# The geothermal heat pump boom in Switzerland and its background

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**Abstract**

Geothermal heat pump systems spread out rapidly in Switzerland, with annual increase rates up to 15%. The reasons for rapid market penetration are technical, economic, and environmental. In 2001, the total installed capacity of GHP systems was 440 MWt, the energy produced about 660 GWh. With over 1 GHP units every 2 $km^2$ their areal density is the highest worldwide. This secures Switzerland a prominent worldwide rank in geothermal direct use.

***Keywords:*** *market penetration, technical, environmental and economic incentives, growth rates.*

## 1 Introduction

At present there are over 25,000 geothermal heat pump (GHP) systems in operation in Switzerland. With over 1 GHP units every 2 $km^2$ their areal density is the highest worldwide; new systems are installed with an annual rate of increase >10%. Small systems (<20 kW) show the highest growth rates (>15 % p.a.).

There are three types of heat supply from the ground: shallow horizontal loops (<5% of all GHPs), borehole heat exchangers (100-400 m deep BHEs; 65%), and groundwater heat pumps (30%).

The GHP systems rapidly spread out in Switzerland; alone in 2002 a total of 600 kilometer boreholes have been drilled to be equipped with BHEs. The aim of this paper is to present the current situation in Switzerland as well as the reasons for this remarkable boom. Much of the material originates from a statistical survey of geothermal energy utilization in Switzerland in 2000 and 2001 (Kohl et al., 2002, carried out for the Swiss Federal Office of Energy).

## 2 Reliability and sustainability

GHP systems are ideally suited to tap the ubiquitous shallow geothermal resources. The reliability of long-term performance of GHP systems is now proved by theoretical and experimental studies as well as by measurement campaigns conducted over several heating seasons (Eugster and Rybach, 2000). Seasonal performance factors >3.5 can be achieved.

The studies were performed at a commercially installed GHP system with BHE in Elgg, near Zurich. During the production period of a BHE, the drawdown of the temperature around the BHE is strong during the first few years of operation. Later, the yearly deficit decreases asymptotically practically to zero. During the recovery period after a virtual stop-of-operation, the ground temperature shows a similar behavior: during the first years, the temperature increase is strong but tends with increasing recovery time asymptotically towards zero (Figure 1). The time to reach nearly complete recovery depends on how long the BHE has been operational. Principally, the recovery period equals the operation period.

The measurements and model simulations prove that sustainable heat extraction can be achieved with such systems (Rybach and Eugster 2002). The installation in Elgg supplies about 13 MWh per year on the average. In fact, the BHE's show stable and reliable performance, which can be considered renewable. Reliable long-term performance provides a solid base for problem-free application; correct dimensioning of BHE-coupled GHPs gives great scope of widespread use and optimisation. In fact, the installation of GHPs, starting at practically zero level in 1980, progressed rapidly and provide now the largest contribution to geothermal direct use in Switzerland, as revealed by statistical data.

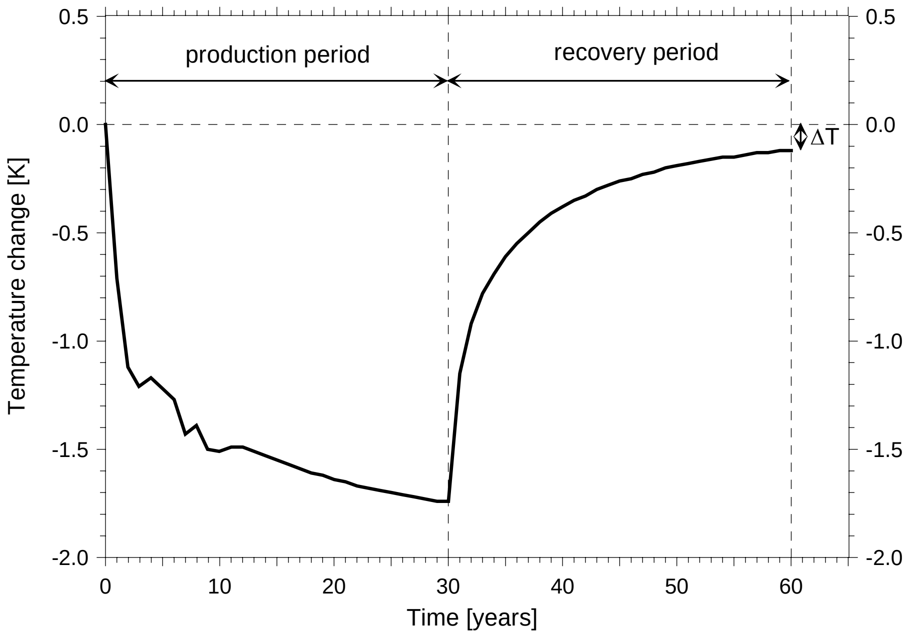


**Figure 1: Calculated temperature change at a depth of 50 m and in a distance of 1 m from a 100 m deep BHE over a production and a recovery period of 30 years each (from Eugster and Rybach, 2000).**

# 3 Statistics, trends of growth

A statistical data compilation and evaluation, performed to assess the geothermal energy usage in Switzerland for the years 2000 and 2001 (Kohl et al., 2002) reveals that GHPs contribute with 634 GWh in 2001 over 62% to the total geothermal heat production (Table 1).

**Table 1: Direct use of geothermal heat in Switzerland (from Kohl et al. 2002).**

| Energy source / use | Heat produced in 2001 (GWh) | Percent of total (%) |
|---|---|---|
| GHP with borehole heat exchangers (incl. shallow horizontal loops) | 532 | 52.3 |
| GHP with groundwater | 102 | 10.1 |
| Thermal springs/boreholes (balneology) | 322 | 31.7 |
| Deep aquifers | 37 | 3.7 |
| Tunnel waters | 14 | 1.3 |
| Deep borehole heat exchangers | 1 | 0.1 |
| Geostructures | 9 | 0.9 |
| Total | 1018 | 100.0 |

The installation of GHP systems in Switzerland proceeds since their introduction in the late 70ties at high speed: Figures 2 and 3 show the impressive growth.

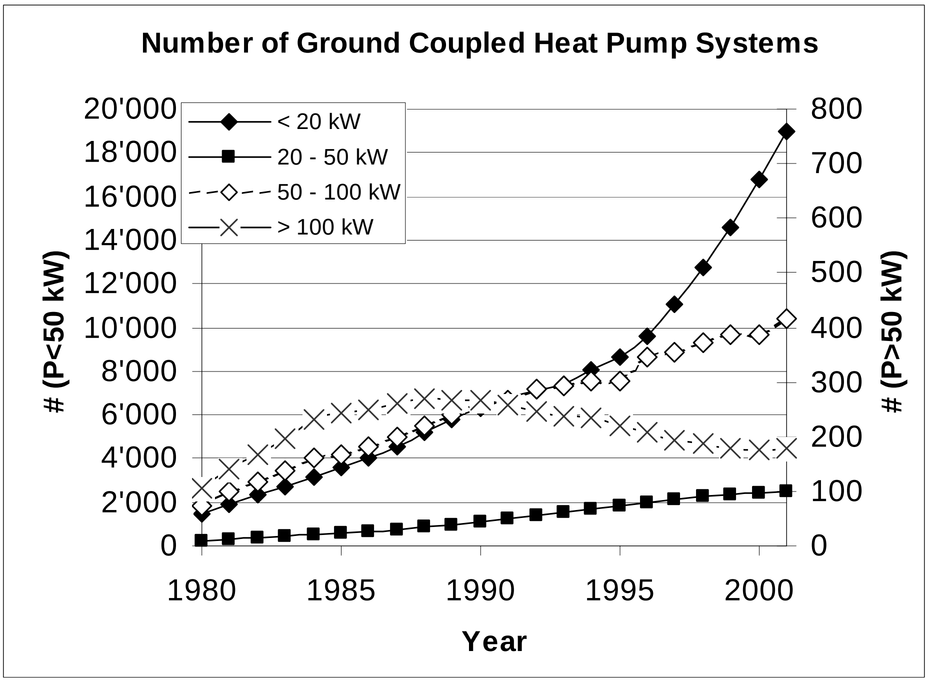


**Figure 2: Development of geothermal heat pump installations in Switzerland in the years 1980-2001. From Kohl et al. (2002).**

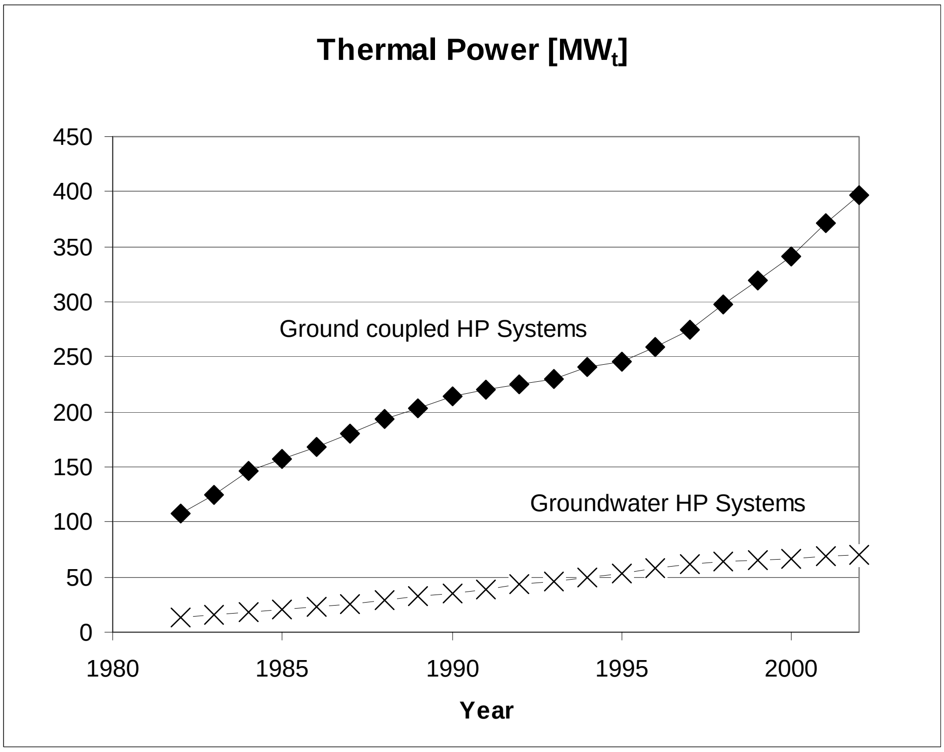


**Figure 3: Development of installed capacities (MWt) of BHE-coupled (top) and groundwater-based (bottom) geothermal heat pumps in Switzerland during the years 1980-2001 (from Kohl et al., 2002).**

The annual increase rates are remarkable: the number of newly installed systems increase with an annual rate of >10%. Small systems (<20 kW) show the highest growth rate (>15% p.a., see also Figure 2). In 2001 the total installed capacity of GHP systems was 440 MWt, the energy produced about 660 GWh. With over 1 GHP units every 2 $km^2$ their areal density is the highest worldwide.

# 4 Reasons for rapid market penetration

The main reason for the rapid market penetration of GHP systems is that in Switzerland there is 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. Besides, there are numerous and various further reasons: these are technical, environmental, and economic.

*Technical incentives*

- Appropriate climatic conditions of the Swiss Plateau (where most of the population lives): Long heating periods with air temperatures around 0°C, little sunshine in the winter, ground temperatures around 10-12°C already at shallow depth.
- The constant ground temperature provides, by correct dimensioning, a favourable seasonal performance factor and long lifetime for the heat pump.
- The GHP systems are installed, to fit individual needs. Costly heat distribution (like with district heating systems) is superfluous in a decentral manner.
- Relatively free choice of position next (or even underneath) to buildings and little space demand inside.
- No need, at least for smaller units, of thermal recharge of the ground; the thermal regeneration of the ground during heat extraction breaks is continuous and automatical.

*Environmental incentives*

- No risk with transportation, storage, and operation (as e.g. with oil).
- No risk of groundwater contaminations (as with oil tanks).
- The systems operate emission-free and helps to reduce greenhouse gas emissions like $CO_2$.

*Economic incentives*

- The installation cost of the environmentally favourable GHP solution is comparable to that of a conventional (oil based) system (Table 2).
- Low operating costs (no oil or gas purchases, burner controls etc. like with fossil-fueled heating systems).
- Local utility electricity rebates for environmentally favourable options like heat pumps.
- A $CO_2$ tax is in sight (introduction foreseen for 2004).

Further incentives and reasons for rapid spreading of GHP systems is “Energy Contracting” by public utilities. The latter implies that the utility company plans, installs, operates, and maintains the GHP system at its own cost and sells the heat (or cold) to the property owner at a contracted price (cents/kWh).

**Table 2: Comparison of BHE/HP installation and operation cost with a conventional oil burner heating system (from 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.- |
| **4.1.1.1 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 = 0.74 US$ (as of March 2003); **) Price in March 2003

# 5 Novel solutions, outlook

Whereas the majority of GHP installations serve for space heating of single-family dwellings (± sanitary water warming), novel solutions like multiple BHE’s, combined heating/cooling, “energy piles” are rapidly emerging.

- Multiple BHE’s: There is a tendency to increase the size of geothermal installations by using a multitude of BHE’s. Extensive studies are being carried out to determine optimum depths and borehole spacings in order to guarantee an economic life span. As an example, the BHE field with 2x49 160 m deep BHE’s at the Technology Park in Root/LU can be mentioned.
- Combined heat extraction/storage: Multiple BHE’s can also be used to access a ground storage volume for seasonal storage of waste heat from large buildings or with solar energy (solar collectors, flat building roofs, surfaces of streets or parking areas). Several such installations work satisfactorily, e.g. the road bridge snow/ice melting system SERSO at Därligen/BE with 91 65 m deep BHE’s, no heat pump.
- Heating/cooling: Climatic warming leads, even within the meteorological conditions of Switzerland, to an increasing demand for climatization. Therefore, GHP operation in the combined heating/cooling mode is increasingly popular,

especially for larger building complexes like factories. As an example, the BHE field with 32 BHEs, each 135 m deep each at the Meister jewellery factory in Wollerau/ZH can be mentioned.
- Geostructures, “Energy piles”: Foundation piles can be equipped with heat exchangers. A prominent example represents the new Terminal “Dock Midfield” at the Zurich Airport (315 piles, 30 m deep each), for heating and air-conditioning.

# 6 Conclusions

- Geothermal heat pump (GHP) systems spread out rapidly in Switzerland; at present there are over 25,000 geothermal heat pump systems in operation. In 2001, the total installed capacity of GHP systems was 440 MWt, the energy produced about 660 GWh.
- New systems are installed with an annual rate of increase >10%. Small systems (<20 kW) show the highest growth rates (>15% p.a.). The reasons for rapid market penetration are technical, economic, and environmental.
- GHP systems with borehole heat exchangers (BHE) are the most frequent types of heat supply from the ground. Alone in 2002 a total of 600 kilometer boreholes have been drilled to be equipped with BHEs.
- With over 1 GHP units every 2 $km^2$ their areal density is the highest worldwide; this secures Switzerland a prominent rank in geothermal direct use (for installed capacity per capita among the first five countries worldwide).
- The main reason for the rapid market penetration of GHP systems that in Switzerland there is 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. Besides, there are numerous and various further reasons: these are technical, environmental, and economic.
- Novel solutions (multiple BHEs, combined heat extraction/storage e.g. of solar energy, geothermal heating/cooling, “energy piles”) are rapidly emerging.

## Acknowledgements

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