

Research and utilisation of geothermal resources in Switzerland: achievements and outlook

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ABSTRACT

The geothermal R & D work in Switzerland is at present concentrated on the development of a Hot-Dry-Rock (or Deep Heat Mining) plant in the city of Basle and on technical / economical improvements of vertical ground coupled (borehole) heat exchangers. This concerns both the optimisation of drilling techniques for holes of about 500 m in depth as well as the development of new types of more efficient vertical borehole heat exchangers.

Concerning the utilisation of geothermal resources, a considerable increase in the variety of geothermal applications for space heating and domestic warm water production has taken place over the past years. Aside from the very low cost of fuel oil, this astonishing development is clearly visible from heat pump sale statistics, and was also confirmed by a recent inquiry undertaken by the Swiss Geothermal Association. According to this information, nearly 50 % of all heat pumps sold in Switzerland are installed in geothermal heating systems (i.e. as ground-coupled heat pumps).

In 1997, the total heat produced by geothermal installations amounted to 599 GWh (including the heat pumps production) where the geothermal portion was 396 GWh. The corresponding figures for 1990 were 316 GWh and 211 GWh, respectively. This means an increase of 88 % over seven years, or an average annual increment of more than 12 %.

KEYWORDS

Heat production, statistics, geothermal research, utilisation techniques, Switzerland

1. Geothermal research

1.1 Hot Dry Rock / Hot Wet Rock projects

The HDR / HWR concept is now being renamed EGS/Enhanced Geothermal Systems in the USA, DHM/Deep Heat Mining in Switzerland. The principle remains the same.

Two potential sites for constructing a pilot plant in the immediate vicinity of the district heating system of the city of **Basle** have been identified for more detailed investigations. Thus, the drilling of a first **2300** m exploratory hole in the crystalline basement is scheduled to commence in 1999 and will later serve as a monitoring well. A technical assessment of the integration of the geothermal plant into the existing district heating network, and the information gained from the well will determine the final plant site selection. An additional site evaluation has also been initiated for the Canton of Geneva.

The ongoing study of the economics of Hot Dry Rock / Hot Wet Rock / DHM projects is concentrating on plant-specific and increasingly on site-specific parameters. Basic studies on the stress field and temperature development in crystalline basement rock indicate favourable conditions in the region of Basle. The first phase of a study has been completed with the aim to quantify minimum reservoir design parameters necessary for sustainable heat extraction combined with the production of electric power.

Closely linked to above activities is Swiss participation in the new Geothermal Implementing Agreement (GIA) of the International Energy Agency which was formally put into operation in March 1997. Within the past two years, its organisation and activities have developed considerably.

The Swiss contribution to GIA is twofold: on one hand, the third author has been Chairman of the governing Executive Committee since the start of the planning phase and continues to take on this responsibility; on the other hand, a Swiss team is taking part in the technical Annex concerning Hot-Dry-Rock geothermal energy. The principle contribution here is the organisation and leadership of the Subtask C; defining and, at the technical level, collecting the data necessary for the construction of a Hot-Dry-Rock power plant as well as linking data requirements to project phase. The Swiss »Deep Heat Mining« project offers a considerable synergy with this work by bringing in recent experience. The framework of the activities directly associated with this Subtask C has largely been established.

Co-operation with the other HDR subtasks is also progressing, in particular with the teams in the USA and in Japan. These teams deal with economic assessment via modelling and HDR reservoir characterisation techniques.

Finally it can be mentioned that several Swiss scientists take active part, within the Joule project of the EU, in the European Hot Dry Rock Project Soultz/F. The contributions include data analysis, management and processing, creation of a conceptual model, computer code development to include chemical effects like fluid-rock interactions, European coordination of modelling activities. The participating teams are from the

Institute of Geophysics, ETH Zurich (with subcontractors) and from the Centre d'Hydrogéologie, Université de Neuchâtel.

1.2 Technical and economical improvements of vertical borehole heat exchangers

The main construction costs of borehole heat exchangers (BHE) generally stem from drilling the hole and completing the BHE. Here, a major cost saving factor can be to reduce drilling and operation time, which means lower personnel costs and equipment charges.

A large number of different drilling tools and methods are available from oil and gas exploration as well as from the mining industry. A major geothermal research project identified a Swedish drilling tool, i.e. a very high pressure, hydraulic down-the-hole hammer, as the most suitable drilling method for the installation of borehole heat exchangers. In an actual field test in Weissbad, an inclined drill hole of > 600 m was accomplished in less than three days! This borehole is located close to an existing, deep geothermal drill hole at Weissbad.

Several other geothermal research projects, presently in progress, deal with faster installation techniques and the development of new BHE. Such innovative prototypes, one called «Umbrella» heat exchanger and another system «Mudair», are presently being tested in the field. Furthermore, the cost / benefit of an isolated upper part of the delivery line to the heat pump (starting at about 20 m below ground surface) is **also** undergoing extensive field tests.

1.3 Influence of thermal stress on the stability of foundation piles («Energy piles»)

Foundation piles can also be applied as heat exchangers for heat and cold production (room climatization). With the financial support of the Swiss Federal Office of Energy, several large industrial complexes have been equipped with energy piles, which have functioned quite successfully over several years. Further applications are planned, such as an extension of the Zurich airport (Kloten) and a new building for the Swiss Federal Institute of Technology at Lausanne (EPFL.).

When using foundation piles as heat exchangers, the general stability of the supported building must not be put in danger due to friction loss and / or expansion / shrinkage caused by thermal stress within the piles. This problem is at present being addressed by a respective research project of the EPFL, both in theory (by means of computer simulations) and by actual field tests.

2. Utilisation of Geothermal Resources in Switzerland

2.1 Production Statistics

The heat supply from geothermal sources is based on (electric) heat pumps. In 1997, the total heat production for direct applications (mainly space heating and domestic warm water

supply) was 589 GWh (plus an estimated 10 GWh produced by Swiss spas). The geothermal sources (=input to the heat pumps) amounted to a total of 396 GWh. The following breakdown clearly indicates the predominance of ground coupled heat pumps:

Table 1: Heat production of geothermal installations in Switzerland during 1997, including the heat pumps production. The arrangement is by increasing depth.

Geothermal source	Production (GWh)	% of total
Horizontal ground source heat exchangers	49	8.2
Energy piles	5.3	0.9
Groundwater wells	63	10.5
VERTICAL GROUND SOURCE HEAT EXCHANGERS	439	73.3
Deep borehole heat exchangers	0.7	0.1
Deep aquifers	29	4.8
Tunnel (drainage) waters	2.9	0.5
Spas (thermal springs)	10	1.7
Total	598.9	100

Presently, the annual growth rate is 12 %. Based on a 1998 compilation of the Swiss Geothermal Association, this will represent about 9 % of the total alternative heat energy production in the year 2000 (i.e. 3'000 GWh) or in other words, a heat energy production of 290 GWh in addition to the geothermal energy produced in 1990.

2.2 Vertical ground source heat exchangers

These borehole heat exchangers are the most frequently used sources of ground coupled heat pumps in Switzerland. Recently, a tendency to increasingly greater depths (300 m – 500 m) can be observed, where higher formation temperatures prevail. The considerably higher hydrostatic and ground pressures will require special construction methods, including special materials like thermally insulated tubes, proper back filling and adequate heat extraction techniques.

Financially sponsored by the Swiss Federal Office of Energy, several theoretical studies and practical projects are underway. Ideally, borehole heat exchangers might finally be constructed at depths with sufficiently high temperature levels that can avoid the use of heat pumps. Indeed, a deep drill hole completed by a private investor already exists: Thermal 1 in Weggis/LU, with a total depth of 2'302 m and showing a wellhead temperature of 45° C, which is partly operated for space heating without a heat pump.

Another tendency is to increase the size of geothermal installations by using a multitude of vertical ground heat exchangers. Here, extensive studies were carried out to determine optimum borehole spacings in order to guarantee an economic life span (e.g. a spa in Scuol/GR, which is, after some initial adaptations, now operating quite satisfactorily).

2.3 Groundwater heat extraction

A general rule is applied in Switzerland that extraction of ground water for potable water supply has priority over extraction for heat energy,. However, the application of ground water protection laws differs from one canton to the other. In the Canton Bern for instance, there are already about 870 ground water heat extraction plants with a total installed capacity of about 50 MW (status 1997). Undoubtedly, many heat resources remain untapped (e.g. along the Rhone valley)! As average ground water temperatures in Switzerland vary between 8° C and 12° C, the widespread aquifers represent an excellent source for space heating and domestic warm water production, but always in combination with a heat pump.

2.4 Heat and cold extraction from foundation piles and (re-enforced concrete) diaphragm walls

Switzerland was one of the pioneers in extracting heat from foundation piles by installing heat exchange tubes. Depending on foundation conditions and type of piles (i.e. massive or hollow), these tubes can be embedded in re-enforced concrete either prior to, during or after piling procedures (collectively called energy piles). Subsidised by the Swiss Federal Office of Energy, several projects involving energy piles have been realised during the past years.

The profitability of energy piles can be greatly enhanced when cold is also extracted during summer time ("free cooling"). This means reinjecting heat during summer for cooling purposes, whereas heat will be stored underground and readily available during the cold months.

Diaphragm walls function similarly, but there are only very few examples in Switzerland so far. In Bregenz, Austria, just across the border, a new gallery is being heated and cooled by such diaphragm walls.

2.5 Heat extraction from deep aquifers

The success of large-scale geothermal heating systems in France led to exploration drilling activities in Switzerland. Both the doublet and singlet concept has been followed, encouraged by a Government Risk Guarantee: a total of 15 mio. Sfr. Has been reserved to cover drilling and testing activities from 1987 to 1998.

However, the deep drillings were only partly successful. Due to the complex geological subsurface conditions prevailing in Switzerland, predicting the presence of fissured/permeable aquifers or water bearing faults at great depths by means of geophysical and geochemical exploration methods alone proved to be difficult. Out of a total of 12

geothermal drill holes covered by the above Risk Guarantee, five complete successes, one partial success and seven failures (or low productivity holes) can be reported.

Two of the successfully drilled wells resulted in the construction of the first Swiss doublet system in Riehen/BS, which has been in operation since 1994. Its geothermal capacity amounts to $4.7 \text{ MW}_{\text{th}}$, the total heating power of the installation is $15.2 \text{ MW}_{\text{th}}$. Since 1998, a singlet system installed in Schinznach Bad/AG is functioning as a cascaded heat extractor for a spa and other uses (i.e. in a greenhouse).

Furthermore, several of the total or partial failure boreholes were also put in service for geothermal heat supply later on, either by installing a coaxial ground heat exchanger (e.g. Weissbad/AI) or by directly using the somewhat smaller quantities of thermal water available (e.g. Kreuzlingen/TG and Saillon/VS).

Due to the high risk in locating productive aquifers at great depths as explained above, it seems rather unlikely that deep geothermal drilling will be resumed without the cover of a Government Risk Guarantee in the near future, except maybe for spas.

2.6 Heat extraction from tunnels

Being a typical Alpine country, Switzerland has many road and railway tunnels. For the planning of the future construction of two tunnels of considerable length and rock cover such as the Gotthard and Lotschberg base tunnels of the AlpTransit project, a deep exploratory shaft and an investigation tunnel have already been accomplished.

2.6.1 HEAT EXTRACTION FROM TUNNEL (DRAINAGE) WATERS

Warm water frequently encountered during tunnelling can be directed from a tunnel portal directly to potential heat consumers instead of being wasted. However, the distance between portal and consumer should not exceed 1 to 2 km, because the length of a feeder pipe represents a major cost factor in such a project. According to the temperature of the tunnel water, a central or decentralized heat pump system might be applied for space heating.

The heat capacity of the 16 geothermally and economically most interesting tunnels in Switzerland amounts to more than 16 MW, enough to provide several thousands of inhabitants with heat energy. At four sites, tunnel water is already being used for space heating and domestic warm-water production, i.e. the Furka, Ricken, Gotthard road tunnel and Mappo-Moretta tunnel. Another project using water from the Hauenstein base tunnel with a capacity of 1.5 MW is at present under construction.

Of particular interest will be the geothermal utilisation of the above mentioned AlpTransit tunnels. Theoretical calculations and actual temperature measurements in deep exploratory excavations indicate a considerable heat potential.

2.6.2 HEAT EXTRACTION FROM VENTILATION AIR

Not only water but also ventilation air from tunnels can be used for heat production. About one year ago, a project of this type of utilisation was put into operation. Ventilation air from

the Great St. Bernhard tunnel provides, yearlong, space heating, in combination with a heat pump, for a large administrative building including the tunnel control station, situated at the north portal at an elevation of 1'700 masl.

3. Outlook

Until the early eighties, Switzerland had little presence on the world geothermal map. Today, all kinds of geothermal systems are market items. Relating to the installed geothermal capacity for direct use per capita, Switzerland ranks third in a world-wide comparison.

In the near future, geothermal R&D in Switzerland will remain concentrated on the development of Hot Dry Rock technologies and the technical / financial improvements of vertical ground source heat exchangers. However, it is hoped that the Hot Dry Rock project in Basle will move very soon from pure research to a Pilot & Demonstration project, financed mainly by third parties, such as local electric power producers. In this respect, a very encouraging start has already been accomplished in the form of substantial financial support for the execution of a 2'300 m exploratory borehole in Basle.

The Swiss Federal Office of Energy gives high priority to actual project realisations in order to reach the heat production targets from alternative sources envisaged by the Energy2000 programme.

In order to obtain financial support of the Swiss Federal Office of Energy for geothermal project realisations, two fundamental prerequisites must be fulfilled

- the proposed project must include distinct innovative aspects;
- the termination of construction must be followed by a quality control such as recording of heat production, determination of heat pump performance coefficients, etc. Such controls should last at least two years to enable a comparison between targeted and actually obtained heat energy output as well as to check on cost / benefit ratios of the subsidised project.

In this context, high priority will be given to multipurpose projects, e.g. double use for heating and cooling (free cooling), double use of ground water for heat extraction and domestic water supply, heat extraction and electric power production (e.g. using hydraulic heads of tunnel water outlets) and cascade use of heat extraction of thermal waters (e.g. heating of therapeutic baths, sanatoriums and other nearby buildings, greenhouses, etc.).

Of further interest are projects involving «heat contracting», where installations are financed and operated by a contractor and heat is then sold to the consumer, based on long-term contracts. In this case, the designer, builder and operator comprise the same company, which helps to optimise design and performance.

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