO₂ emissions even more significantly.



 **World Geothermal Congress 2010**
Geothermal: „The Energy to Change the World“
25- 29 April 2010, International Conference Center, Nusa Dua-Bali, Indonesia

<http://www.wgc2010.org/>

Welcome to the World Geothermal Congress (WGC) 2010 – Bali Website

The World Geothermal Congress 2010 (WGC2010) - Geothermal powering world's today energy, will take place in Bali Indonesia at the Bali International Conference Center (BICC), Nusa Dua, Bali's largest conference venue, named top in the category "World's leading Conference & Convention Centre 2006". Over 3000 participants from more than 80 countries are expected to attend and learn about the latest breakthroughs in the field. An Exhibition, held simultaneously with the Conference, will feature foremost companies and state-of-the-art products of the Geothermal industry

Co - Convened by:

International Geothermal Association (IGA)



Indonesian Geothermal Association (INAGA)



Ministry of Energy & Mineral Resources Republic Of Indonesia





Many thanks for your attention !

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