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Developing Deep Geothermal Resources in Switzerland

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ABSTRACT

In the last three decades, continuous efforts in the exploration of geothermal resources in Switzerland have been made. In the 1980's and the 1990's, geothermal projects with wells down to 2600 m were realized at several sites for space heating or balneological applications.

According to several studies, the potential of deep geothermal exploitation (>3000 m) in Switzerland is very high. Due to relatively limited exploration activities, the database of the deep subsurface in Switzerland is small. This implicates a relatively high risk for hydrothermal projects. On the other hand, the EGS technology for petrothermal projects is not yet well developed. Furthermore, the current legal situation does not support efficient exploration, and the financial encouragement by the federal government is very limited.

Nevertheless, several deep (and nearly deep) geothermal projects are currently in different stages of development.

All efforts should be combined to establish a generalized concept and procedure for the development of deep geothermal resources in Switzerland. To this end, a national cooperative for the exploration and development of the deep geothermal energy in Switzerland is proposed. This organization could be supported by electricity supply companies, other relevant industries, regional and federal governments, institutions and universities.

1. INTRODUCTION

Switzerland has 7.7 million inhabitants in an area of about 41,000 km^2. The total energy consumption in 2007 was 865,420 TJ. Of this amount, 206,760 TJ (24%) was electricity.

55% of electricity in Switzerland is produced by hydropower, 40% by nuclear power plants and 5% by other sources (thermal or others). Considerable amounts of electricity are exported and imported annually.

An "electricity gap" is expected in Switzerland in the next 5 to 10 years due to an increase in demand, the required shutdown of old nuclear power plants, and the expiration of importation contracts, which cannot be renewed.

Apart from the construction of new nuclear power plants and new conventional thermal power plants (gas), renewable energy should play an important role in the future electricity supply of Switzerland. The use of hydropower will be expanded, and new renewable energy sources, such as solar, wind, biomass and geothermal energy, should play increasingly important roles.

2. GEOLOGICAL AN GEOTHERMAL OVERVIEW

2.1 Geothermal Gradients and Heat Flow in Switzerland

Most of the population of Switzerland lives in the Swiss Molasse Basin, a flat-lying area at 300–600 m altitude located north of the up to 4000 m high Alpine range and south of the 1000–1500 m high Jura mountains, a folded mountain belt.

The Swiss Molasse Basin consists of a crystalline basement containing old, permo-carbonifereous troughs and is covered by a thick sedimentary sequence of Triassic to Tertiary age. The surface is structured by the Quaternary glaciations and the subsequent alluvial and colluvial processes.

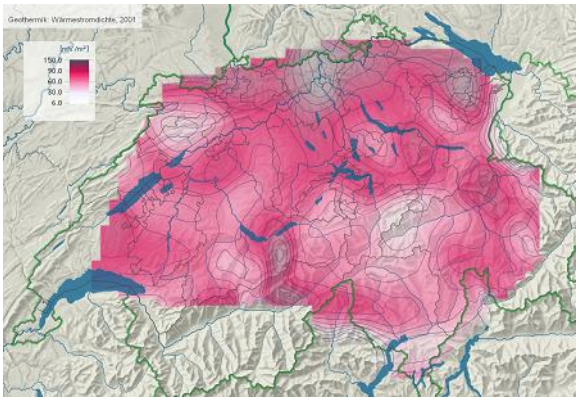


Figure 1: Heat flow map of Switzerland (from: Atlas der Schweiz, 2004).

In the Molasse Basin, the geothermal gradients are considered to be normal, with values between 25–40°C/km. Heat flow values range from 40 to 140 mW/m^2, with an average of 60 mW/m^2.

2.2 Types of Geothermal Resources

In Switzerland, geothermal resources can be divided into four types (Signorelli and Kohl, 2006):

1. Shallow resources: <200 m, borehole heat exchanger or groundwater use with heat pump.
2. Low temperature hydrothermal resources: 200–3000 m, direct use of warm water for space heating purposes.
3. Deep resources: 3000–5000 m, T > 100°C, suitable for power production (hydrothermal and petrothermal). Medium term technology development required for utilization of the resources (EGS).
4. Tight resources at greater depth: new technologies are needed in the long term.

The focus of this paper is mainly on type 3 resources.

2.3 Geothermal Potential

A study conducted at the Paul Scherrer Institute (PSI, Multi-disciplinary research center for natural sciences and technology) provided an estimate of theoretical potential (geothermal heat in place) of 57.3×10^{21} J at 3–7 km depths. With a recovery factor of 4% and power production efficiency of 10%, a power production of about 0.23×10^{21} J electricity can be estimated.

A study performed by a major power supplier in Switzerland estimates the potential for power production from geothermal sources in the year 2050 at about 0.0612×10^{18} J electricity per year (Axpo 2007). This is by far the largest potential of any new renewable energy resource in Switzerland, but the technical feasibility for production is not yet given. This is the major challenge for the future of geothermal energy for power production in Switzerland. Relevant parts of this potential can only be developed if artificial heat exchangers in the subsurface can be produced on a routine base.

3. CONSTRAINTS AND DELIVERABLES

3.1 Exploration Maturity

Compared to other areas in Europe, the geological knowledge of the deep subsurface of Switzerland is quite limited.

In the last six decades, the petroleum industry has completed about of 7000 km seismic lines and 30 HC exploration wells. Only a few of these wells reached the crystalline basement. Only one gas producing well resulted from the activity of the HC industry. Therefore, the activity of the industry remained limited, and the exploration density is quite low.

Important subsurface exploration was carried out by the Nagra (National Cooperative for the Disposal of Radioactive Waste), but only in a relatively small area.

14 geothermal wells drilled in the 1980's and the 1990's provided additional information on the deeper subsurface of Switzerland.

Geothermal potential and resource studies were carried out in several areas from the existing data. These studies provided a deeper insight into the possibilities for the geothermal use in the deeper subsurface. The hydrothermal potential is of medium size and is associated with a medium to high productivity risk. On the other hand, the petrothermal potential is quite high, but the development of viable technologies to build efficient artificial heat exchangers in the deeper subsurface (EGS-technology) is required.

3.2 Concession Situation

Switzerland has a very poorly developed legal base for mining and subsurface use. The sovereignty is in the hands of 26 cantons (member states). About half of the cantons have a mining law, but mainly without specific regulations for the use of geothermal energy in the deeper subsurface. There is no federal mining law.

At present, a drilling license has to be acquired for every geothermal project, but no general geothermal exploration permits are available.

The heterogeneous laws and the lack of specific regulations for geothermal exploration are a handicap for the development of the deep geothermal resources.

3.3 Support of the Federal Government

An initiative proposed by a National Councilor in 2007 requested 60 million CHF to fund the research of deep geothermal energy in Switzerland. The initiative was approved by the Swiss Parliament, but was not included in the budget for 2008 or 2009.

In 2009, the federal budget for geothermal research in Switzerland was increased from 1.25 million to 2.5 million CHF. A cutback in the geothermal research budget is expected in 2010.

The new Energy Supply Ordinance («Stromversorgungs-verordnung StromVV» of 14.3.2008) defines several measures for the improvement of the electricity production from new renewable energies (solar, wind, biomass, small hydro, geothermal).

A maximum of 320 million CHF per year are provided for the improvement of the power production from new renewable energies. This cost covering remuneration is funded with a fee on electricity sold in Switzerland. As the cap of 320 million CHF has already been reached in 2008, no further projects can be funded in 2009, and the following years are already booked. Until 2009, no geothermal project has been applied for.

A total of 150 million CHF are reserved for the risk coverage of geothermal power production projects. In the case of failure of a geothermal project, a reimbursement of 50% of the testing and drilling costs can be achieved.

These measures are applicable only to deep geothermal projects for power production. No adequate measures are available for hydrothermal projects for heat production.

3.4 Induced Seismicity

After induced seismicity up to a Richter Magnitude of 3.4 was experienced with the Deep Heat Mining project in Basel (Ladner et al., 2008), induced seismicity became a major public concern regarding the use of deep geothermal resources.

The improvement of public knowledge in this field and the careful communication of relevant aspects to the public are essential.

3.5 Strategy and Areas of Interest

Based on the existing knowledge of the deeper subsurface of Switzerland and the experiences from HC exploration and previous geothermal projects, it seems to be more promising to first develop hydrothermal projects in order to acquire more knowledge of the deeper subsurface.

A main area of interest is therefore along the northern boundary of the Alps, where known aquifers exist at adequate depths. Nevertheless, the knowledge of quality of these aquifers is very limited, and the projects bear a certain risk.

A further focus on the development of deep geothermal resources could relate to fractured areas in the crystalline basement or adjacent to permo-carboniferous troughs. With this strategy, wider areas of the Swiss Molasse Basin could be considered as target areas.

If, after the execution of several deep geothermal projects, the knowledge of the deeper subsurface in Switzerland has increased and worldwide EGS technology has experienced sufficient development, specific EGS projects to produce

artificial deep heat exchangers can be tackled in Switzerland.

4. FORMER GEOTHERMAL PROJECTS IN SWITZERLAND

In the 1980's and the 1990's, 14 geothermal projects were performed in Switzerland. They focused on hydrothermal targets for heat production and balneological applications, as described in Table 1.

The development of most of these hydrothermal projects was stimulated by risk coverage provided by the Swiss Federal Government. This support began in 1987 and ended in 1998.

Some of these projects were successful, while others were partly successful or unsuccessful in terms of the encountered flow rate. Later projects received risk coverage up to 50% of the drilling and testing costs (Rybach 2005).

Table 1: Geothermal wells (>400 m depth), drilled in Switzerland between 1983 and 1998 (from Vuataz et al., 2000).

Well	Date drilled	TD [m]	T at bottom [°C]	Flow rate. [l/s]	Geothermal utilization in 1999
Kloten	1983	400	22.7	5.0	Heating 70 apartments
Riehen 1: producer Riehen 2: injector	1988 1988	1547 1247	67.0	20 14	District heating
Kreuzlingen	1988	655	30.0	3.7	Pool
Reinach	1989	1793	72.0	0.10	None
St. Moritz	1991	1600	47.2	1.3	None
Bulle	1992	800	30.0	0.08	None
Bassersdorf	1992–93	553	23.0 Wellhead	4.3	Heating
Weggis	1992–93	2302	73.0	0	Heating 3 buildings
Thônex	1993	2650	88.5	3.1	Project suspended
Weissbad	1993	1618	45.0	0	Spa
Schinznach Bad	1996	891	63.0	8.3	Spa
Saillon	1996	929	32.4	4.9	Heating and spa
Lavey-les-Bains	1997	595	72.0	22.5	Spa
Yverdon-les-Bains	1998	1440	60.0	92	None

5. CURRENT PROJECTS

In several cantons of Switzerland, potential studies were recently carried out or are still ongoing. These studies deal with the potential of shallow and deep geothermal resources.

Concerning the heat potential, at a realistic geothermal efficiency of shallow borehole heat exchangers and hydrothermal resources at depth, far more than the required energy could be provided for heating purposes in Switzerland. A prediction concerning electricity supply in Switzerland is very difficult to make because the future technical and economic conditions are unknown.

Today, several geothermal projects in Switzerland are at different stages of planning, as described in Table 2.

The projects of Brig and Geneva are at the concept or pre-feasibility phase. Their focus is mainly on heat production.

Feasibility studies of the Lavey-les-Bains and La Côte projects are currently ongoing. The target of the Lavey project is a prospective aquifer in an Alpine nappe structure with potential for power production. The focuses of the La Côte project are limestone aquifers at three locations in the Swiss Molasse basin suitable for heat production.

The concept study for the St. Gallen project was recently completed. Two aquifer horizons at 4–5 km depths are targets for a heat and power production project. The next step is a seismic survey to identify fracture zones.

The Zurich project primarily aims at exploring the Mesozoic strata and the crystalline basement in order to obtain new data for the long-term strategy of geothermal exploration in the area of Zurich, where no data was available until now. Two potential aquifer horizons in the Mesozoic sequence are the targets for heat production.

Table 2: Current deep geothermal projects in Switzerland.

Project name area	Geothermal target	Forecasted drilling depth [km]	Expected temperature [°C]	Status in 2009 Energy use
Brig	Fractured granite	1.5 ± 0.5	80 ± 10	Concept District heating
AGEPP Lavey-les-Bains	Fractured gneiss	2.5 ± 0.5	100 ± 10	Feasibility study District heating, electricity, spa
Géothermie profondeLa Côte Nyon-Gland-Aubonne	Mesozoic limestones	1.5 ± 0.5	55 ± 15	Feasibility District heating, spa
MICA Thônex, Geneva	Mesozoic limestones, Basement	2.7 ± 0.5 3.7 ± 0.5	70 ±10 140 ± 10	Pre-feasibility study District heating, electricity
Triemli Zürich	Malm, Muschelkalk (Basement)	1.9 2.4 (2.6)	78 97 104	Drilling project District heating
St. Gallen	Malm	4.0	150 ± 10	Concept study District heating, electricity
Basel	Basement	5	185	Pending risk assessment Electricity, district heating

The Deep Heat Mining Project in Basel is focused on the tight crystalline basement at a depth of 5000 m. The first borehole encountered 200°C temperatures, and hydraulic stimulation led to induced seismicity, so that the project was halted by the local authorities. A seismic risk assessment is currently ongoing.

6. PERSPECTIVES

Until now, all former and ongoing geothermal project in Switzerland were initiated and financed by local energy suppliers or authorities. Therefore, the locations of these projects were not chosen as a result of a systematic geothermal exploration of Switzerland, but depended on the interests of the local parties.

In order to exploit the large geothermal energy potential for power production, a systematic approach should be taken into consideration. The various efforts should be combined into a generalized concept and procedure for the development of deep geothermal resources in Switzerland.

First, all existing data should be combined and updated. Potential “geothermal plays” in several areas should be defined. After advanced investigations (e.g. seismic), favorable locations for 5–10 geothermal projects should be defined. In these projects, the reservoir enhancement technology and/or the creation of an artificial subsurface heat exchanger should be developed and improved.

As a basis for the future exploration and exploitation of geothermal resources in Switzerland, the legal framework should be changed so that future workers in this field have the opportunity to work under conditions where a long-term engagement can be established in a reliable framework.

Possible actors in the geothermal exploration in Switzerland should be large electricity supply companies, other relevant industries, regional and federal governments, institutions and universities.

The Swiss Geothermal Association has therefore proposed the idea to create a national cooperative for the exploration and development of deep geothermal resources in Switzerland. Such a cooperative could act as a center of competence and could be financed by the industry and the federal government.

The extent of the large geothermal potential that is economically exploitable in the mid- and long-term future can only be determined with a systematic approach.

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