Status and prospects of geothermal energy in Europe –

and the achievements of Switzerland

Ladislaus Rybach
GEOWATT AG Zürich

The Institute of Energy Economics, Japan
Tokyo, 12 October 2006

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PRESENTATION STRUCTURE

- status of geothermal energy in Europe
  (separately for power generation and for direct use)
- development trends
- possible future options
- Achievements of Switzerland

Electricity generation from renewables

(refers to 2005)

	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

WGC2005 was held in Antalya/Turkey, 25-29 April 2005. From the country reports submitted, two overview papers have been elaborated:

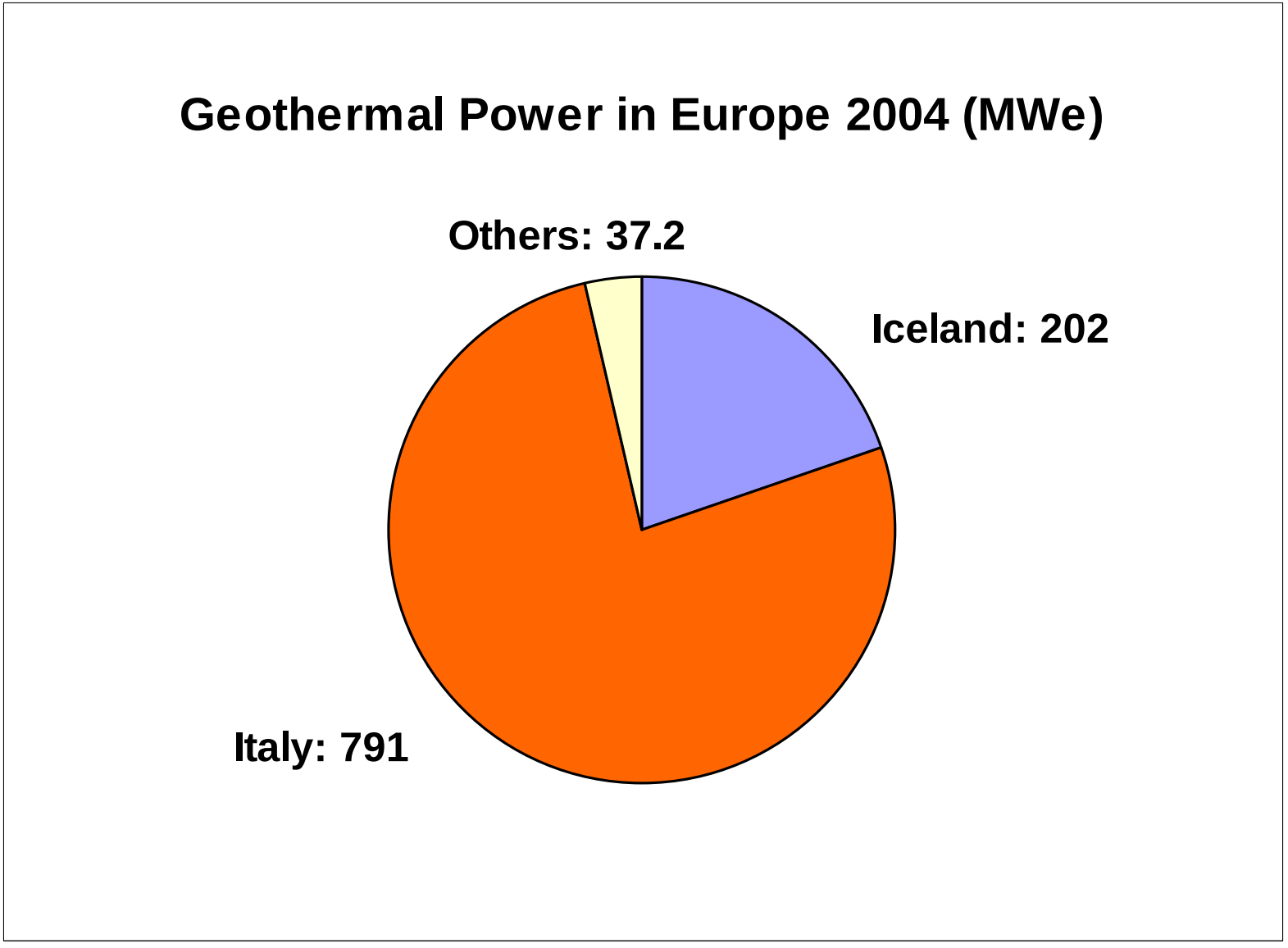
- Bertani, R. (2005): World geothermal power generation in the period 2001-2005. Geothermics 34, 651-690

- Lund, J.W., Freeston, D.E., Boyd, T.I. (2005): Direct application of geothermal energy. Geothermics 34, 691-727

Geothermal power in Europe (from Bertani 2005)

Country	Installed Capacity [MWe]	Running Capacity [MWe]	Annual Energy Produced [GWh/y]	Number of Units	% of National Capacity	% of National Energy
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	791	699	5340	32	1.0	1.9
Portugal (San Miguel island)	16	13	90	5	25*	n/a*
Turkey	20	18	105	1	Negligible	Negligible
Total in Europe proper	**1030.4**	**933.3**	**7022.7**	60	-	-
France (Guadeloupe island)	15	15	102	2	9*	n/a*
Russia (Kamtchatka)	79	79	85	11	Negligible	Negligible
GRAND TOTAL	**1124.4**	**1027.3**	**7290.7**	**73**	-	-

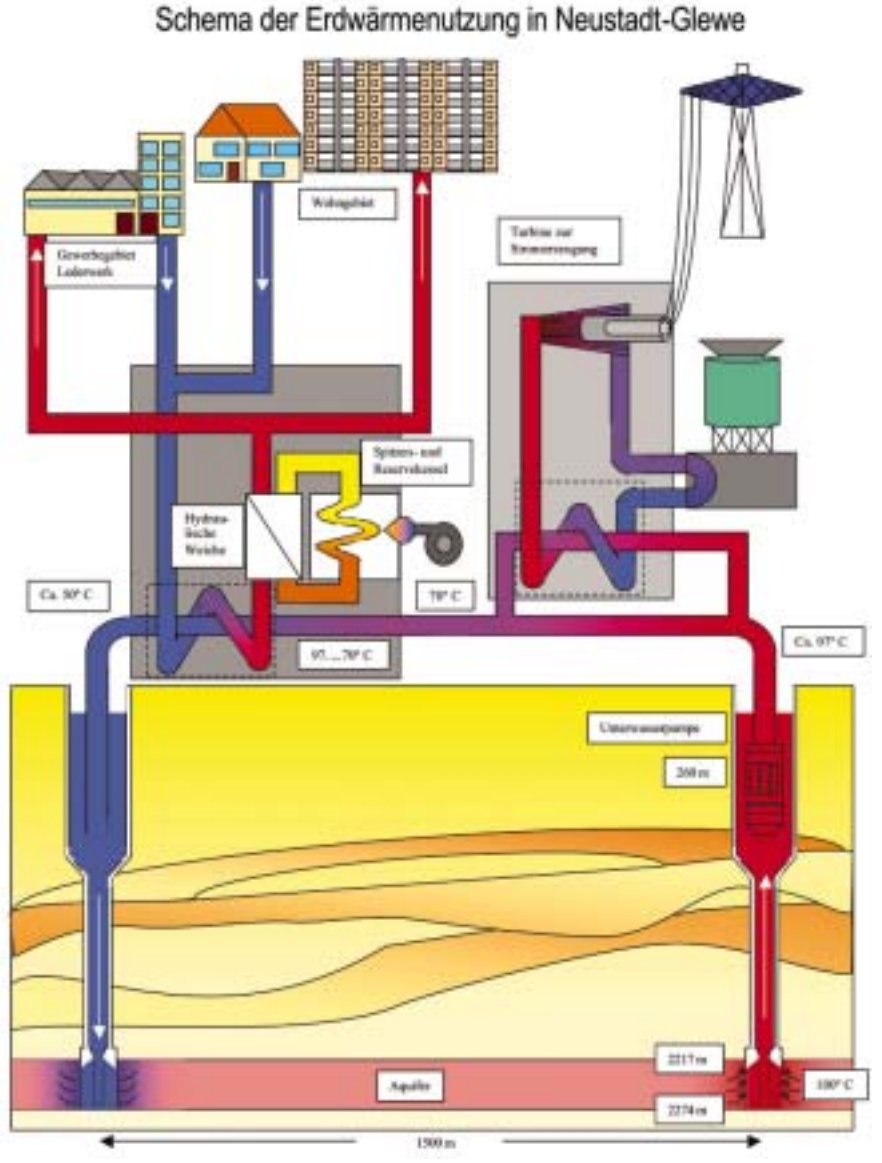
*) Local capacity (Azores islands, Guadeloupe)

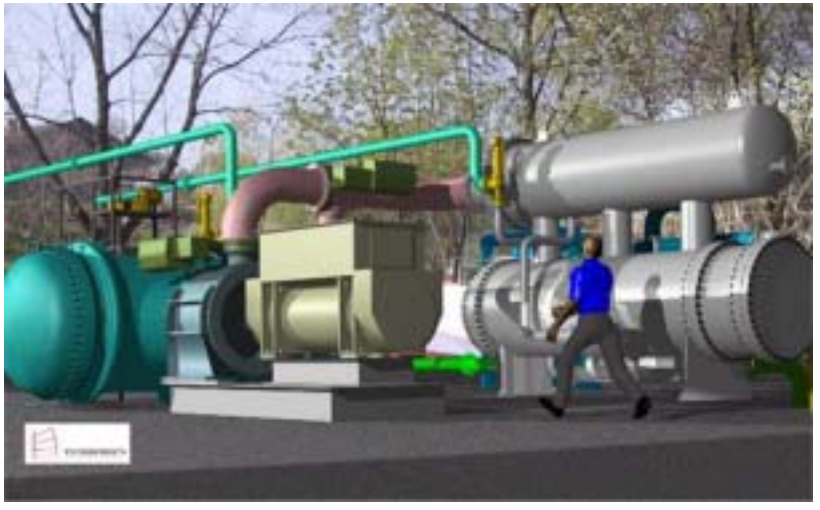

Geothermal Power in Europe 2004 (MWe)
Others: 37.2
Iceland: 202
Italy: 791

Neustadt-Glewe,

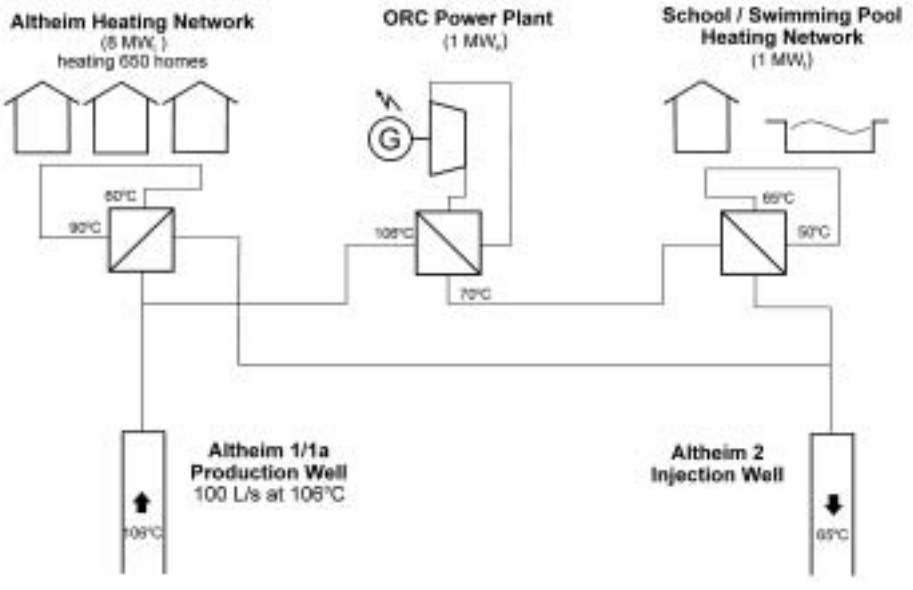
Germany

200 kWe ORC





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



Direct use status

- Various direct uses (for space heating, agriculture, balneology etc.) are reported
- from 34 European countries
- The totals yield 13 GWt and 132’000 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

(from J. Lund, 2005)

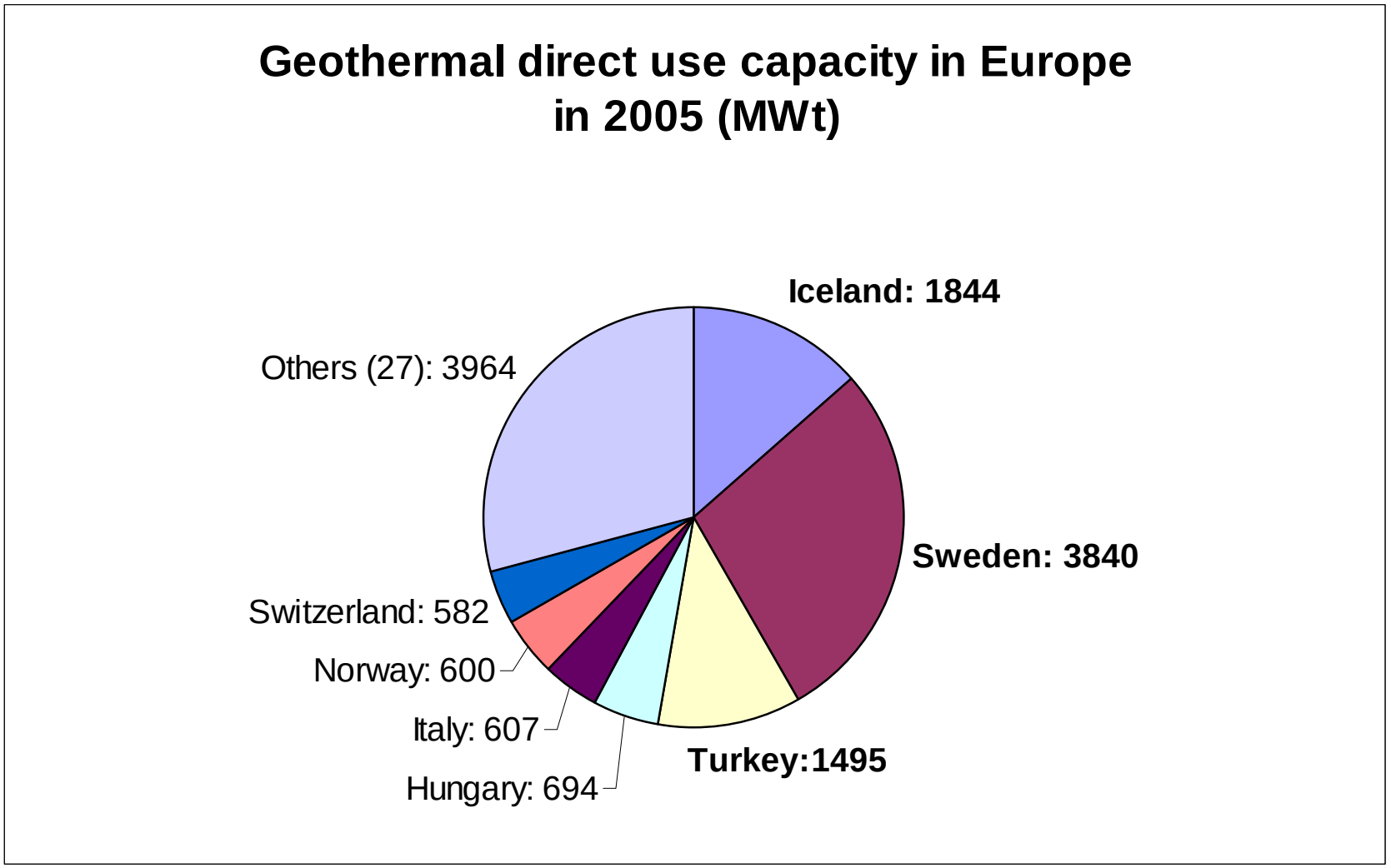
GEOTHERMAL DIRECT USE IN EUROPE IN 2004,

from Lund et. al. (2005)

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	504.6	2909.8	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	606.6	7554.0	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	170.9	838.3	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	581.6	4229.3	0.23
Turkey	1495.0	24839.9	0.53
Ukraine	10.9	118.8	0.35
United Kingdom	10.2	45.6	0.14
TOTAL	**13625.8**	**132037.8**	

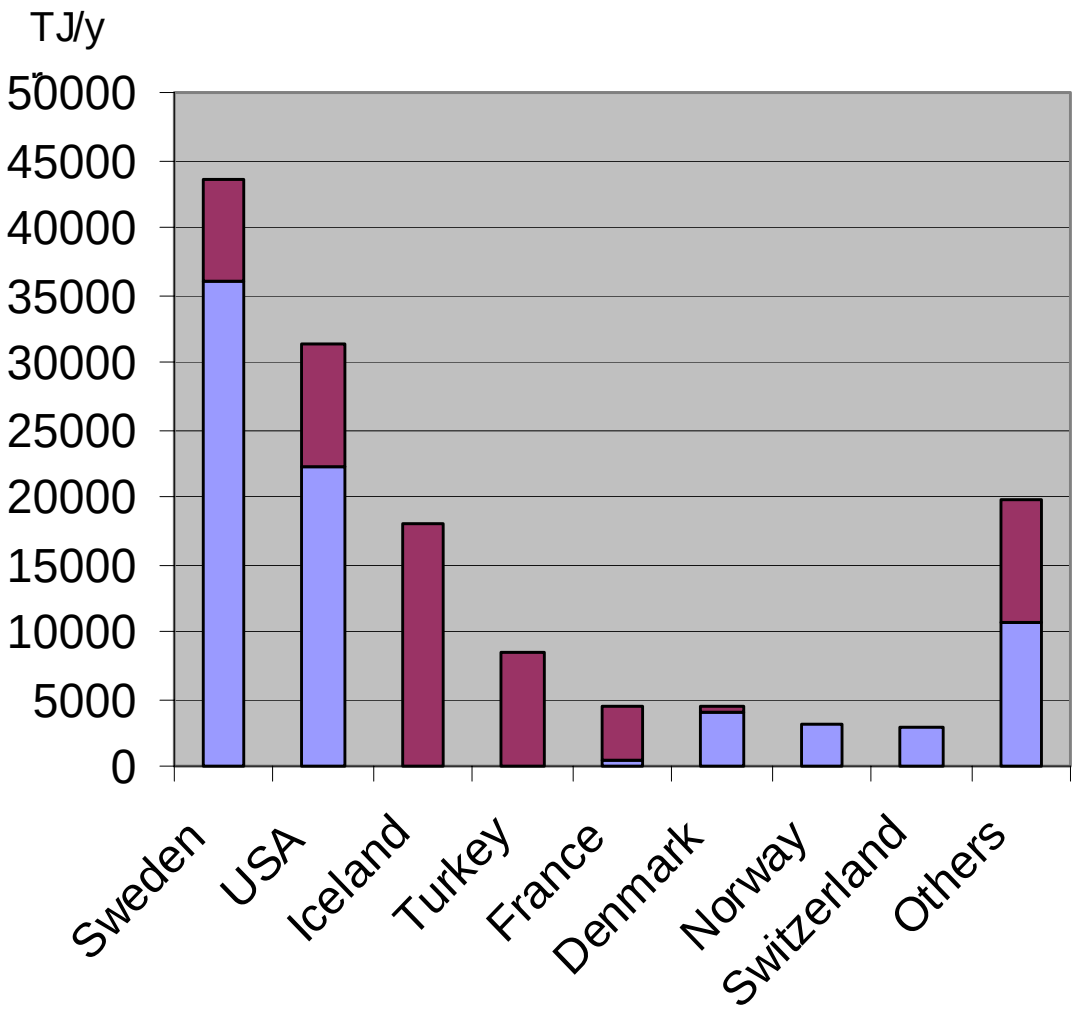

Geothermal direct use capacity in Europe in 2005 (MWt)
Iceland: 1844
Others (27): 3964
Sweden: 3840
Switzerland: 582
Norway: 600
Italy: 607
Hungary: 694
Turkey:1495

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)



Individual & district heating

Geothermal heat pumps

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

The latter can be installed practically everywhere.

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GEOTHERMAL HEAT PUMPS IN EUROPE 2004,

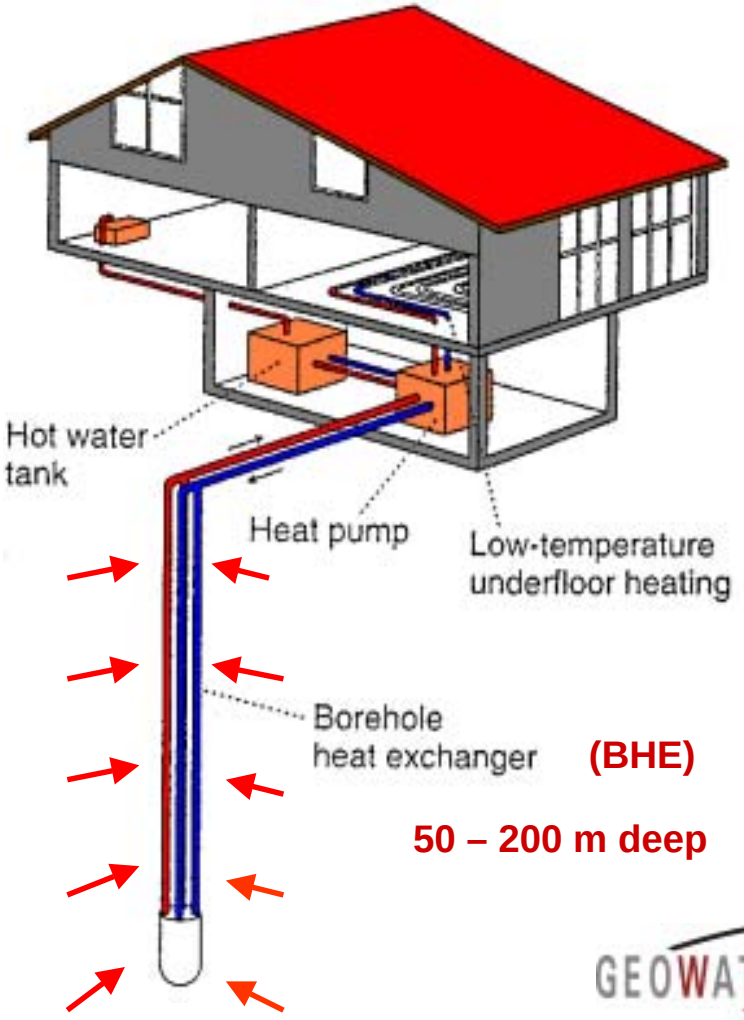
26 countries (after J. Lund, 2005)

Country	Installed capacity (MW_{th})	Annual energy use (TJ/yr)	Equivalent 12 kW units*
Austria	300.0	1'450.0	25 000
Belarus	0.5	3.3	42
Belgium	60.0	324.0	5 000
Bulgaria	0.3	4.4	25
Czech Republic	200.0	1 130.0	16 667
Denmark	309.0	3 940.0	25 750
Finland	260.0	1 950.0	21 667
France	16.1	468.8	1 342
Germany	400.0	2 200.0	33 333
Greece	4.0	39.1	333
Hungary	4.0	22.6	333
Iceland	4.0	20.0	333
Ireland	19.6	83.6	1 633
Italy	120.0	500.0	10 000
Lithuania	21.3	458.0	1 775
Netherlands	253.5	685.0	21 125
Norway	600.0	3 085.0	50 000
Poland	103.6	574.4	8 633
Portugal**	0.2	0.0	17
Russia	1.2	11.5	100
Serbia	6.0	40.0	500
Slovak Republic	1.4	12.1	117
Slovenia	3.9	89.1	325
Sweden	3 840.0	36 000.0	320 000
Switzerland	532.4	2 854.0	44 367
United Kingdom	10.2	45.6	850
TOTAL	**6'921.2**	**55'219.5**	**576'767**

*) 12 kW is the typical size for a residential unit

**) the one unit in Portugal is not operational – thus zero value for annual energy.

Geothermal heat pump with BHE



BHE drilling and installation

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Worldwide ranking results (in order) of geothermal heat pump utilization in 2004, from Rybach (2005)

Capacity installed(MW_{th})	Energy use (TJ/yr)	Capacity per area (Wt/km^2)	Capacity per capita (Wt/capita)	Energy per area (TJ/yr per km^2)	Energy per capita (GJ/yr per capita)	Units per area (12 kW equiva units per km^2)
1. USA	1. Sweden	1. Switzerland	1. Sweden	1. Denmark	1. Sweden	1. Switzerland
2. Sweden	2. USA	2. Sweden	2. Norway	2. Sweden	2. Denmark	2. Sweden
3. China	3. China	3. Denmark	3. Switzerland	3. Switzerland	3. Norway	3. Denmark
4. Switzerland	4. Denmark	4. Netherlands	4. Denmark	4. Austria	4. Netherlands	4. Netherlands
5. Norway	5. Switzerland	5. Austria	5. Finland	5. Netherlands	5. Switzerland	5. Austria

In terms of the weighted figures (capacity or energy per country area or population), the lead is clearly held by Nordic/Scandinavian countries, with Sweden being the champion.

In terms of fictitious medals, the results are as follows:

- **Gold to Sweden 3x, Switzerland 2x, Denmark and USA 1x**
- **Silver to Sweden 4x, Denmark, Norway and USA 1x**
- **Bronze to China, Denmark and Switzerland 2x, Norway 1x.**

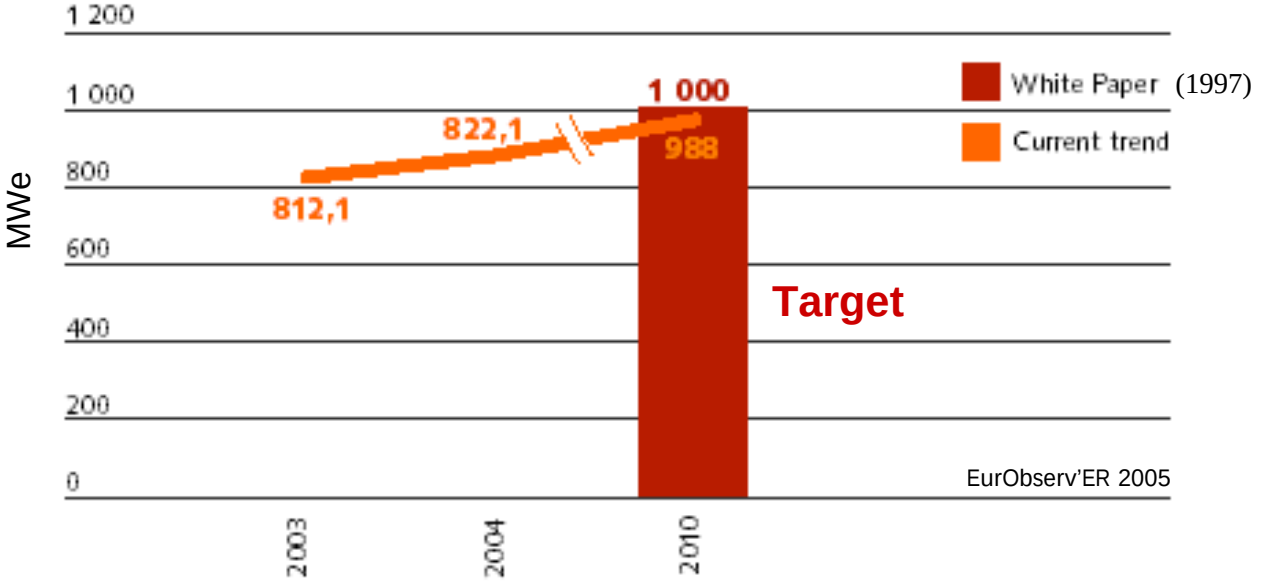
DEVELOPMENT TRENDS

- 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 later).

Geothermal power in EU: current trend

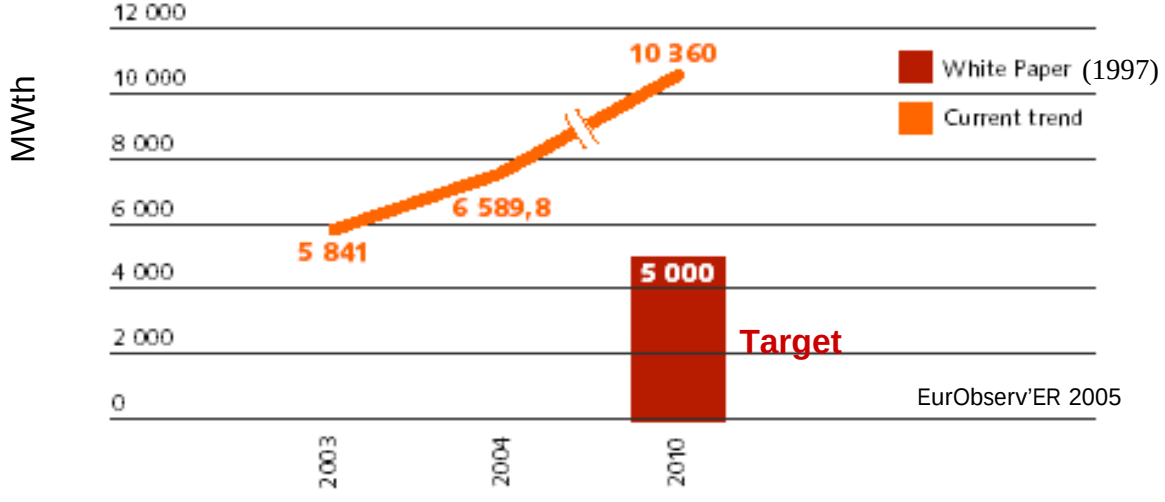
Cumulated announced efforts will bring European Union capacity up to

988 MW, i.e. a little less than the objective set by the European Commission



Geothermal heat in EU: current trend

- ✓ For medium to low temperature heat an increase of 50 MW per year until 2010 seems a reasonable assumption, which will bring capacity up to 2 360 MWth
- ✓ Geothermal heat pumps could reach 8 000 MW capacity in 2010 if average annual growth rate of 10% is maintained



The Commission will work towards legislation on renewable energy in heating in 2006

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.

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).


EGS steam production at Soultz s.F., June 2005

IEEJ:October 2006

Table 8. Guaranteed feed-in tariffs (FIT, in Eurocents/kWh) for electricity from renewable sources in Europe. From energie extra 3.03, Swiss Federal Office of Energy, Berne (2003), EU Green-X (2004), Bundesgesetzblatt 2004, Teil I, Nr. 40

Energy source	Austria	Germany	France	Luxembourg	Portugal	Spain
Solar PV	47 – 60	54.0 – 57.4	15.2 – 30.5	45	22.4 – 41.0	180 - 360
Wind	7.8	5.5 – 6.2	3.05 – 8.38	2.5	4.3 – 8.3	2.7
Biomasse	2.7 – 16.5	8.4 – 11.5	4.5 – 4.9	2.5	0	2.5 – 3.3
Small hydro	3.15 – 6.25	6.65 – 9.67	5.49 – 6.10	2.5	7.2	2.9
Geothermal	7.0	7.16 – 15.0	7.62	0	0	0

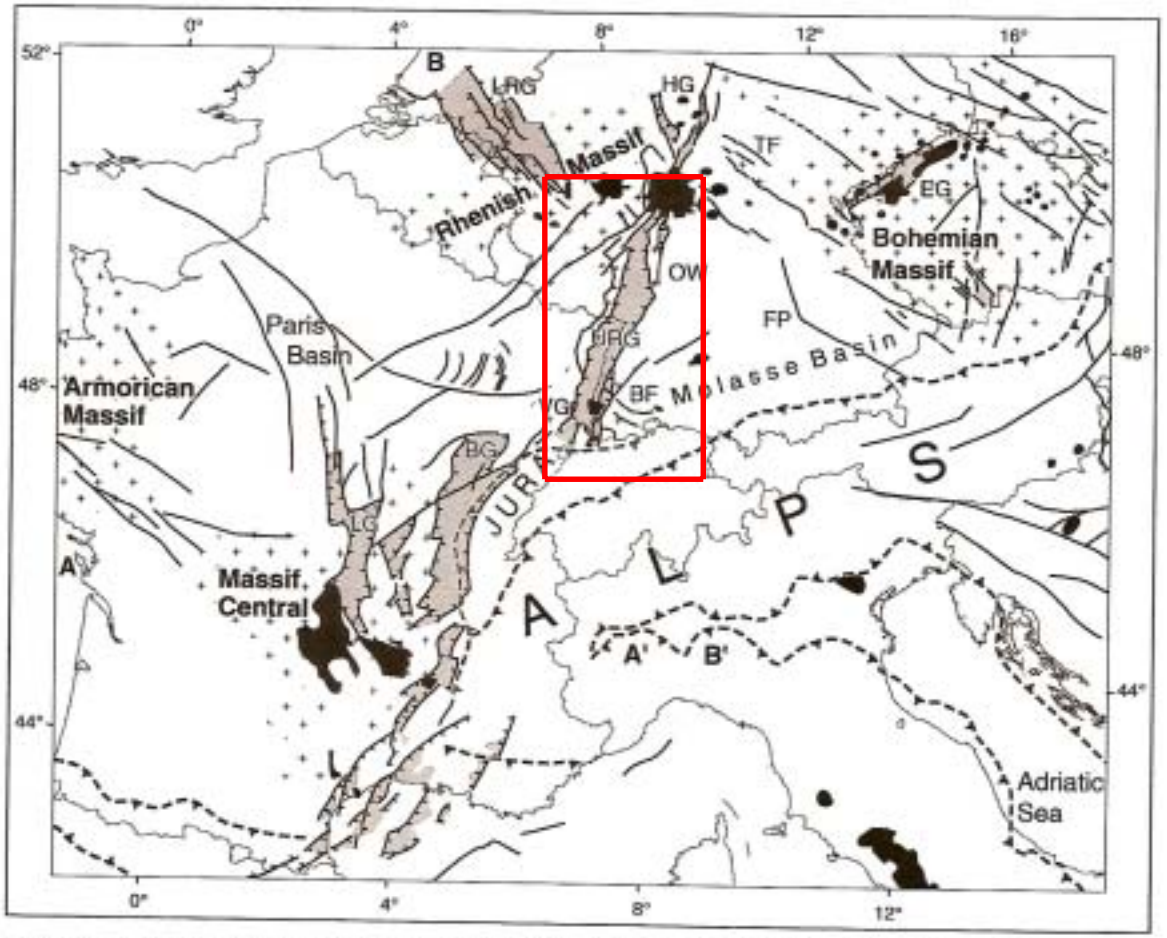


Fig. 9. Location map of the European Cenozoic rift system (ECRIS) in the Alpine and Pyrenean foreland, showing Cenozoic fault systems (black lines), rift-related sedimentary basins (light gray), Variscan massifs (cross pattern) and volcanic fields (black). Solid barbed line: Variscan deformation front; stippled barbed line: Alpine deformation front. BF, Black Forest; BG, Bresse Graben; EG, Eger (Ohre) Graben; FP, Franconian Platform; HG, Hessian Grabens; LG, Limagne Graben, LRG, Lower Rhine (Roer Valley) Graben; URG, Upper Rhine Graben; OW, Odenwald; VG, Vosges (after Dèzes et al., 2004).

Cloeting et al. (2005)

German projects for geothermal power and heat production in the Upper Rhine Valley (status in summer 2006)

Bruchsal
Karlsruhe
Karlsruhe-Nord
Hockenheim-Philippsburg
Rastatt-Lichtenau-Rheinau
Weinheim (only heat production)
Neuried-Altenheim
Mannheim
Emmendingen
Kehl am Rhein
Dinkelberg
Breisach
Markgräfler Land
Lahr
Offenburg
Neuried-Ichenheim
Neuenburg am Rhein
Heidelberg
Goldscheuer
Freiburg-West
Schwetzingen

Bietigheim
Schriesheim
Wiesloch
Karlsdorf
Rhust-Whyl
Freiburg-West (balneology, heat production – online)
Speyerdorf
Landau in der Pfalz
Offenbach an der Queich
Bellheim
Speyer
Riedstadt
Bad Bergzabern
Steinfeld
……

A total of 35

Baumgärtner (2006)

CONCLUSIONS - Europe overwiew

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

PRESENTATION STRUCTURE

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

➢ Achievements of Switzerland

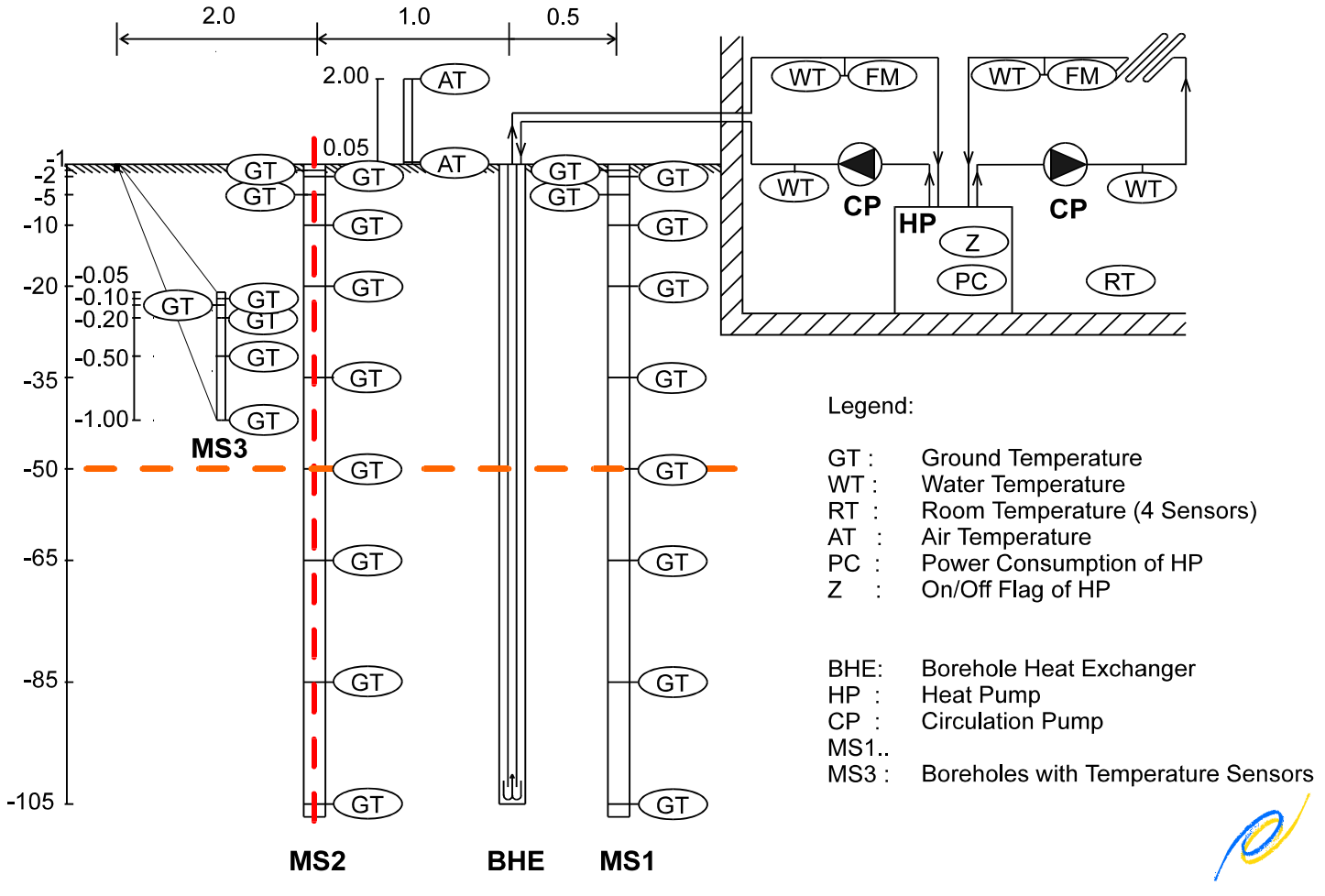
Achievements of Switzerland

Switzerland occupies a prominent rank in geothermal direct use (several „Olympic medals“).

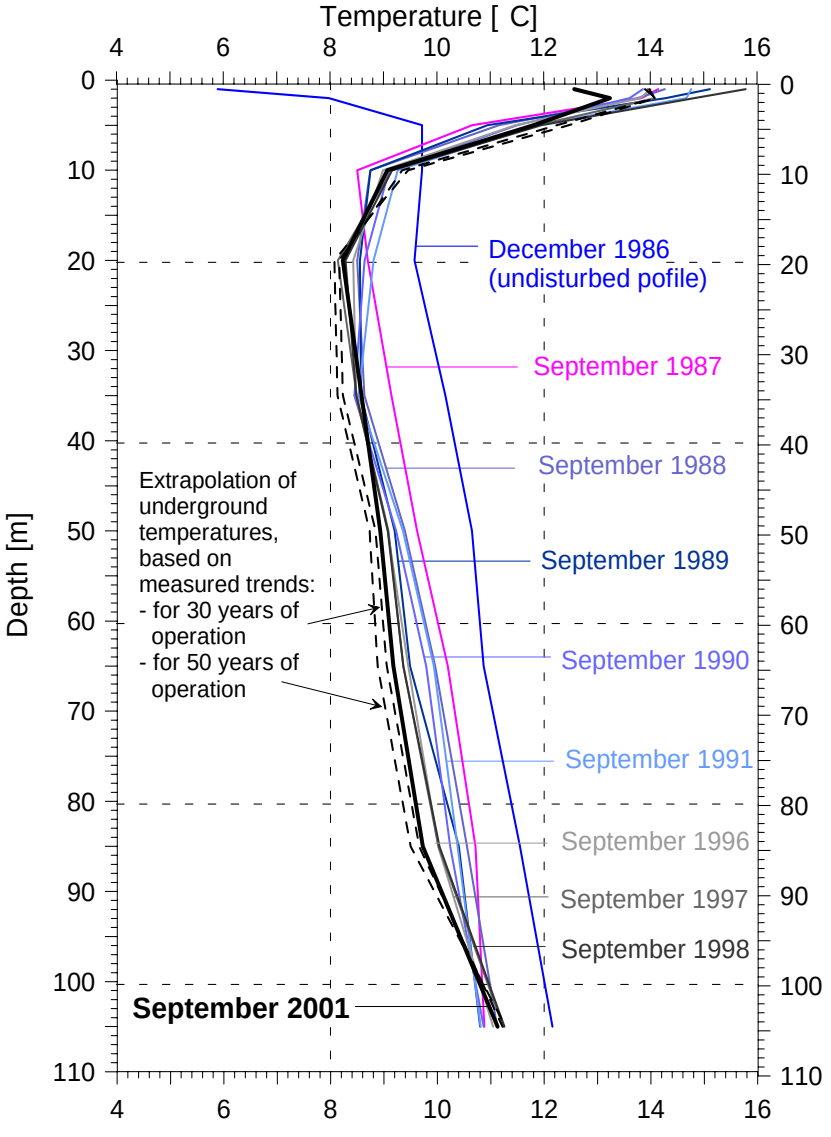
How come ?

Increasing market penetration of geothermal heat pumps

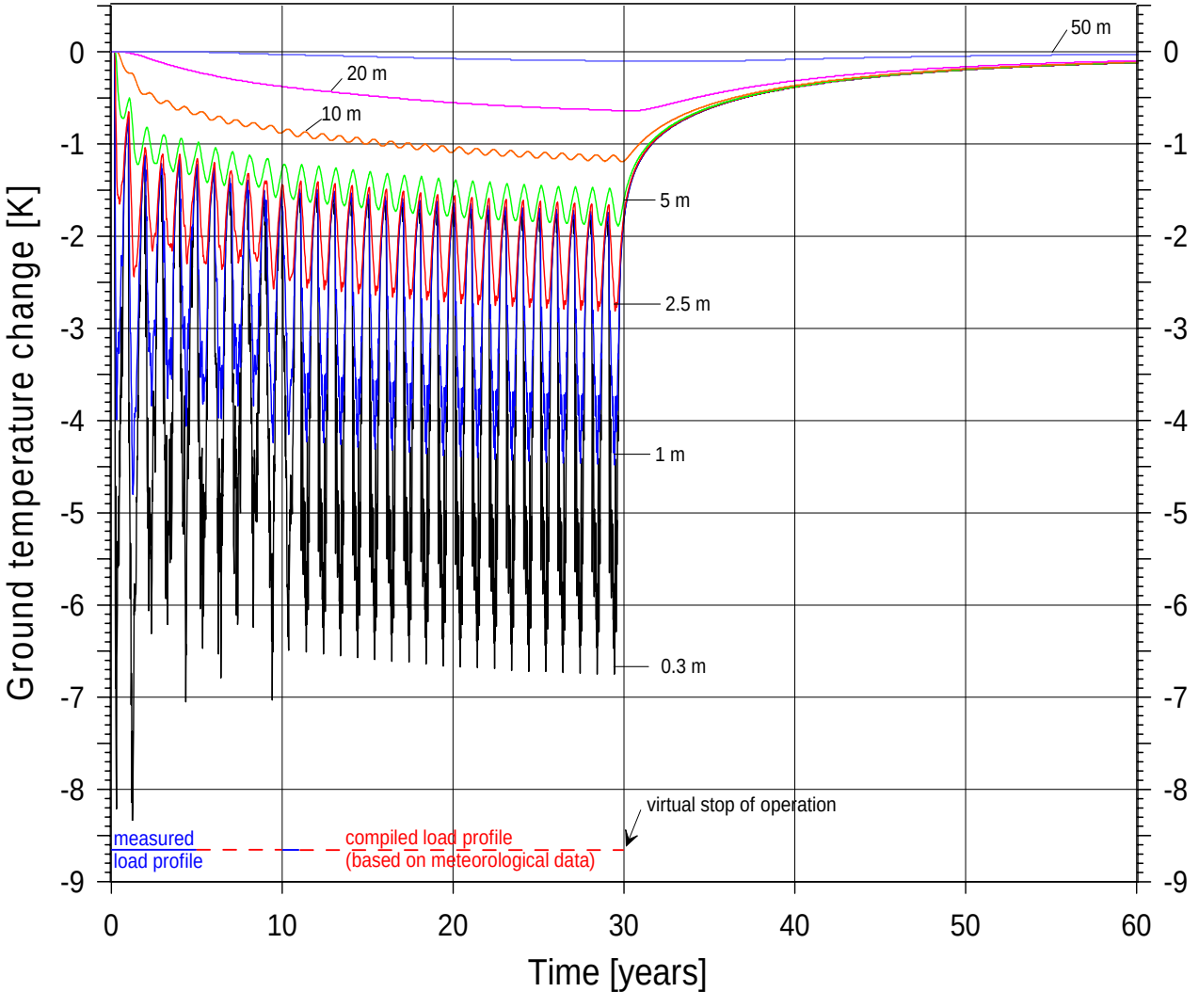
- Proof of reliable system operation (also on the long term) by theoretical and experimental investigations;
- Increasing awareness, confidence, promotion and demand;
- Experience and expanding market leads to price reduction.



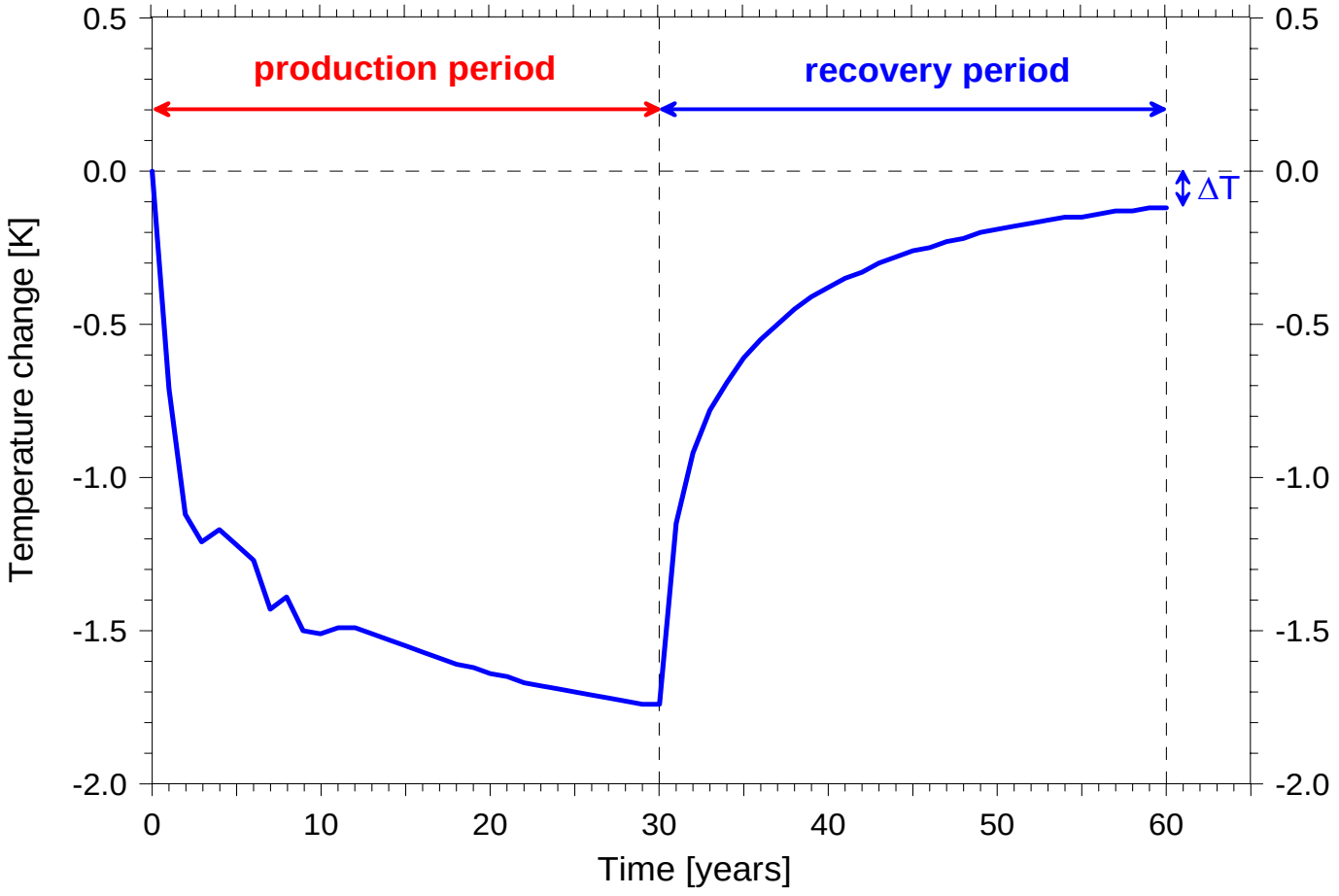
Measurement setup at Elgg/ZH, Switzerland



Ground temperature profiles at 1m distance from the BHE at Elgg/CH (Rybach & Eugster 2002)



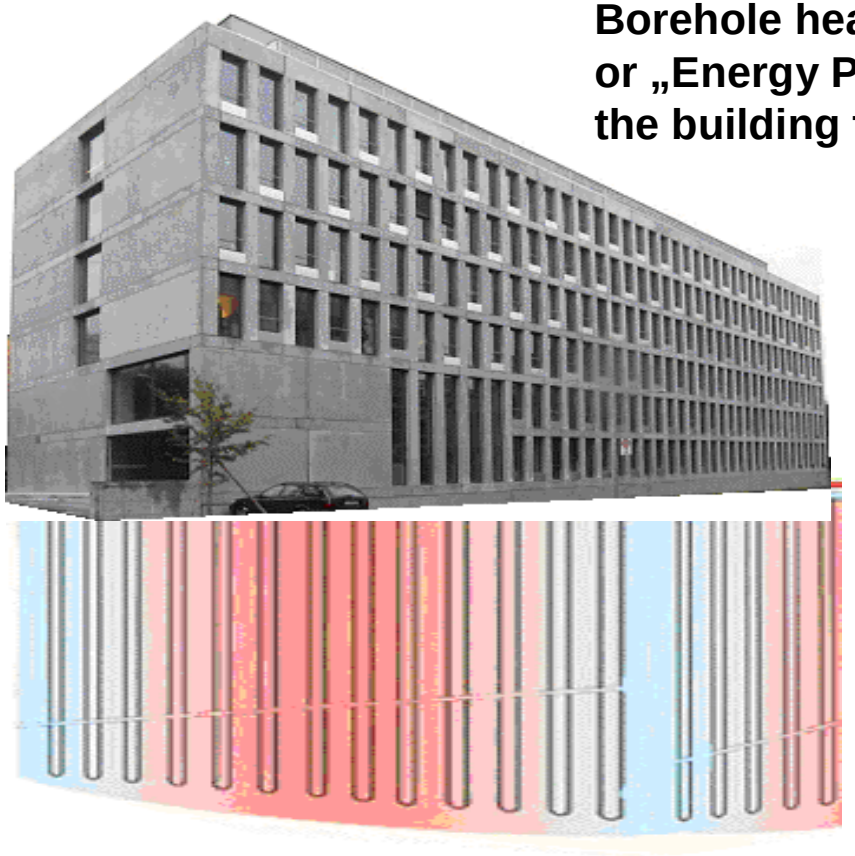
Temperature evolution in the ground around BHE



Asymptotic temperature decline and recovery at 50 m depth and 1 m distance from the BHE (from Rybach & Eugster 2002)

Optimum property use

**Borehole heat exchangers (BHE)
or „Energy Piles“ (EP) directly beneath
the building to be heated / cooled**



**Office building,
Amstein & Walthert AG
Zurich**

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BHE field beneath a building

BMW Headquarters Dielsdorf, Switzerland (140 kW Heiz-, 130 kW Kühlleistung)

Production and business building

Production and business building of a medical company in St. Gallen. The entire building is heated by 17 BHE of an average of 280 m ø 40 mm. The BHE are hydraulically adjusted

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heating / free-cooling

energie-cluster.ch

- Railway station Aarau (CH) south
- climatisation over ceiling components and concrete core
- 16 BHE à 150 m deep, d=32 mm
- 250 kW heating, 100 kW cooling power

http://www.geowatt.ch

17. Mai 2004

energieschweiz

Grand Hotel Dolder, Zurich: Reconstruction and major extension

before: 22‘000 m², after: 47‘000 m²

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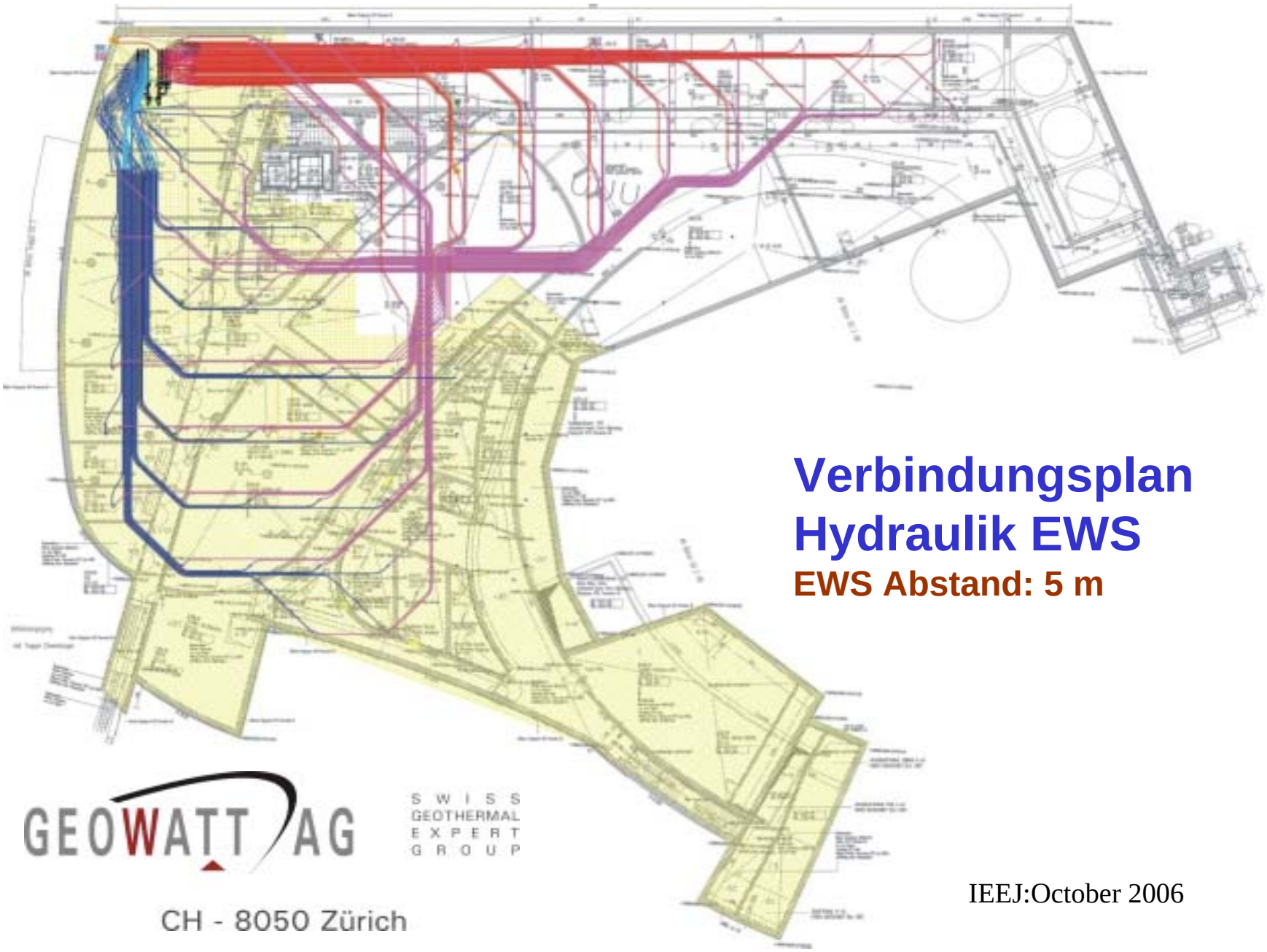

Verbindungsplan Hydraulik EWS

EWS Abstand: 5 m

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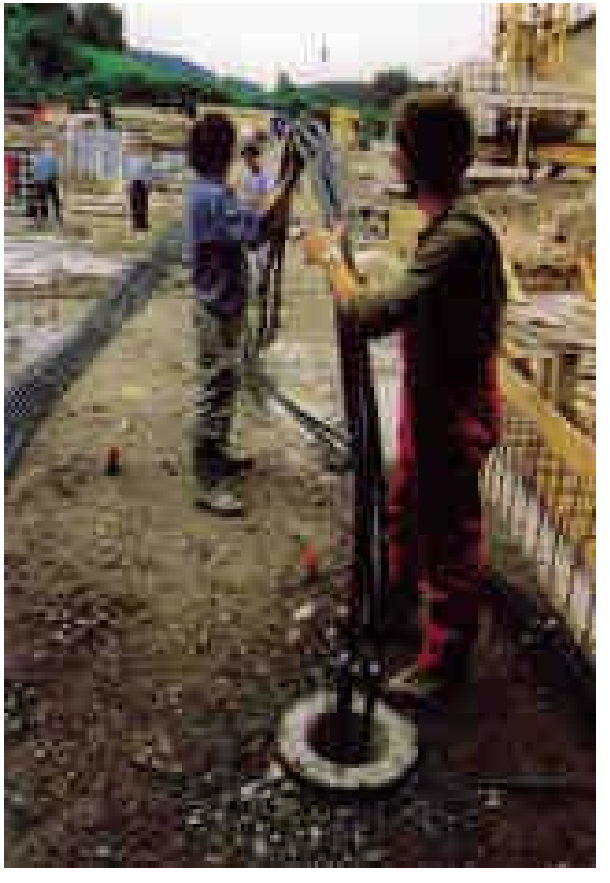
Energy piles: Borehole heat exchangers underneath buildings

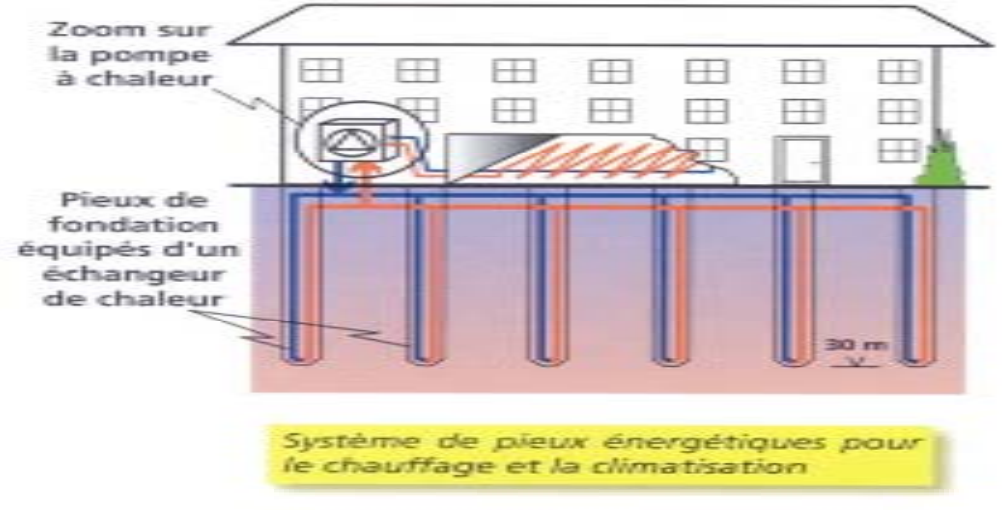


Energy piles installation

ENERGY PILES

IEEJ:October 2006

Schoolhouse in Fully/VS
Heating power 56 kW
41 energy piles, average depth 25 m



Système de pieux énergétiques pour le chauffage et la climatisation

Energy piles

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Prominent example: Terminal E, Zurich airport (2001)

200‘000 m^3 construction space
58‘000 m^2 energy supply area

1100 MWh heating, 600 MWh cooling load

300 energy piles à 30 m

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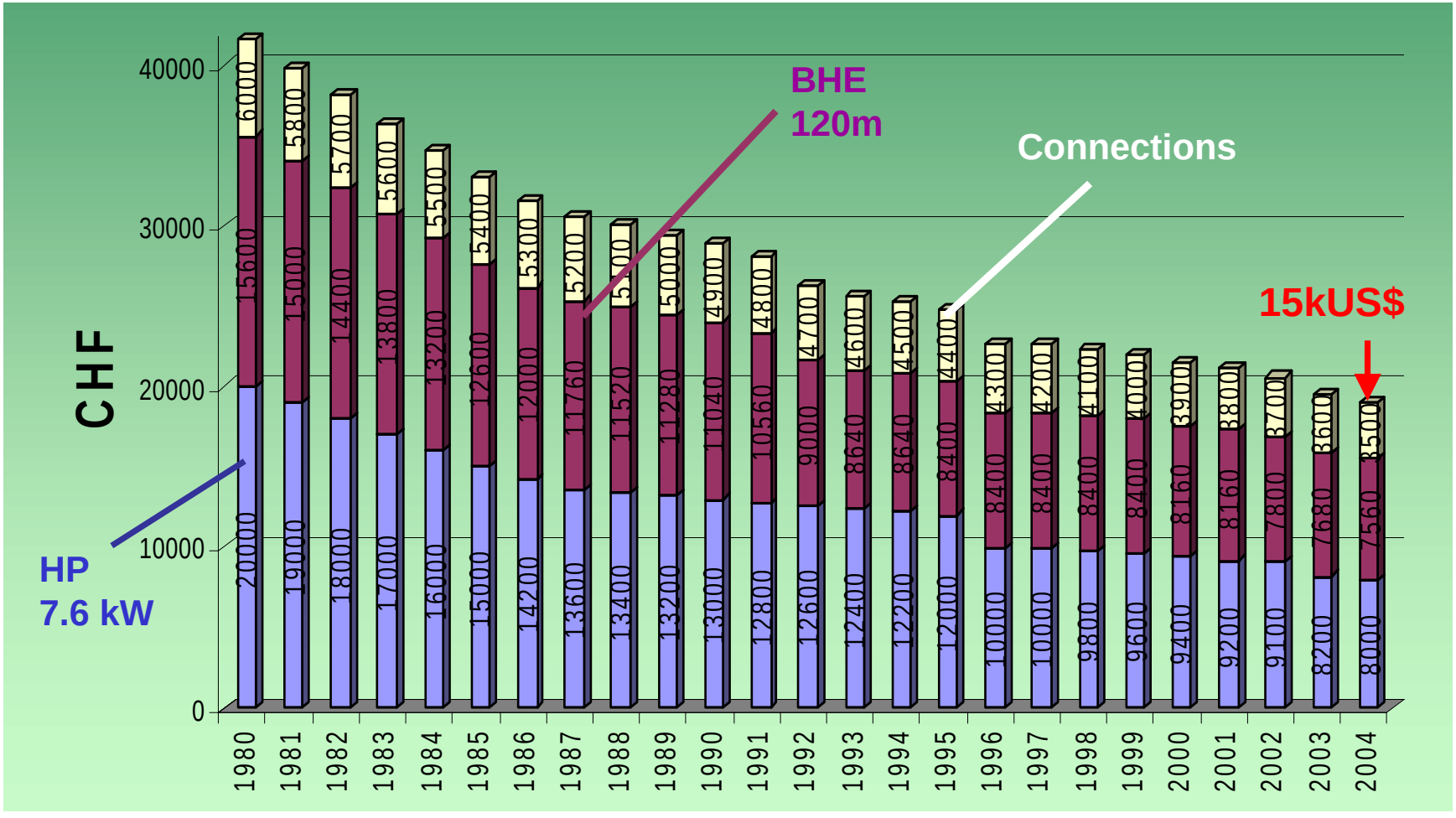
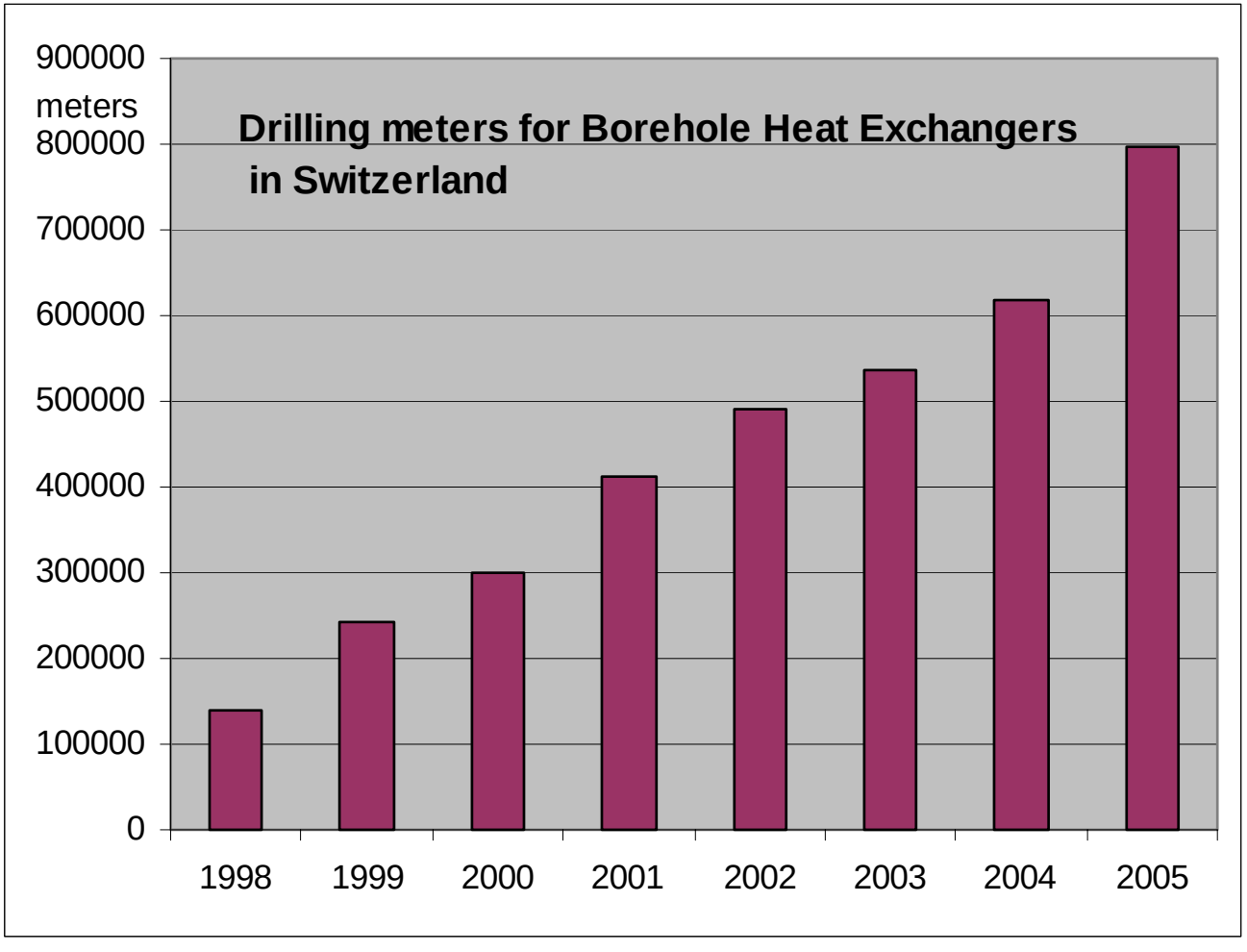
BHE/HP system price development in Switzerland 1980-2004 (corrected for inflation)





Development of BHE drilling in Switzerland 1998 – 2005

Advise for Japan:

- Geothermal heat pumps are ideal for Japan;
- They should be strongly promoted;
- Drilling costs can greatly be reduced.

Many thanks for your attention !

Prof. Dr. Dr.h.c. L. Rybach
GEOWATT AG Zurich
Dohlenweg 28
CH-8093 Zurich, Switzerland
rybach@geowatt.ch

Contact:report@tky.ieej.or.jp