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2005 Country Update for Switzerland

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ABSTRACT

So far, there is no electricity generation from geothermal sources in Switzerland. However, there is a major project underway (DHM: Deep Heat Mining) with the aim to establish, within the next 10 years, HDR-type co-generation plants at sites in Basle and Geneva. The DHM project is funded by federal and local governments; some private funding is also provided.

Geothermal energy utilization for direct use is advancing well in Switzerland. Geothermal heat pump systems (GHP) spread out rapidly, with annual increase rates of up to 15 %. The reasons for this rapid market penetration are technical, economic, and environmental. In 2004, the total installed capacity of GHP systems was 525 MWt with an energy production of about 780 GWh. With over 1 GHP units every 2 km^2, their density area-wise is the highest worldwide. Thus, Switzerland holds a prominent rank worldwide in geothermal direct use. In addition, novel applications, like the use of warm tunnel waters and of other innovative solutions (e.g. “geo- structures” and road and runway de-icing) are emerging.

The total installed capacity for direct use was 585 MWt in 2004, with the following breakdown:

- GHP with borehole heat exchangers (BHE; the overwhelming majority) and horizontal loops 77.0 %,
- GHPs with groundwater 12.9 %,
- spas 7.0 %,
- deep aquifers for space heating 1.0 %,
- tunnel waters and deep BHEs 0.9 %,
- geo-structures (generally foundation piles for combined heating and cooling purposes) 1.2 %.

In total, 1’190 GWh of energy were produced in 2004.

Over thousand boreholes are drilled every year to install double U-tube BHEs into the ground. Average BHE drilling depth is now around 150-200 m, however, depths of more than 300 m are becoming increasingly common. Average BHE cost (drilling, U-tube installation incl. backfill) amounts now to around 40 € per meter. In 2003, a total of 550 km (!) of BHE boreholes have been drilled.

The total energy of 1’190 GWh produced from geothermal sources in Switzerland in 2004 represents a considerable substitution of fossil fuels (~100’000 toe). Equally significant is the reduction of CO_2 emission, which amounts to about 300’000 tons of CO_2 per year.

1. INTRODUCTION

A rather comprehensive overview of geothermal energy utilization in Switzerland has been presented in the Swiss Geothermal Update 1995-2000 (Rybach et al. 2000). In the present paper, priority is given to report on new results and developments within the subsequent time period.

In 2001, an extensive energy program called SwissEnergy was initiated by the Swiss Government, where the support and promotion of indigenous, renewable energy utilization are central issues.

The targets set for the new 10-year program *SwissEnergy* are based on the Federal Constitution and on the Energy as well as CO_2 Laws thus reflecting Switzerland's commitments to the international convention to control climatic warming. Specifically, the objectives are as follows:

- The consumption of fossil fuels and concomitant CO_2 emissions has to be reduced by 10 per cent until 2010.
- The growth of electricity demand must not exceed 5 per cent.
- Hydropower's contribution to net demand must not be reduced despite deregulation of the Swiss electricity market.
- The contribution made by other forms of renewable energy to total electricity production must increase to 0.5 TWh or 1 per cent and to heat production by 3 TWh or 3 per cent of respective energy demands in 2010.

To raise the awareness of the general public to deal more carefully with their energy consumption will represent another important, but even more difficult goal of *SwissEnergy*. This awareness will be necessary as a prerequisite for the optimum implementation of voluntary measures, a closer co-operation among all partners, and to create a spirit of innovation within all energy related fields for an overall strengthening of the Swiss economy.

The basic strategy of *SwissEnergy* is to employ voluntary measures as much as possible, so that there is little or no need of new "command and control" measures or the implementation of a CO_2 tax. However, the experience of the preceding program *Energy2000*, and the latest energy forecasts make it clear that voluntary measures will not be sufficient. Necessary efforts to succeed with the *SwissEnergy* program are summarized in the following:

- Co-operation with private sector organisations (agencies) for the implementation of voluntary energy saving measures on the basis of performance contracts and general agreements.
- Promotional programs such as overall subsidies provided to the cantons, and to the Lothar (hurricane damage) wood energy promotion program (2000-2003, SFr 45 million), in accordance with the Energy Law.
- Umbrella and flanking measures to back up the voluntary measures and to supplement the promotional program: marketing, public relations, consulting, training at all levels, quality assurance (including labels and standards); applied research and development, plus pilot and demonstration projects
- Regulations, particularly in connection with goods declarations and target values, and requirements on the energy consumption of motor vehicles, appliances and buildings.
- Incentives, particularly in the transport field.
- Provided that CO_2 reduction targets might be in question, implementation of a CO_2 tax (as of 2006 at the earliest).

Up to date, the *SwissEnergy* programme is generally on track.

Since 2001, the geothermal energy activities in Switzerland are coordinated by the Swiss Geothermal Association SVG, an affiliated organization of IGA. Financial support is provided by the Swiss Federal Office of Energy (BFE; Bern). In particular, three activities are supported by BFE:

- Promotion of geothermal energy utilization "Mandate Geothermie" (contract with SVG); 4 modules (Information, Education, Quality Assurance, Marketing), ~ 0.4 M€/yr
- R & D (various projects) and
- Pilot & Demonstration facilities (various projects); together approximately 1.25 M€/yr.

Additional information can be found in Vuataz et al. (2003).

2. GEOLOGY BACKGROUND, RESOURCES, POTENTIAL

A description of geology, resources and potential is given in the 1995 Country Update (Rybach and Gorhan 1995). Showing the main geologic units of Switzerland, Figure 1 is presented here for reference and major site locations.

A new, extensive potential and resource assessment study has been initiated in 2002. The project is financed by both the Swiss Geophysical Commission and the Swiss Federal Office of Energy. The study started with investigations in Northern Switzerland and will be successively extended to other parts of the country (preliminary results are given in Kohl et al., 2003).

3. CURRENT STATUS OF GEOTHERMAL UTILIZATION

a. Electricity Generation

Up to date, there is no electricity generation from geothermal sources in Switzerland. However, there is a major project underway (DHM: Deep Heat Mining) aiming to establish HDR-type co-generation plants (at sites in Basle and Geneva) within the next 10 years. Funds are provided by federal and local governments including some private provisions. Just recently, a very significant financial support for the oncoming deep drilling activities in Basel has been secured by the local parliament.

At the Basel site, a newly drilled 2.7 km deep exploration well is being instrumented to record natural as well as artificially induced seismic events. At the Geneva site, detailed investigations are conducted to site the first exploratory drilling.

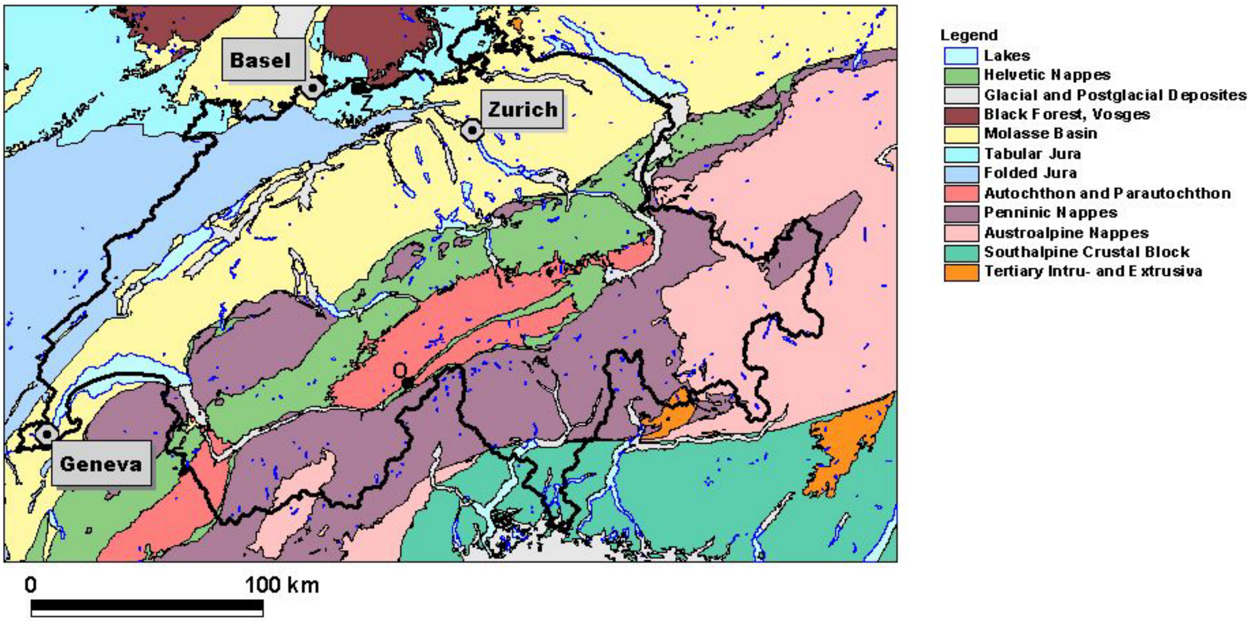

Figure 1: Geological map of Switzerland indicating major cities and other locations mentioned in the text. (O: Oberwald, Z: Zurzach).

There is a strong involvement of various Swiss researchers in the European Hot Dry Rock Project in Soultz–sous–Forêts/F, financed by the Swiss Federal Office for Education and Science (see e.g. Kohl et al., 2004). Investigations on the hybrid concept of heat/power conversion are also pursued (Kohl and Speck 2004).

b. Direct Use

The data about geothermal direct use in Switzerland are derived from a statistical data compilation and evaluation performed on behalf of the BFE (Signorelli et al. 2004).

i. Category use

The following systems are applied to utilize geothermal direct heat in Switzerland:

- Ground-coupled heat pumps with borehole heat exchangers and, to a limited extent of a few per cents, buried horizontal pipes
- Heat pumps using shallow groundwater as a heat source
- Thermal springs and special production wells used at spas for balneology, recreation, wellness
- Deep aquifers used for space/district heating (e.g. the doublet system at Riehen/canton Basel city, supplying a heat distribution network now extending into Lörrach/Germany)
- Warm tunnel drainage waters, transported by gravity to tunnel portals, are used at various locations for space heating (e.g. to heat the Village of Oberwald, canton Wallis)
- “Geo-structures”, i.e. underground building construction elements equipped with heat exchanger pipes (e.g. foundation piles at the new airport terminal in Zurich).

In the following, the first two categories mentioned above will be termed “geothermal heat pumps”.

ii. Installed thermal power

According to the statistical survey of 2004, geothermal heat pumps (GHP) represented by far the largest part of installed capacity in Switzerland (i.e. 525 MW or 90 % of 585 MW of total installed geothermal capacity for direct use, Table A).

iii. Thermal energy used

Furthermore, according to the statistical survey mentioned above, the GHPs contributed 781 GWh or 66 % of the total geothermal heat production (Table B) in 2004. Total energy produced was 1’190 GWh.

iv. Rates and trends in development.

Since their introduction in the late 1970ties, the number of installations of GHP systems in Switzerland is increasing very fast. Figures 2, and 3 are depicting this impressive growth. The rapid spreading of GHPs called for particular quality controls. In 2002, the establishment of a special quality label for the entire GHP system (heat source like borehole heat exchanger, heat pump (HP), circulation hydraulics, heating circuit) has been initiated.

The annual growth rates are indeed remarkable. The number of newly installed systems increases with an annual rate of greater than 10. With over 1 GHP units every 2 km^2, their density area-wise is the highest worldwide (Lund et al., 2003). As of 2004, a total of over 30’000 geothermal heat pumps are operating in Switzerland.

Table A: Direct use of geothermal heat in Switzerland: installed capacity in 2004 (Signorelli et al., 2004).

Energy source / use	**Capacity (MWt)**	**Percent of total (%)**
GHP with borehole heat exchangers (incl. shallow horizontal pipes)	450.0	77.0
GHP with groundwater	75.4	12.9
Thermal springs/production wells (balneology)	40.8	7.0
Deep aquifers	6.1	1.0
Tunnel waters	5.2	0.9
Deep borehole heat exchangers	0.2	0.03
Geo-structures	7.0*	1.2
Total	**584.7**	**100.0**

*) Heating: 4.8 MWt, cooling: 2.2 MWt

Table B: Direct use of geothermal heat in Switzerland: heat production in 2004 (Signorelli et al., 2004).

Energy source / use	**Heat produced in 2004 (GWh)**	**Percent of total (%)**
GHP with borehole heat exchangers (incl. shallow horizontal pipes)	666.3	56.0
GHP with groundwater	114.4	9.6
Thermal springs/boreholes (balneology)	341.5	28.7
Deep aquifers	37.2	3.1
Tunnel waters	13.7	1.2
Deep borehole heat exchangers	0.9	0.1
Geo-structures	15.2*	1.3
Total	**1’189.2**	**100.0**

*) Heating: 12.2 GWh, cooling: 3.0 GWh

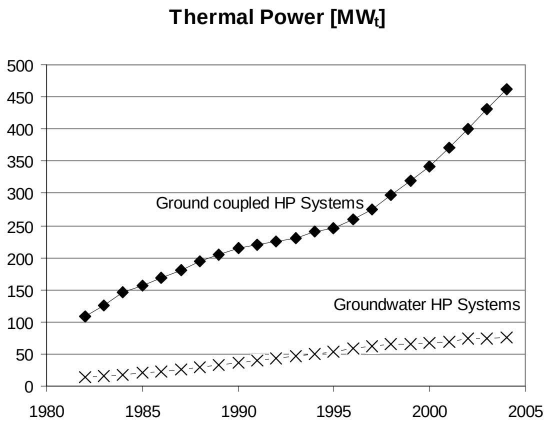

Figure 2: Development of installed capacities (MWt) of ground-coupled and groundwater-based geothermal heat pumps in Switzerland (1982 – 2003, Signorelli et al., 2004).

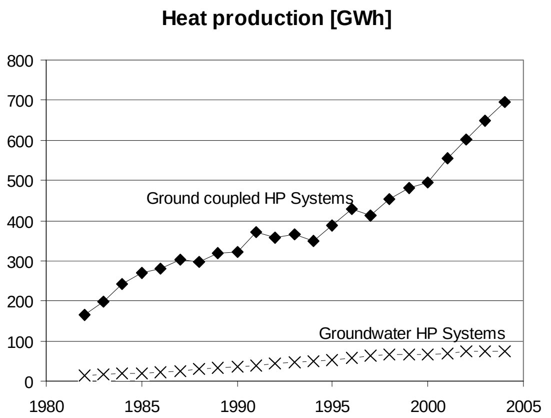

Figure 3: Development of heat production (GWh) by ground-coupled (upper curve) and groundwater-based (lower curve) geothermal heat pumps in Switzerland (1982 – 2003, Signorelli et al., 2004).

Due to climatic conditions, the average load factor amounts to approximately 20 % corresponding to a running time of 1’800 hours/year. A low capacity factor is not necessarily disadvantageous as in well-isolated buildings the heat pump running times can be kept rather short thus reducing electricity consumption.

v. Drilling activities

Over thousand boreholes are drilled each year to install double U-tube borehole heat exchangers (BHE) into the ground. Average BHE drilling depth is now around 150-200 m, but depths more than 300 m are becoming increasingly common. Average BHE cost (drilling, U-tube installation incl. backfill) amounts now to around 40 € per meter. Figure 4 shows the growth rate. In 2003, over 550 km (!) of drill holes have been sunk for BHE’s. Since 2003, the drillings of multiple BHE arrangements (i.e. installations with more than 10 BHEs, and more than 1000 m in drilled length) are separately registered (Signorelli et al., 2004).

Concerning deep drilling after 2000, only the execution of the 2.7 km deep Otterbach 2 borehole in Basel (part of the DHM project, see above) and of one further drilling at Zurzach can be reported (i.e. an exploratory well for balneology, 0.59 km in depth).

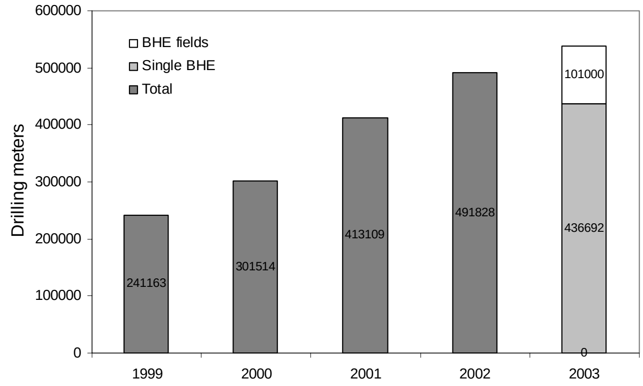

Figure 4: Development of drillings for borehole heat exchangers in Switzerland (Signorelli et al., 2004).

vii. Energy and CO2 emission savings

The total energy produced from geothermal sources in Switzerland (1’190 GWh in 2004) represents a considerable substitution of fossil fuels (i.e. saving of over 100’000 toe). Equally significant is the reduction of CO_2 emission which amounts to about 300’000 tons of CO_2 per year.

viii. Market Development and Stimulation

In Switzerland, there exists practically no other resource for geothermal energy utilization than the ubiquitous heat content within the uppermost part of the earth crust, directly below our feet. This can be taken as one major reason for the rapid market penetration of GHP systems in this country. However, the following technical, environmental and economic aspects can be considered equally advantageous (Rybach and Kohl, 2003):

Technical incentives

- Appropriate climatic conditions of the Swiss Plateau, where most of the population is living. Here, long heating periods with air temperatures around 0 °C and little sunshine in the winter occur, with ground temperatures around 10 – 12 °C already at shallow depths,
- Subject to a correct design, constant ground temperatures will provide a favorable seasonal performance factor, and a long lifespan for a geothermal heat pump system,
- To fit individual requirements, GHP systems are installed in a decentralized manner. Therefore, costly heat distribution systems are superfluous (as compared with district heating),
- Relatively free choice of BHE positions next to or even beneath of buildings, and little spatial demand for a heat pump,
- At least for smaller units, there will be no need of a thermal recharge of the ground. Thermal regeneration of the ground during interruptions of heat extraction will be continuous and automatic.

Environmental incentives

- Contrary to oil, there exists no risk with transportation, storage, and other operations,
- No risk of groundwater contaminations (as with oil tanks),
- The geothermal systems are operating emission-free thus contributing to reduce greenhouse gas emissions like CO_2.

Economic incentives

- Installation cost of the environmentally favorable GHP solution is comparable to that of a conventional (oil based) system (Table 3),
- Low operating costs (no oil or gas purchases, burner controls etc. like with fossil-fuelled heating systems),
- Local utilities are offering discounts for environmentally favorable installations with heat pumps,
- Avoidance of a possible CO_2 tax which might come into force in 2005.

A further reason for rapid spreading of GHP systems stems from "Energy Contracting" by public utilities. The latter implies that a utility company plans, installs, operates and maintains a GHP system at own cost, and sells the heat (or cold) to the property owner at a contracted price (cents/kWh).

DISCUSSION

Additionally to Tables A and B, the statistical data on geothermal direct use in Switzerland are also shown in the standard reporting Tables 1, 3-8. These statistical data have already been analyzed above. Some further issues are treated below.

i. Economics

The geothermal (BHE/HP) solution for space heating is now becoming quite competitive, even when comparing with fossil energy sources (oil burner), see Table C.

Average BHE cost (drilling, U-tube installation incl. backfill) is now around 40 € per meter.

Natural gas is the most serious competitor for geothermal space heating systems in Switzerland. Besides of a rather aggressive marketing, there is also a financial advantage for gas-based systems. Always two pipes, i.e. one for delivery and restitution, are required for geothermal installations where as gas fired installations needs only one pipe; the return pipe being the atmosphere……..

Table C: Comparison of BHE/HP installation and operation costs in Swiss Francs with those of a conventional oil burner heating system (Rybach, 2001).

	BHE *(1 BHE 90 m)*	**Oil burner** **(Tank 2x2000 l)**
Basis: heating demand 6.5 kW		
Heating energy need per year (kWh/a)	13'600	13'600
System efficiency (%)	95	80
Seasonal Performance Factor	3.5	-
Effective energy used (kWh/a)	4'900	17'000
Fuel consumption (liter/a)	-	1'703
Space required (m^3)	2.6	23
CO_2 emission (tons/a)	-	3.8
Installation costs (CHF; Swiss francs)*		
Complete system incl. storage	12'730.-	16'300.-
BHE	11'010.-	-
Space in house (400.-/m^3)	1'040.-	9'200.-
Miscellaneous costs (trenches, chimney...)	1'620.-	1'600.-
Total	***26'400.-***	***27'100.-***
Energy costs (per year, CHF)		
Electricity, high tariff	337.40	49.-
Electricity, low tariff	224.95	22.-
Basic payment	102.-	8.-
Fuel cost (68.-/100 l)	-	1'158.-
Total	***664.35***	***1'237.-***
Running costs (per year, CHF)		
Maintenance	150.-	370.-
Chimney cleaning, smoke gas control	-	180.-
Total	***150.-***	***550.-***

*) 1 CHF = 0.80 US$ (as of May 2004)

ii. Legislation and Regulations

In Switzerland as a country of federal structure, there is legislation on the state (Confederation) and the county (Canton) level. According to federal law, ground property extends below ground surface down to the realm of direct practical interest (a few storeys deep). Below that depth everything belongs to the government. No Mining Law exists on the federal level.

Nevertheless, geothermal energy utilization is poorly defined, both in the federal and cantonal legislation. Legal experts like Gottesmann (1985) differentiate between geothermal heat (an energy *source*, characterized by the physical conditions of the subsurface) and geothermal energy, which is used and distributed at ground surface. Geothermal heat could be subsumed under public law, and geothermal energy, through its use, under private law. Existing federal legislation regulating electricity, atomic power and pipelines is not applicable to geothermal energy issues.

However, where the use of geothermal energy involves water as a heat carrier, water management legislation comes into play. Shallow and deep groundwater belongs to the cantons, and therefore they represent the regulating agency for tapping and using geothermal fluids. By applying well-established cantonal Water Laws, the use of geothermal energy needs a permit and concession.

A special situation exists with ground-source heat pumps involving borehole heat exchangers (BHE). Their construction and operation falls under an environmental legislation, although such systems operate in closed circuits. Reason is the concern that BHEs might cause hydraulic connections between otherwise separated aquifers, and possibly impair groundwater quality. In fact, both the federal Environment Protection Law (Umweltschutzgesetz USG) and the Water Protection Law (Gewässerschutzgesetz GSchG) are applicable with the following consequences:

- no permits will be given to install BHEs or groundwater heat extraction systems within groundwater protection zones or in areas with potential groundwater occurrences;
- only after the execution of suitable field investigations, permits will be obtainable in groundwater boundary zones, in karstic areas and in the vicinity of thermal as well as mineral springs;
- there are no restrictions to obtain permits for remaining areas.

Based on this practice several cantons have already published maps indicating zones where BHEs will be permitted and where not. For instance, such a map is available for the canton Zurich (http://www.wasserwirtschaft.ch). The list of permitting cantonal authorities can be found in www.fws.ch. The applications must state the name of the applicant, of the geologic advisor, the location, the BHE and heat pump specifications as well as the foreseen safety and control measures. The open-mindedness of cantonal authorities contributed significantly to the rapid BHE development in Switzerland (Rybach and Kohl 2003).

According to the Federal Order on Environmental Impact Assessment (19 October 1988), for geothermal installations with a thermal capacity greater than 5 MW, an environmental impact report must be submitted. Application and approval are governed by cantonal legislation.

So far, no particular tax has to be paid for geothermal energy utilization in Switzerland. Recently, however, the administration of canton Berne considered the introduction of a geothermal taxation such as:

- a fee of 3 Swiss francs (equivalent of 2.4 US$) per year and MWt capacity was foreseen for thermal water production from deep drill holes;
- 0.5 – 2 Swiss francs per BHE meter and year(!).

Fortunately, thanks to the protests of national and international organizations (including a letter of GRC President John Lund in February 2002) the legislative body (cantonal Parliament) did not follow the suggestion of the administration.

4. FUTURE DEVELOPMENTS

As in many parts of Europe, the summer of 2003 has been extremely hot also in Switzerland. Naturally, cooling of housing and office buildings was suddenly very much in demand. For this purpose geothermal heat pumps are well suited. Often “direct or free cooling” (i.e. only by circulating the fluids in BHEs) is sufficient to create a comfortable indoor environment. It can be expected that in coming years space cooling by BHEs will significantly increase.

ACKNOWLEDGMENTS

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APPENDIX

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2004			807	2866	14126	36445	3220	25931	24 wind+photovoltaics	19	18177	65261
Under construction in December 2004												
Funds committed, but not yet under construction in December 2004												
Total projected use by 2010	5	20	925	3285	14140	36481	3220	25931	40	33	18330	65750

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

[1] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Bassersdorf (ZH)	H							4.3	2.95	0.4
Itingen (BL)	H							4.8	0.25	0.03
Kreuzlingen (TG)	B/H							0.4	0.29	0.45
Kloten (ZH)	H							5	2.38	0.4
Riehen (BS)	D							20	103.3	0.75
Seon (AG)	D/H							25	24.8	0.75
TOTAL									134	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

Report the COP = (output thermal energy/input energy of compressor) for your climate

Report the equivalent full load operating hours per year, or = capacity factor x 8760

Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
~25'000 localities	9 - 15		~25'000	V/H	3 - 4	~1800	2400	
~5'000 localities	10 - 12		~5'000	W Groundwater	4 - 6	~1800	410	
~10 localities	9 - 10		~10	V Geo-structures	3 - 4	~1800	44	11
TOTAL							2854	11

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]	6.1	134	70%
Air Conditioning (Cooling)	2.2	11	16%
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting	0.1	0.3	20%
Bathing and Swimming[7]	40.8	1230	97%
Other Uses (specify)			
Subtotal	49.2	1375	
Geothermal Heat Pumps	532.4	2854	~20 %
TOTAL	584.7	4230	

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)		1	1		3.3
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total			1	1		3.3

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	2	1	3	0	0	6
2001	2	1	3	0	0	7
2002	2	1	3	0	0	7
2003	2	1	3	0	0	8
2004	2	1	3	0	0	9
Total	10	5	15	0	0	37

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1990-1994	5.5	50	53.5		85	15
1995-1999	10	105	115		80	20
2000-2004	12	110	120		85	15