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Country Update of Switzerland

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ABSTRACT

So far no kWh electricity is being produced from geothermal sources in Switzerland. Geothermal energy utilization for direct use is advancing well. Geothermal heat pump systems (GHP) spread out rapidly, with annual increase rates of up to 17 %. Statistical data exist up to the end of 2008 for direct use installed capacity and energy delivery. The predominant contribution is from geothermal heat pumps (GHP). among these the borehole heat exchanger (BHE)-coupled systems predominate**.**

In 2008 the total installed capacity in direct use was 1’060 MWt with an energy production of 2’130 GWh. With about 1 GHP installations every square km^2, their density area-wise is the highest worldwide. Novel applications, like the use of warm tunnel waters and of other innovative solutions like energy piles are also established. The number of boreholes drilled for BHE installations is highly remarkable; alone in 2009 the total drilling length was nearly 2’000 km. The majority of the BHE systems are installed in new buildings but an important and increasing portion is for retrofitting existing buildings.

The total energy of 2’130 GWh (7.7 PJ) produced from geothermal sources in Switzerland in 2008 represents a considerable substitution of fossil fuels (~180’000 toe). Equally significant is the saving of further CO_2 emission, which amounts to about 560’000 tons of CO_2 per year.

1. INTRODUCTION

This report concentrates on the changes since the last Swiss Geothermal Update (Rybach and Gorhan 2005). An intermediate report has been prepared for EGC2007 (Rybach and Minder 2007). The statistical data presented here are taken from the compilation of Signorelli et al. (2009); they cover the changes up to the end of 2008.

The major change in governmental policy was the introduction of a feed-in tariff and of a risk coverage system in 2008. The cost-covering remuneration for feeding electricity from renewable energy sources into the grid is based on the new Federal Electricity Supply Act (entered into force on 1st January 2008).

A first governmental risk coverage system for geothermal drillings existed 1987-1997. In 2008 a new system has been introduced. The new Swiss Electricity Supply Decree (14 March 2008) stipulates that geothermal power projects may apply for a risk guarantee (whereas the type of geothermal power project –hydrothermal or EGS– is not specified). Only pure geothermal projects can apply; hybrid systems are not considered. The maximum guarantee is 50% of the subsurface costs (drillsite constructions; well drilling and completion for production, borehole geology, injection and observation wells; borehole logging and instrumentation; pumping tests; reservoir stimulation; circulation tests; chemical analysis). New element is the source of financing: the National Grid Company (NGC). For applicability the geothermal facilities must provide at least 1.5 % electricity utilization degree. Detailed information on geothermal feed-in-tariffs and on the risk guarantee system can be found in Rybach (2010a).

2. GEOLOGICAL BACKGROUND

Reference is made here to Rybach and Gorhan (2005), where an overview is given, along with a geologic map, depicting the main geologic units.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Distinction is made here between shallow and deep resources. In Switzerland, the depth of 400 m is taken as the boundary between shallow and deep. In the last years a significant number of resource delimitation, mapping, and evaluation studies have been performed, both on regional and national level. The regional studies are usually at the level of cantons like Fribourg (2005), Zurich (2007), Neuchâtel (2008). Currently additional resource and potential studies are underway in the cantons Schaffhausen and Thurgau, as well as in the city of St. Gallen,

On the national level the extensive potential and resource assessment study, jointly financed by both the Swiss Geophysical Commission and the Swiss Federal Office of Energy, must be mentioned. The methodology comprises of comprehensive 3-D regional geological and thermal models, incl. discretization and numerical modelling, and calculation of the technical potential. The Swiss Geothermal Resource Atlas, prepared by Geowatt AG Zürich, currently extends over must of the Swiss Plateau (northern Alpine foreland) and is published in two volumes by the Swiss Geophysical Commission: Signorelli and Kohl (2006), and Baujard et al. (2007).

4. GEOTHERMAL UTILIZATION

4.1 Electricity generation

So fare there is no electricity generation from geothermal sources in Switzerland.

4.2 Direct use

The statistical study of Signorelli et al. (2009) about direct use compiles installed capacities is various usage categories, energy produced, fossil fuel and CO_2 emission savings up to the end of 2008. The annual values clearly show the steady increase of geothermal direct use.

The last Swiss Country Report (Rybach and Gorhan 2005) had the numbers por 2004. Table A and Table B show the development between 2004 and 2008; Figure 1 the relative proportions of the various direct usage categories. It is evident that the use of shallow resources by geothermal heat pumps have the largest share. The second largest category is the traditional use of thermal waters is spas and wellness facilities.

The key geothermal achievement of Switzerland is in the increasing use of shallow geothermal resources by ground-coupled heat pumps. An evaluation of available global data reveals that Switzerland occupies a prominent worldwide rank in installing and running geothermal heat pump (GHP) systems (Rybach and Xu, 2008). Figure 2 shows the impressive growth in installing borehole heat exchanger-coupled GHPs over the years 1990-2008. The heat produced is documented and compiled in the statistical study of Signorelli et al. (2009). Figure 3 shows the increase of heat production by GHP systems 1990-2008. Geothermal heat pumps are now increasingly and soon routinely used for cooling as well as for heating. Figure 4 shows the development of all usage categories by the heat delivered in the years 1990-2008. The accelerating growth is mainly due to the rapid market penetration of GHP systems.

Table A: Development of total installed direct use capacity 2004-2008 (MWt) of systems using heat pumps. From Signorelli et al. (2009).

System*)	2004	2005	2006	2007	2008	%in 2008
BHEs (incl. horizontal loops, geothermal baskets)	502.8	560.1	649.7	749.5	861.2	84.3 %
Near-surface groundwater	103.5	105.1	114.4	123.5	143	14.0 %
Geostructures (Energy piles)	7.0	7.9	8.6	8.9	10.4	1.0 %
Deep aquifers	5.0	5.0	5.0	5.0	5.0	0.5 %
Tunnel waters	2.4	2.4	2.4	2.4	2.4	0.2 %
Deep BHEs	0.2	0.2	0.2	0.2	0.2	<0.1 %
Total	**620.8**	**680.7**	**780.3**	**889.4**	**1022.1**	

*) Thermal spas are not included; in 2008 the total installed capacity was 35 MWt.

Table B: Development of total heating energy from direct use 2004-2008 (GWh). From Signorelli et al. (2009).

System	2004	2005	2006	2007	2008	%in 2008
BHEs (incl. horizontal loops, geothermal baskets)	897.5	1030.8	1102.0	1229.8	1573.6	73.9 %
Thermal spas	297.9	289.7	289.7	289.7	290.4	13.6 %
Near-surface groundwater	154.2	162.9	162.6	175.8	221.8	10.4 %
Geostructures (Energy piles)	14.5	16.3	17.8	18.4	21.5	1.0 %
Deep aquifers	15.1	15.3	14.6	11.5	13.4	0.6 %
Deep aquifers (without heat pump)	3.3	3.4	3.0	2.7	2.1	0.1 %
Tunnel waters	4.0	4.2	4.6	4.4	4.3	0.2 %
Deep BHEs	1.0	1.0	1.0	1.0	0.8	<0.1 %
Total	**1387.4**	**1523.5**	**1595.2**	**1733.2**	**2127.9**	

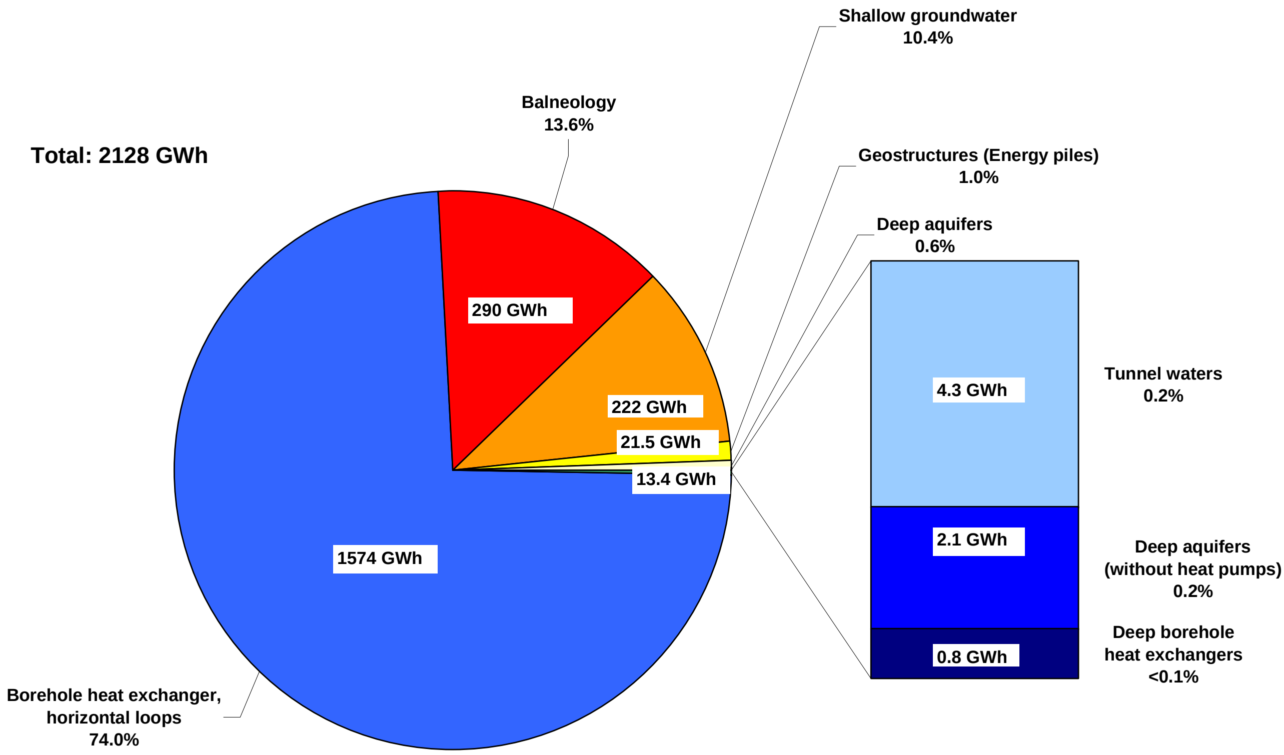

Figure 1: Relative contributions of the various direct use categories in 2008, from Signorelli et al. (2009).

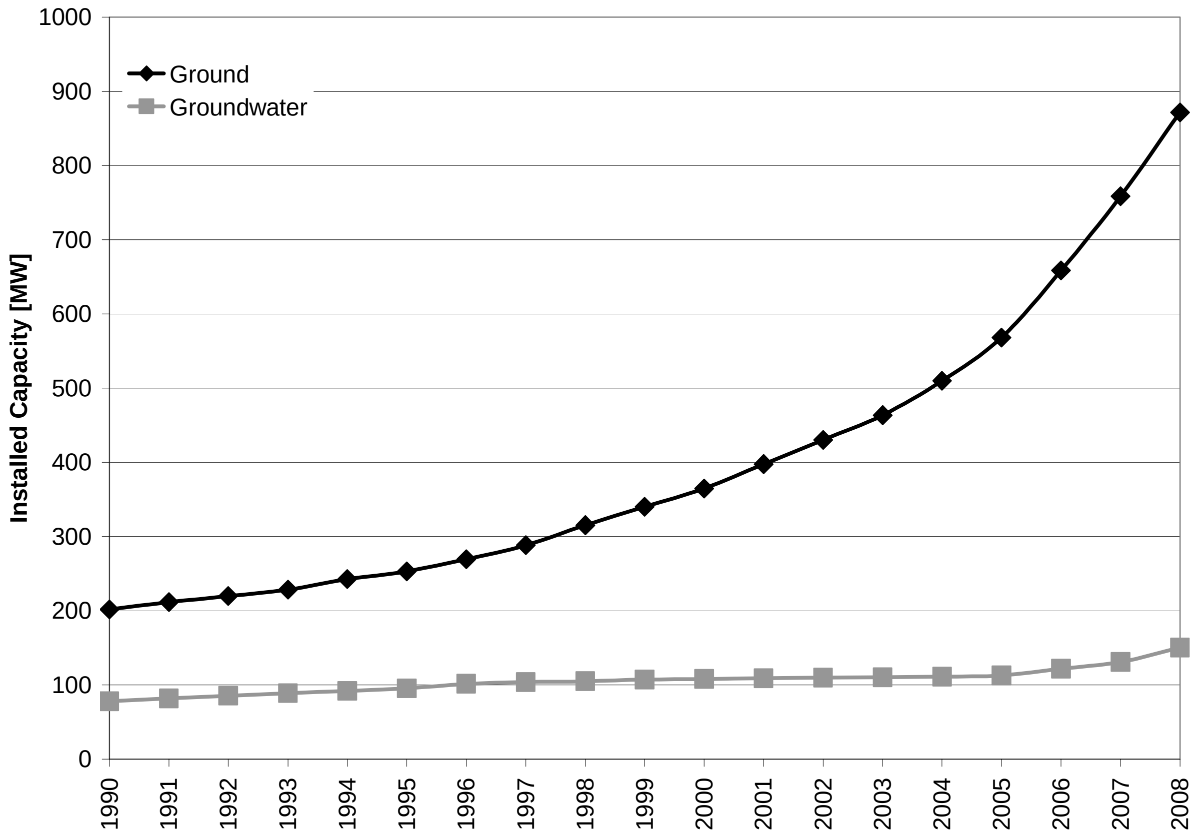

Figure 2: Growth of installed capacity of geothermal heat pumps 1990 – 2008, from Signorelli et al. (2009).

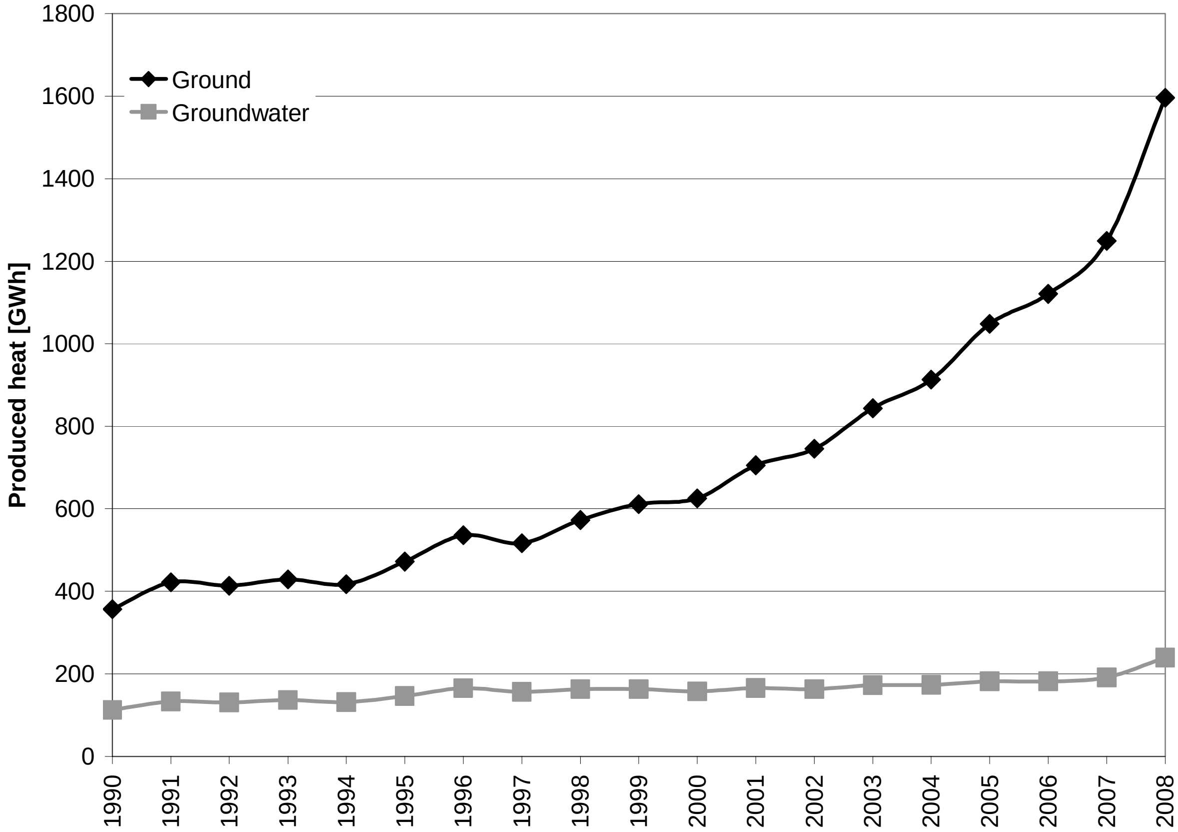

Figure 3: Growth of heat produced by geothermal heat pump systems 1990 - 2008. The small fluctuations correspond to stronger/colder winters, from Signorelli et al. (2009).

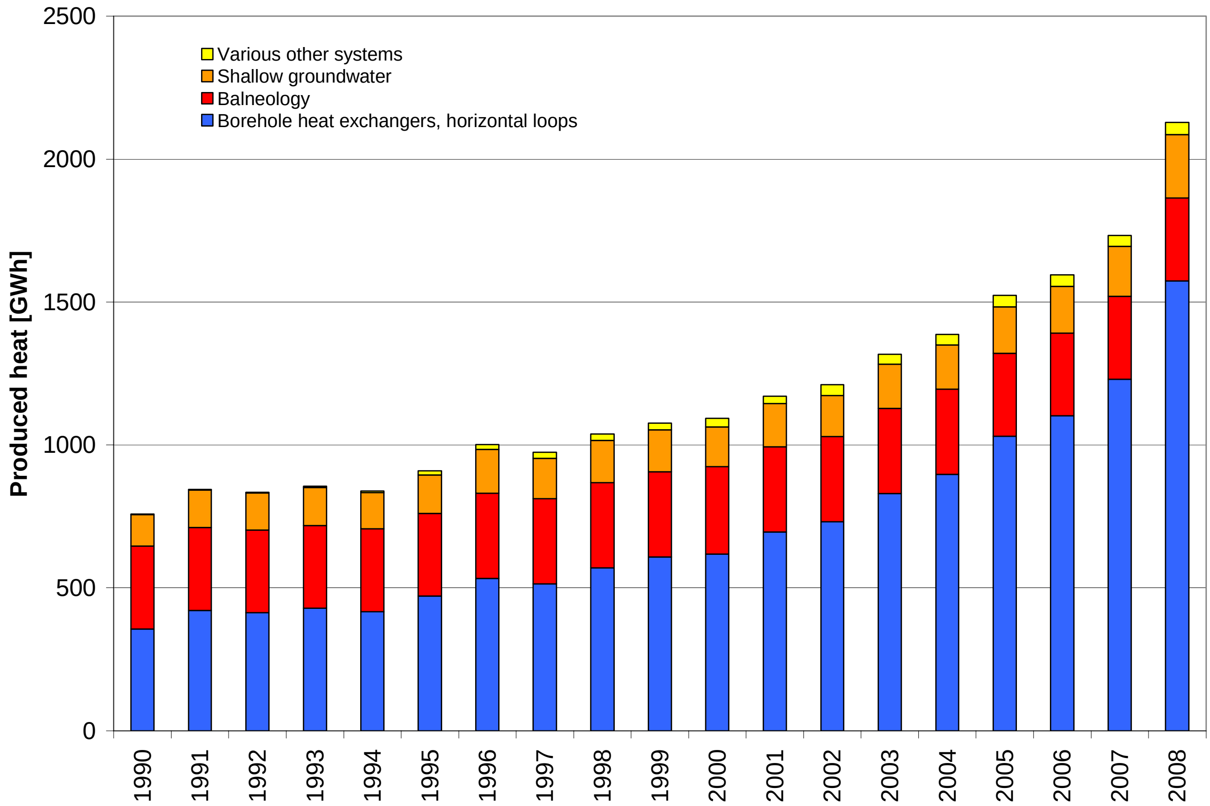

Figure 4: Development of direct usage categories over the years 1990 – 2008, from Signorelli et al. (2009).

5. RESEARCH, EDUCATION

On the national level a substantial number of R&D projects have been carried out, in the fields of shallow and deep resource utilization. The national activities are mainly financed by the Swiss Federal Office of Energy (SFOE). SFOE responsible is Dr. Gunter Siddiqi (Geothermal energy, Carbon Capture & Storage, and Power Generation); Geothermal Research Projects Leader is Dr. Rudolf Minder. All research projects have to deliver their final reports; these can be downloaded from the SFOE database: http://www.bfe.admin.ch/dokumentation/energieforschung/. Financial support of R&D by the SFOE amounts to about 1.7 mln Swiss francs per year (1 CHF ≈ 0.92 US$).
On the international level the participation of Switzerland in the IEA Geothermal Implementing Agreement must be mentioned first. The Enhanced Geothermal System Project Management Decision Assistant (EGS PMDA), completed under Annex III, Subtask C (Leader: Th. Mégel, GEOWATT AG, Zurich), received international attention. The EGS PMDA can be ordered through http://www.iea-gia.org/publications.asp .

Switzerland is also active within R&D programs of the European Union. Cooperation by various research teams was ongoing during the reporting period in the following geothermal projects:

- EGS Scientific Pilot Plant Soultz/F
- ENGINE
- I-GET
- GROUNDHIT
- GROUND-REACH.

Information dissemination, outreach, education are treated wit high priority. The the Swiss Geothermal Association SVG, an Affiliated Member of IGA, operates now as under the label GEOTHERMIE.CH. It assembles all key geothermal players in Switzerland.Its regular bi-lingual (G/F) publication also carries the name GEOTHERMIE.CH. The SVG also publishes newsletters, information leaflets, technical notes, and application examples. These can be downloaded, along with a comprehensive brochure “Overview, technology, visions” (in German) from the SVG website http://www.geothermie.ch/ under “Dokuthek”.

Significant efforts are constantly undertaken for education. A great step forward was the establishment of the first full professorship in geothermics at the University of Neuchâtel. Since 1st January 2009 Dr. Eva Schill occupies this position. Besides regular courses at universities and technical schools there are numerous special geothermal courses, workshops and excursions. The activities are planned and implemented by Geowatt AG Zurich for GEOTHERMIE.CH and financed by the Swiss Federal Office of Energy (SFOE). Since the establishment of the educational activities in 2001, totally 125 events have been organized with over 3’500 participants. The events are taking place in all parts of Switzerland: in the French speaking Romandie, the Italian speaking Ticino, and the German speaking Deutschschweiz.

6. DISCUSSION

The standard tables of Country Update Papers have been completed whenever possible, see after References. So the relevant data are assembled in Tables 1 and 3 – 8. The data in Table 1 are from the Schweizerische Elektrizitätsstatistik 2008, those in Tables 3 – 5 from Signorelli et al. (2009). For Tables 6 – 8 there are no official sources; the numbers are rough estimates. Generally a significant growth – especially in the GHP category– is evident. The 2005 à 2008 increase in direct use (by all categories) amounts to 40 %, in geothermal heat pumps to 50 %, i.e. 13 % and 17 % per year.

The market penetration on GHPs is really remarkable. This is clearly demonstrated by the great amount of drilling for BHE installations (1900 kilometers in 2008!). Not only the growth of installations in new buildings is evident, but also the increase in renovation (Figure 5). In 2009 over 40 certified BHE drilling companies operated in Switzerland.

The growth in GHP deployment is driven by various factors: technical, economic, and environmental. Many installations operate since decades without any problem, thus the maturity of the technology is demonstrated. Environmental awareness also provides incentives when decision-making is needed in selecting the method of heating/cooling for new or retrofitted buildings. Since no fossil fuel burning takes place with GHPs, and a CO_2 tax is effective for fossil-fired systems since 1st January 2008 (0.03 CHF per liter oil, 0.025 CHF per m^3 gas), there is – besides the environmental benefits–, also a financial incentive.

After creating a „learning curve“ for the installations cost of BHE-coupled GHP systems since 1980 by technology development, increasing experience and market competition (cf. Figure 6) the cost did not significantly decrease in the last years. But with the current oil and gas prices most of such systems can be built and operated to yield a return of investment in about 4-6 years. In general it is recognized that geothermal systems are indigenous and thus contribute to energy supply security. Various subsidies, tax exemtions, and rebates provide additional incentives. These vary from Canton to Canton; a compilation can be found (in German) through

http://www.bfe.admin.ch/energie/. The average cost of heating by GPH systems is around 0.15 CHF/kWh and currently the lowest in comparison with other systems, including fossil-fired ones (source: Förderverein Wärmepumpen Schweiz, www.fws.ch).

The regulatory/licensing environment is generally favourable. Geothermal installations with <5 MWth do not require an environmental impact assessment. GHP systems need a permit, usually issued by the water protection agencies of the Cantons. Most Cantons published maps with exclusion areas like groundwater protection zones. As an example the exclusion map of Canton Zurich shall be mentioned here, accessible through http://www.gis.zh.ch/gb4/bluevari/gb.asp?app=awelgsews.
In Canton Bern no BHEs are allowed to be installed underneath buildings.

The use of emission-free geothermal resources in Switzerland enables to save considerable amounts of fossil fuels and CO_2 emissions. Heat production from geothermal direct use, with the total of 2’130 GWh (7.7 TJ) in 2008, enabled to save 180’000 toe fossil fuels. By these means the emission of additional 560’000 tons of CO_2 has been avoided.

Here it must be mentioned that when it comes to heat pumps some caution about CO_2 emission issues is needed. Since heat pumps are usually driven by electric components the origin of the electricity and the corresponding CO_2 emissions must be considered. Although Switzerland's indigenous electricity production (60 % hydro, 40 % nuclear) is practically free of CO_2 emissions, there is substantial import of electricity through the interconnected European grid for Swiss users. There are only few data about the exact source of such imports but sometimes the imported electricity can originate from Poland, where power generation originates nearly completely from coal-fired power plants. More on the CO_2 footprint of GHPs can be found in Rybach 2010b).

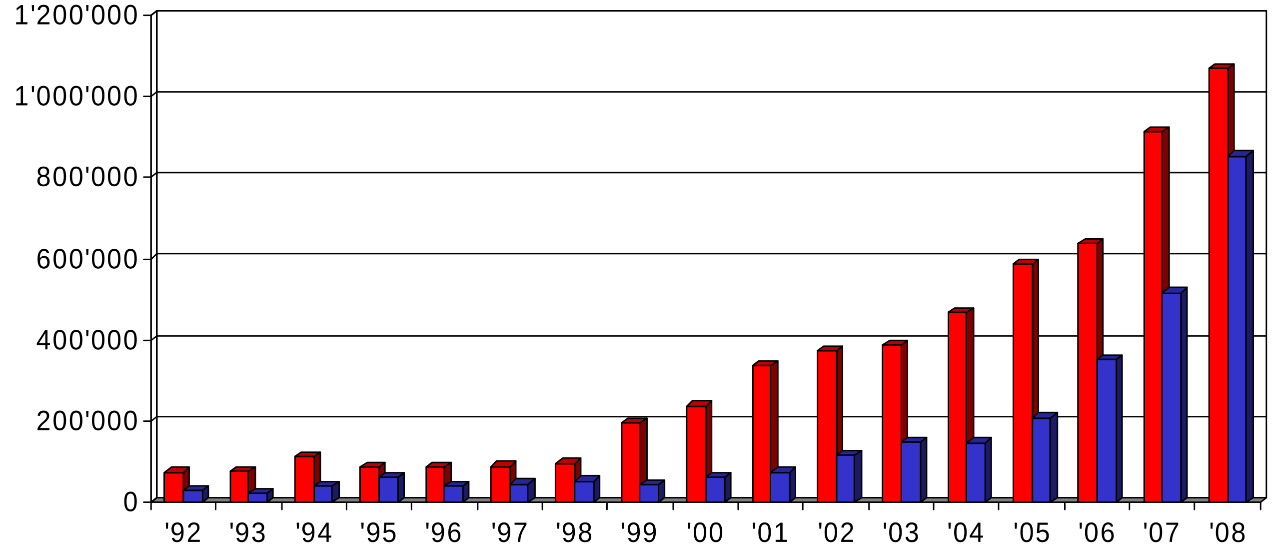

Figure 5: Development of total drilling meters for borehole heat exchanger-coupled geothermal heat pumps in Switzerland 1993 – 2008. Red bars: BHEs for new buildings, blue bars: for renovation. From Förderverein Wärmepumpen Schweiz (www.fws.ch).

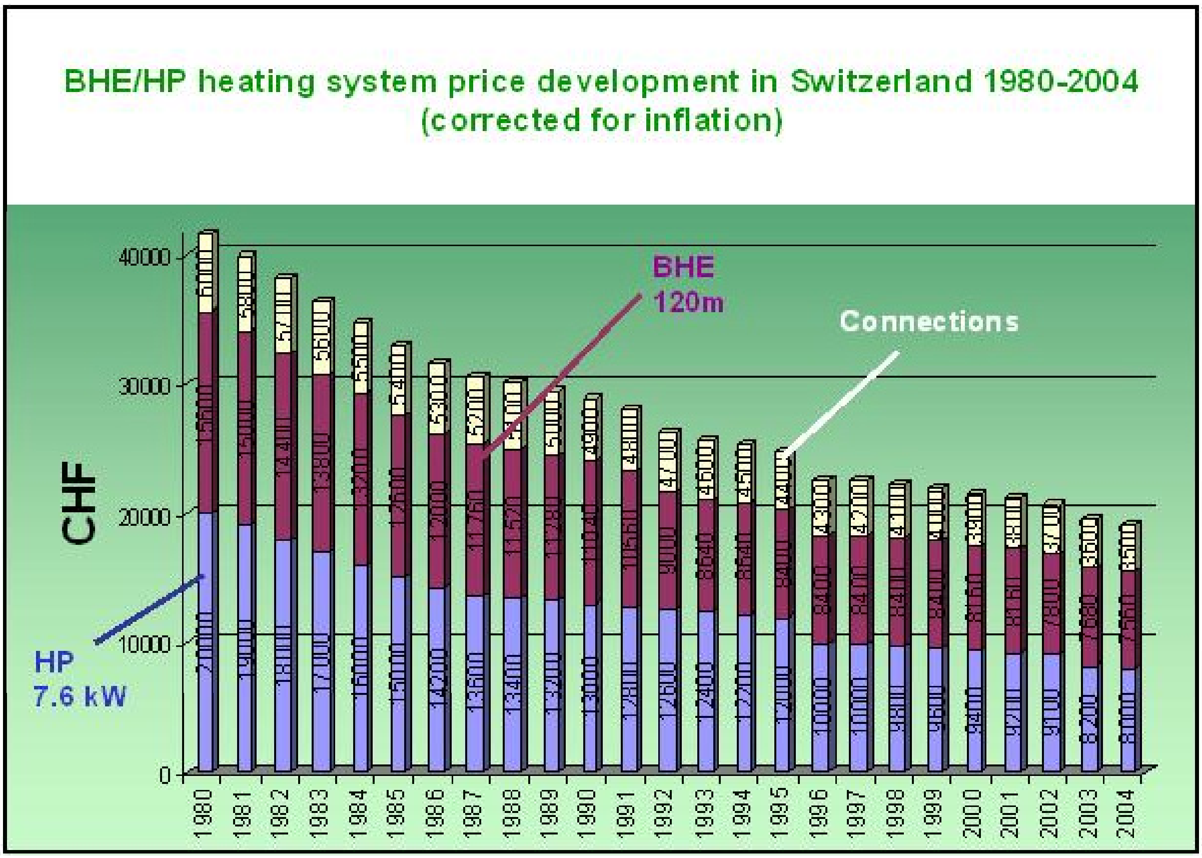

Figure 6: Installation costs of BHE-coupled geothermal heat pumps decreased significantly over time in Switzerland. The numbers refer to an average single-family house. From Förderverein Wärmepumpen Schweiz (www.fws.ch).

7. FUTURE DEVELOPMENT AND INSTALLATIONS

So far no kWh electricity is being produced from geothermal sources in Switzerland. The Deep Heat Mining Project in Basel, aimed at co-generation by means of an EGS system, has been suspended by the local authorities since induced seismic events occurred in late 2006 and early 2007 (maximum magnitude M_L = 3.4). An ongoing seismic risk study, to be completed in 2010, should indicate whether, and if possible under what conditions could the project be continued in Basel. A similar EGS project ("Thônex") is at the preparatory stage in the city of Geneva.

The development of hydrothermal resources (=deep aquifers with thermal water) is pursued at different locations. Recently at a special symposium, organized by SFOE and the Centre de Récherche en Géothermie (CREGE; operating at the University of Neuchâtel) on 11th June 2009, presented numerous projects at various stages of implementation in West Switzerland in Thônex/GE, Neuchàtel/NE, Lavey/VD, Lausanne/VD, La Côte/VD, and Brigerbad/VS.

In East Switzerland there is also significant activity in hydrothermal resources development: resource evaluation and drilling preparation (City of St.Gallen, cantons Schaffhausen and Thurgau). In the city of Zurich an exploratory drilling to 3 km depth is planned at the location Triemli; builder-owner is EWZ, the electricity utility company of Zurich.

Several large-scale GHP installations are in implementation, for example Science City and Sonnengarten in Zurich, Richti in Wallisellen/ZH, each with several 100 BHEs. It can be expected that the development trends continue, irrespective of the current problems within the financial sector.

ACKNOWLEDGMENTS

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STANDARD TABLES 1, 3 - 8

Table 1: Present and planed production of electricity

	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 Decembe 2008	-	-	897	3287	13464	37554	3220	26128	46 Wind + Solar PV	45	17627	67014
Under construction in December 2009												
Funds committed, but not yet under construction in December 2009												
Total projected use by 2015	5	20										

Table 3: Utilization of geothermal energy for direct heat as of 31 December 2009 (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						0.24	4.3	1.71	0.23
Kreuzlingen (TG)	H						0.082	0.4	0.59	0.23
Kloten (ZH)	H						0.3	5	3.04	0.32
Seon (AG)	H						1.35	25	9.32	0.22
TOTAL							1.97		14.66	0.24

Table 4: Geothermal (Ground-source) heat pumps as of 31 December 2008

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.

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

2) 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)

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

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

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^{o}C) - outlet temp. (^{o}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. (^{o}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)
			55343	V/H	3 - 4	~ 1800	5665	
			4192	W	4 - 6	~ 1800	860	
			~ 50 Energy piles	O	3 - 4	~ 1800	77	11
TOTAL			59585				6602	11

Table 5: Summary table of geothermal direct heat uses as of 31 December 2008

[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. (^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

[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]	2	14.7	0.23
District Heating [4] in Riehen/BS	3	33.5	0.35
Air Conditioning (Cooling)	1.4	11	0.25
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting	0.1	0.3	0.2
Bathing and Swimming[7]	34.9	1045.4	0.95
Tunnel waters	2.4	7.7	0.1
Subtotal	43.8	1112.6	0.81
Geothermal Heat Pumps	1017.1	6602	0.21
TOTAL	1060.9	7714.6	0.23

[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, 2005 to December 31, 2009 (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		5
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total				1		5

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)
2005	2	1	3			20
2006	2	1	3			23
2007	2	1	4			17
2008	3	2	5			18
2009	3	2	7			20
Total	12	7	22			98

Table 8: Total investments in geothermal in 2008 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$	%	%
1995-1999	10	105	115		80	20
2000-2004	12	110	120		85	15
2005-2009	60		600		90	10