Present status and future prospects of geothermal energy in Europe

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PRESENTATION STRUCTURE

- status of geothermal energy in Europe
  (separately for power generation and for direct use)
- development trends
- future prospects

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Electricity generation from renewables

(refers to 2005)

TUHH IUE

	Installed capacity in GW_{el}		Electricity generation in TWh/a	
	World	EU	World	EU
Hydro power	750.0	127.0	2,804	741
• Run-off-river/Storage plants	750.0	127.0	2,803	740
• Tidal power plants	0.3	0.2	< 1	< 1
Wind energy	47.9	34.4	74 – 88	55
Solar energy	3.0	1.0	3 – 4	< 1
• Solarthermal systems	0.4		< 1	
• Photovoltaic systems	2.6	1.0	2 – 3	< 1
Geothermal energy	8.9	0.8	57	6
Biomass	47.8	11.3	190 – 300	57
• Solid biofuels	37.0	6.2	150 – 260	35
• Organic waste	7.6	3.3	21	10
• Biogas (OECD-countries)	3.2	1.8	19	12
Total	approx. 857.6	approx. 174.5	approx. 3,190	approx. 859

DATA BASE

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- Lund, J.W., Freeston, D.E., Boyd, T.I. (2005): Direct application of geothermal energy. Geothermics 34, 691-727
- Rybach, L. (2006): Status and prospects of geothermal energy in Europe – a summary. Geothermal Resources Council Transactions Vol. 30, p. 675-679
- Bertani, R. (2007): World Geothermal Generation in 2007. Proc. European Geothermal Congress 2007
- Antics, M., Sanner, B. (2007): Status of Geothermal Energy Use and Resources in Europe. Proc. European Geothermal Congress 2007

Geothermal power in Europe

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Table 1: Geothermal power production in Europe (from Bertani 2005, Rybach 2006) updated with available data May 2007

Country	Installed Capacity [MWe]	Running Capacity [MWe]	Annual Energy Produced [GWh/y]	Number of Units	% of National Capacity	% of National Energy	2007 DATA
Austria	1.2	1.1	3.2	2	Negligible	Negligible	
Germany	0.2	0.2	1.5	1	Negligible	Negligible	
Iceland	202	202	1483	19	13.7	17.2	
Italy	810.5	711	5200	32	1.0	1.9	X
Portugal (San Miguel Island)	16	13	90	5	25*	n/a*	
Turkey	30	30	108	2	Negligible	Negligible	X
Total in Europe proper	**1059.9**	**957.3**	**6885.7**	61	-	-	
France (Guadeloupe island)	15	15	102	2	9*	n/a*	
Russia (Kamtchatka)	79	79	85	11	Negligible	Negligible	X
GRAND TOTAL	**1153.9**	**1051.3**	**7072.7**	**74**	-	-	

*) Local capacity (Azores islands, Guadeloupe)

Installed capacity distribution in Europe

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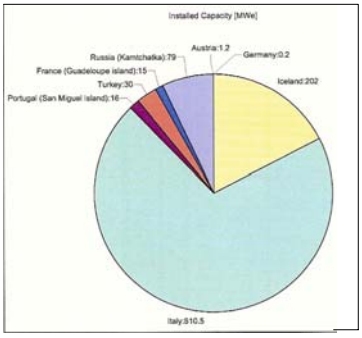
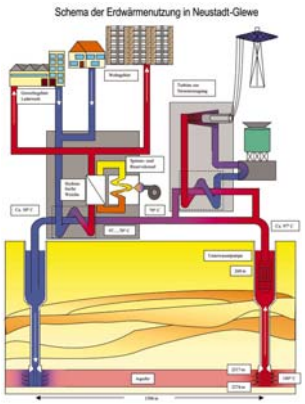
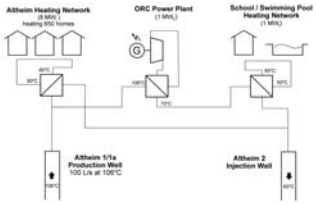




Neustadt-Glewe,
Germany
200 kWe ORC



- **Altheim, Austria**
- **1 MWe ORC**
- **10 MWt – 4.7¢/kWh**
- **Well: 2,300 m**
- **106°C @ 100 L/s**

Geothermal power plant realizations in Germany 2007

Location	Geothermal power (MW_{th})	Electric power (MW_e)	Drill depth (m)	Production temperature (°C)	Production rate (m^3/h)	Planned operation start
Gross Schönebeck	10	1.0	4294	150	<50	2008
Neustadt-Glewe*	1.3 - 3.5	0.21	2250	98	119	2003
Bruchsaal	4.0	ca. 0.5	2500	118	86	2008
Karlsruhe	28		3100	>150	270	2008
Landau*	22	2.5	3000	150	250	2007
Offenbach	30 - 45	4.8 - 6.0	3500	160	360	2008
Riedstadt	21	ca. 3.0	3100		250	2008
Speyer	20 - 50	4.8 - 6.0	2900	150	450	2009
Unterhaching*	>30	3.4	3577	122	>540	2007

*) in operation

Combined heat and power plant, Unterhaching/D

started in 2007, 3.4 MWe

Ormat binary power plant, Landau/D

started in 2007, 2.5MWe

Direct use status

- **Various direct uses (for space heating, agriculture, balneology etc.) are reported,**
- **from 34 European countries.**
- **The totals yield 14 GWt and 158'000 TJ/yr.**

WORLD DIRECT-USE 2005

Region	MWe (%)	GWh/yr (%)
Africa	0.7	1.1
Americas	32.3	16.7
Asia	20.9	29.4
Europe	44.6	49.0
Oceania	1.5	3.8

GEOTHERMAL DIRECT USE IN EUROPE IN 2004,

from Lund et. al. (2005), Rybach (2006) and Antics & Sanner (2007)

Country	Capacity MWt	Use TJ/yr	Capacity Factor
Albania	9.6	8.5	0.03
Austria	352.0	2229.9	0.20
Belarus	2.0	13.3	0.21
Belgium	63.9	431.2	0.21
Bulgaria	109.6	1671.5	0.48
Croatia	114.0	681.7	0.19
Czech Republic	204.5	1220.0	0.19
Denmark	330.0	4400.0	0.42
Finland	260.0	1950.0	0.24
France	308.0	5195.7	0.53
Georgia	250.0	6307.0	0.80
Germany	952.0	6060.0	0.18
Greece	74.8	567.2	0.24
Hungary	694.2	7939.8	0.36
Iceland	1844.0	24500.0	0.42
Ireland	20.0	104.1	0.17
Italy	650.0	8000.0	0.39

(Table continued)

Lithuania	21.3	458.0	0.68
Macedonia	62.3	598.6	0.30
Netherlands	253.5	685.0	0.09
Norway	600.0	3085.0	0.16
Poland	210.0	1108.0	0.16
Portugal	30.6	385.3	0.40
Romania	145.1	2841.0	0.62
Russia	308.2	6143.5	0.63
Serbia	88.8	2375.0	0.85
Slovak Republic	187.7	3034.0	0.51
Slovenia	49.6	729.6	0.47
Spain	22.3	347.2	0.49
Sweden	3840.0	36000.0	0.30
Switzerland	650.0	5500.0	0.23
Turkey	1385.0	24000.0	0.53
Ukraine	10.9	118.8	0.35
United Kingdom	10.2	45.6	0.14
TOTAL	**14'114.1**	**158'734.5**	

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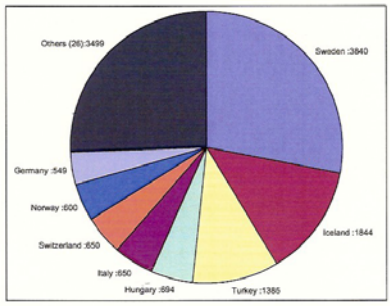
Distribution of direct use capacity in Europe

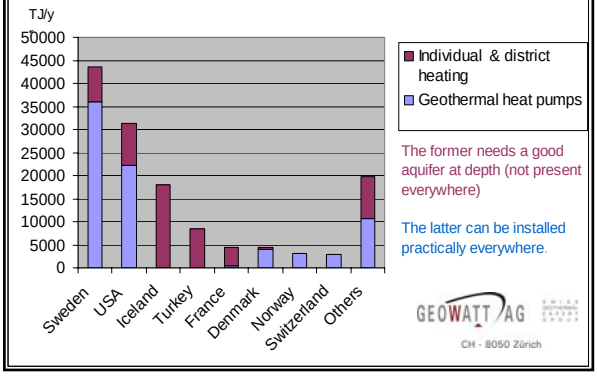


In Iceland:
88 % of all buildings

In the Paris area:
over 100‘000 apartments

are supplied by geothermal district heating

Geothermal heating in IEA countries in 2004 (data from Lund et al. 2005, WGC2005)



The former needs a good aquifer at depth (not present everywhere)

The latter can be installed practically everywhere.

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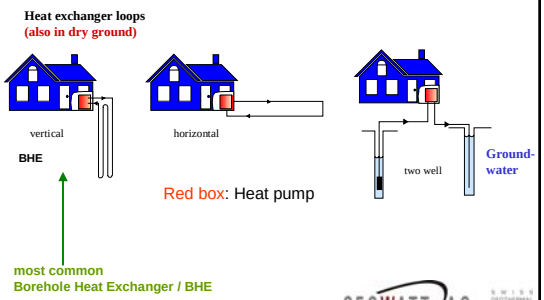
Different geothermal heat pump (GHP) systems



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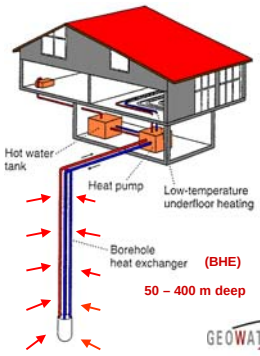
Geothermal heat pump with BHE



BHE drilling and installation

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Real world examples (1)

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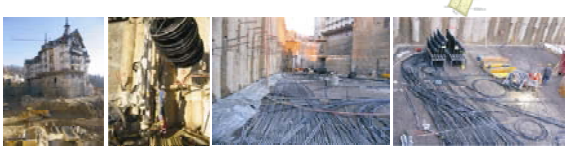
Grand Hotel Dolder in Zurich

Reconstruction, extension
(22'000 m² → 47'000 m²)
Design by GEOWATT AG Zurich
1 GWh/yr heating and 1 GWh/yr cooling
using 75 BHE of total 10'000 m length



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Energy piles: Borehole heat exchangers
underneath buildings

Energy piles installation

ENERGY PILES

Real world examples (2)

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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

Terminal E, Zurich airport

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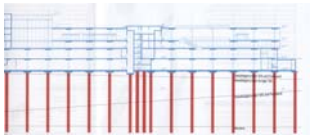
The blueprint:



The realization: from drilling over installation to operation

Large-scale groundwater-based GHP systems in development in Milano (from Sparacino et al. 2007)

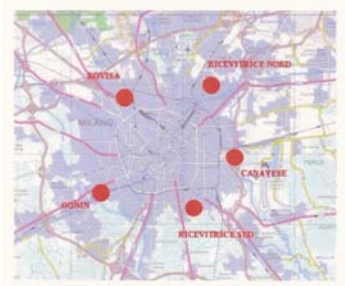


Fig. 6 – Map of Milan illustrating sites of district heating, as foreseen by unified geothermal heat pumps project

Total supply of 650 GWh/yr, for 20'000'000 m³ space, and 250'000 equ. inhabitants

Table 1: GHP number and installed capacity in EU countries (from *Geothermal Energy Barometer, September 2007*)

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Pays/Countries	2005 Nombre Number	2005 Puissance (en MWth) Capacity (in MWth)	2006 Nombre Number	2006 Puissance (en MWth) Capacity (in MWth)
Suède/Sweden	230 094	2 070,8	270 111	2 431,0
Allemagne/Germany	61 912	681,0	90 517	995,7
France/France	63 830	702,1	83 856	922,4
Danemark/Denmark	43 252	821,2	43 252	821,2
Finlande/Finland	29 106	624,3	33 612	721,9
Autriche/Austria	32 916	570,2	40 151	664,5
Pays-Bas/Netherlands	1 600	253,5	1 600	253,5
Italie/Italy	6 000	120,0	7 500	150,0
Pologne/Poland	8 100	104,6	8 300	106,6
République tchèque/Czech Republic	3 727	61,0	5 173	83,0
Belgique/Belgium	6 000	64,5	7 000	69,0
Estonie/Estonia	3 500	34,0	5 000	49,0
Irlande/Ireland	1 500	19,6	1 500	19,6
Hongrie/Hungary	230	6,5	350	15,0
Royaume-Uni/United Kingdom	550	10,2	550	10,2
Crète/Crete	400	5,0	400	5,0
Slovénie/Slovenia	300	3,4	420	4,6
Lituanie/Lithuania	200	4,3	200	4,3
Slovaquie/Slovakia	8	1,4	8	1,4
Lettonie/Latvia	10	0,2	10	0,2
Portugal/Portugal	1	0,2	1	0,2
Total UE à 25/EU 25	**493 236**	**6 158,0**	**599 511**	**7 328,3**
Bulgarie/Bulgaria	19	0,3	19	0,3
Total UE à 27/EU 27	**493 255**	**6 158,3**	**599 530**	**7 328,6**

* Estimation/Estimate

Table 2 – Main GHP markets in the EU with number of installed units* (from *Geothermal Energy Barometer, September 2007)*

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Pays/Countries	2003	2004	2005	2006
Suède/Sweden	31 564	39 359	34 584	40 017
Allemagne/Germany	7 349	9 593	13 250	28 605
France/France	9 000	11 700	13 880	20 026
Autriche/Austria	3 633	4 282	5 205	7 235
Finlande/Finland	2 200	2 905	3 506	4 506
Estonie/Estonia	n. a.	1 155	1 310	1 500
République tchèque/Czech republic	n. a.	600	1 027	1 446
Belgique/Belgium	n. a.	n. a.	1 000	1 000
Pologne/Poland	n. a.	n. a.	100	200
Slovénie/Slovenia	n. a.	35	97	120
Hongrie/Hungary	n. a.	n. a.	80	120
Total	**53 746**	**69 629**	**74 039**	**104 775**
Suisse/Switzerland**	3 558	4 380	5 128	7 130

* Estimation/Estimate.

** Hors Union européenne, pour information/Not in European Union, for information.

Source : EurObserv'ER 2007

DEVELOPMENT TRENDS IN EUROPE

- Over the past years, significant growth took place in power generation as well as in direct use.
- Whereas the increase for power generation was relatively modest, a strong and continuous increase took place in direct use, especially for geothermal heat pumps.
- For example, the drilling for borehole heat exchanger (BHE) installations in Switzerland over the past years shows a typical increase (details see below).

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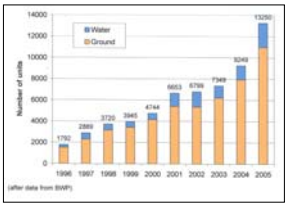
The market plays already...

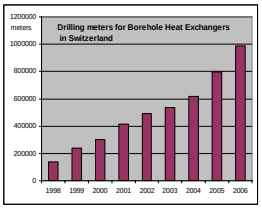
GHP sales in Germany
(B. Sanner, EGEC communication, 9 March 2006)



There was a strong increase of heat pump sales in Germany in 2005, with a total of more than 13'000 ground source heat pumps.

The share of ground source heat pumps in the total heat pump sales was above 80 % until 2002, and decreased to only 72.7 % in 2005.

SWITZERLAND



Development of drilling activities 1998 - 2006

...in some countries

(some 50'000 new GHP units – 600 MWt – start operation in the USA each year)

Heat pump sales in 2006

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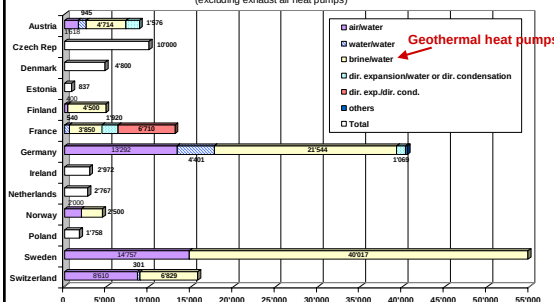
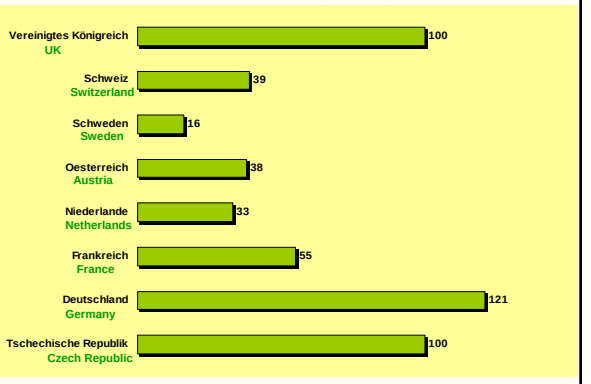
EHPA Heat Pump Statistics 2006: Sales Figures Heating Only
(excluding exhaust air heat pumps)



K. Ochsner, MEGN lecture Budapest, 30.11.2007

Increase in % GHPs in 2006 vesus 2005 (Quelle EHPA)

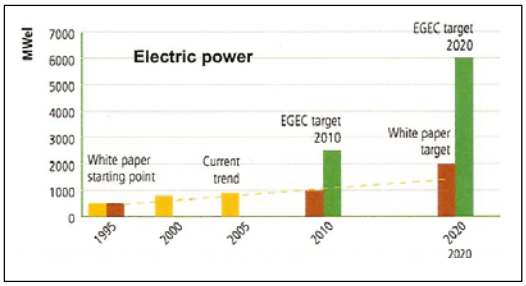


K. Ochsner, MEGN lecture Budapest, 30.11.2007

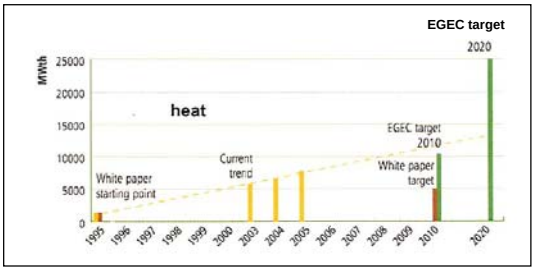
Visionary goals of the EC for year 2020

Energy savings	20 %
Renewable energy share	20 %
CO_2 emission reduction (rel. to 1990)	20 %

EREC Renewable Energy Technology road map (1)



EREC Renewable Energy Technology road map (2)



EREC (=European Renewable Energy Council) projections

Table 5: Renewable Electricity Installed Capacity Projections

TYPE OF ENERGY	2000 EUROSTAT	2004 EUROSTAT	Annual growth rate 2000-2004	PROJECTION 2010	Annual growth rate 2004-2010	PROJECTION	Annual growth rate 2010-2020
1. Wind	13.2 GW	33.6 GW	26.3	80 GW	15.6	180 GW	8.5
2.Hydro	93 GW	107.5 GW	3.7	113 GW	0.8	120 GW	0.6
3. PV	0.18 GW_p	0.86 GW_p	47.8	8 GW_p	45.0	52 GW_p	20.6
4.Biomass	9.5 GW_e	13.1 GW_e	8.6	25 GW_e	11.2	50 GW_e	7.2
5.Geothermal	0.6 GW	0.66 GW	2.4	1 GW	7.2	2 GW	7.2

Table 7: Renewable Heat Generation Projections

TYPE OF ENERGY	2000 Eurostat	2004 Eurostat	AGR 2000-2004	Projection 2010	AGR2004-2010	projection 2020	AGR 2010-2020
Biomass for heat	44.7 Mtoe	48.4 Mtoe	2.0%	65 Mtoe	5.0%	105 Mtoe	4.9%
Solar thermal	0.38 Mtoe	0.68 Mtoe	15.6%	2 Mtoe	19.7%	12 Mtoe	19.6%
Geothermal	0.66 Mtoe	1.5 Mtoe	22.8%	4 Mtoe	17.7%	8 Mtoe	7.2%

FUTURE PROSPECTS

- Generally it will be crucial to secure the sustainability of production.
- For power generation this has been successfully achieved for the Larderello field (Italy) whereas the example of The Geysers (USA) shows that even sophisticated and costly solutions can lead to partial success only, besides creating unwanted side effects like man-made seismicity.
- For direct use and especially for geothermal heat pumps the sustainability can be secured by proper design.

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The future prospects can be viewed on the short and on the long term.

On the short term significant speeding-up in geothermal power development can be expected in some countries (Iceland, Turkey...)

A further, accelerating advance of geothermal heat pumps can definitely be expected

- in countries so far not yet or only marginally applying this technology (e.g. Spain)
- and by progress in new applications like combined heating/cooling or energy piles (foundation piles equipped by heat exchanger tubing).

On the long term the prospects depend on the success of the Enhanced Geothermal Systems (EGS).

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CONCLUSIONS

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- Europe will further develop ist lead in direct use, especially with GEOTHERMAL HEAT PUMPS;
- Soaring oil prices and CO_2 tax help;
- Small power generation units are appearing on the scene (ORMAT / Kalina); feed-in tariffs help;
- Many power plant projects are underway;
- There is increasing interest for EGS, also of decision makers.

Many thanks for your attention !

Prof. Dr. Dr.h.c. L. Rybach
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