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Actual Developments in Deep Geothermal Energy in Switzerland

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ABSTRACT

In the last decades, several deep geothermal projects for district heating or balneological usage have been realised in Switzerland. In contrast, deep geothermal power has not been produced yet. The interest in this kind of power production was low, only the Basel geothermal project tried to exploit a deep geothermal resource in 2006. The perceivable induced seismicity upset the geothermal branch and the general public temporarily. Nonetheless, the two pioneer projects AGEPP and St.Gall were still developed further. In 2010, two exploration companies were founded.

Through the events in Fukushima and the enacted nuclear phase-out in 2011, the perspectives of deep geothermal energy have been distinctively improved and the development has accelerated. Several potential and feasibility studies were conducted and some projects were initiated. Both pioneer projects obtained the national geothermal exploration risk guarantee, but only the drilling of the St.Gall project has been realised.

Deep geothermal energy is of high potential in Switzerland and could play an important role in Swiss energy supply in the future, but to achieve this goal, challenges of the most different kind must be tackled. One of the most urgent tasks is to improve the knowledge of the deep underground to be able to evaluate the technical and economic feasibility. Furthermore, it is necessary to regulate the exploration and exploitation of deep geothermal energy in a suitable manner to provide legal and investment certainty. The business environment is also vitally important for the willingness to invest in geothermal energy.

1. INTRODUCTION

The Swiss Federal Assembly decided on May25th, 2011 to realign their energy politics, back out stepwise of the nuclear energy programme and enhance power production by renewable energies simultaneously.

The great future potential of deep geothermal energy is realised by the Swiss Federal Office of Energy (SFOE) and equivalently taken into consideration in the Energy Strategy 2050.

Until 2050, ~4‘400 GWh_{el} per year should be produced by deep geothermal power plants (Figure 1). This requires an annual growth of 10 % from now on. In comparison, the current energy consumption in Switzerland is about 60’000 GWh_{el} per year.

This goal is ambitious and can only be achieved with adequate framework conditions and power supply companies or project developers which expedite and realise geothermal projects efficiently.

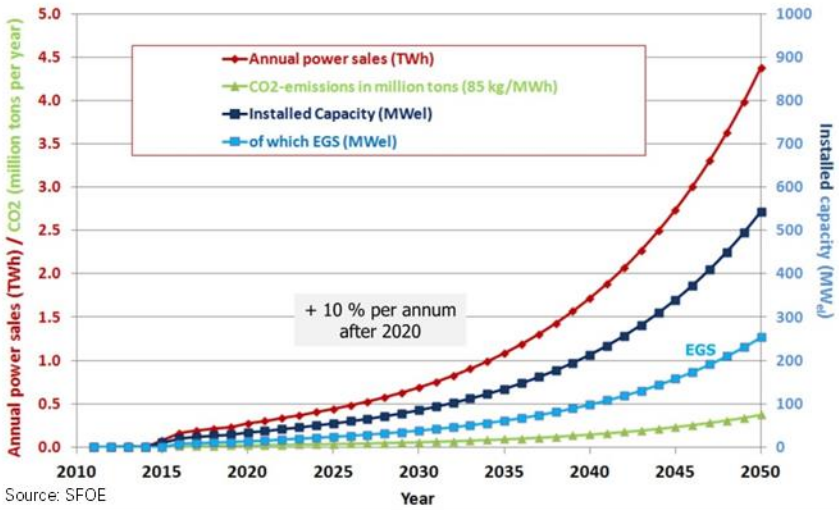

Figure 1: Development of the installed capacity and geothermal power production according to the Energy Strategy 2050 (Source: Swiss Federal Office of Energy SFOE).

In the context of the Swiss Energy Strategy 2050, a comprehensive package of measures is planned to stimulate the deep geothermal market and to achieve the objectives.

Regarding geothermal direct use there are no specific goals defined on a national or cantonal level.

2. GEOLOGICAL BACKGROUND

Switzerland is roughly divided into the Tabular and the Folded Jura in the West and North (blue units in Figure 2), the Swiss Molasse Basin (Swiss Midland; yellow unit) and the alpine orogen in the central and southern parts (other colours).

The Swiss basement consists of crystalline rocks containing troughs with permo-carboniferous sediments. The basement is exposed immediately north of the Swiss border ("Schwarzwald" and "Vosges" in Figure 2). The Tabular and Folded Jura are built up by Mesozoic units. The basement and its Mesozoic topset beds were flexed in Oligocene to Miocene times due to the weight of the emerging alpine orogenic wedge. For that reason, the resulting basin is asymmetric with a maximum thickness up to 4–5 km in its southernmost part, in front of the Alps.

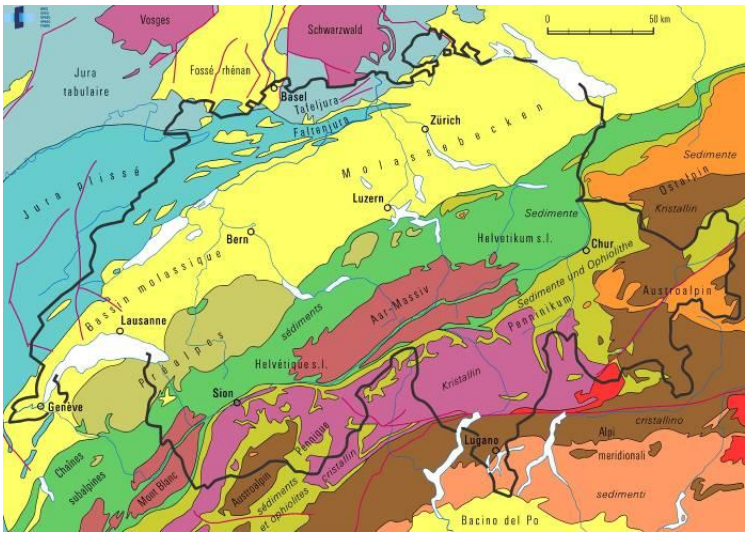

Figure 2: Rough geological classification of Switzerland.

3. KNOWLEDGE OF THE DEEP UNDERGROUND

Compared to many other countries, the deep underground of Switzerland has been scarcely investigated, especially by wells deeper than 3'000 m. The "Seismic Atlas of the Swiss Molasse Basin", published in 2012, shows an interpretation of regional seismic reflection data in connection with drill hole data, surface geology and the resulting regional 3D model. These data are important for projects in the field of subsurface planning such as geothermal energy, CO_2 sequestration, deep geological repositories, regional hydrogeology and natural gas exploration.

In the 1960–1980's, seismic lines were shot for the exploration of oil and gas ("SEAG", Figure 3). The area of interest was the Swiss Molasse basin ("Mittelland"). The National Co-operative for the Disposal of Radioactive Waste (Nagra) also investigated regions of the Swiss Midlands by 2D- and 3D-campaigns. The largest 3D-campaign was done in 2010 in the area of the city "St.Gall", in the northeastern part of Switzerland, with the aim to define the drilling targets of a geothermal project.

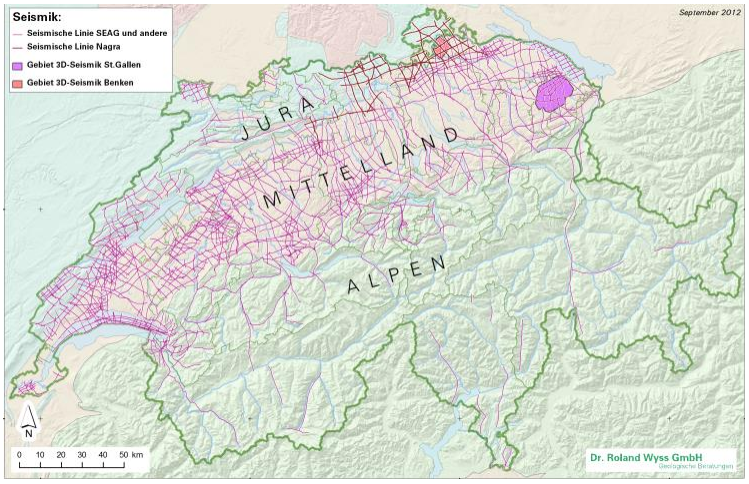

Figure 3: Existing seismic lines in Switzerland.

Several deep wells (> 400 m) were drilled in Switzerland for the most different reasons: exploration for oil and gas, geothermal purposes, the production of drinking water, etc. Due to "normal" geothermal conditions in Switzerland (see below), power production requires a drilling depth of more than 3 km. Until today (spring 2014), only 11 deep wells have reached down into that depth zone. The data basis for the geothermal resource evaluation and the development of geothermal heat and power projects is therefore poor.

4. GEOTHERMAL RESOURCES AND POTENTIAL

The geothermal potential is estimated by numerous studies on a local, regional or national level. Local studies are performed especially by municipal energy suppliers and the regional studies were mandated by different cantons.

In the Swiss Molasse basin, the geothermal gradients are considered to be normal, with values between 25 and 40°C/km. The heat flow values range from 40 to 140 mW/m^2, with an average of 60 mW/m^2 (Signorelli and Kohl, 2006; Baujard et al., 2007).

Possible targets of deep hydrothermal projects for heat and power production are potential Mesozoic Aquifers ("Oberer Malm", "Oberer Muschelkalk"), Top crystalline basement, and fault zones (Figure 4). Petrothermal projects (or EGS) are in theory possible in the whole country. Currently, the crystalline basement north of the Alps is considered as target rock.

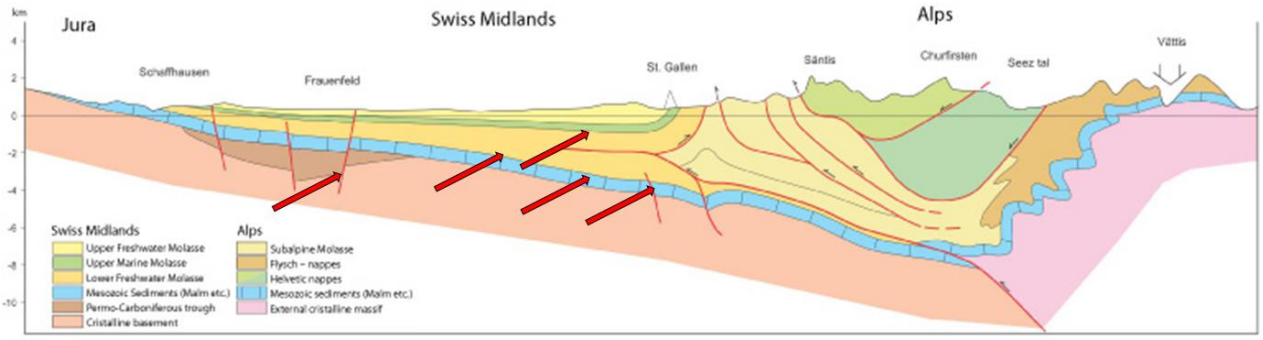

Figure 4: Possible hydrothermal target horizons and/or target areas in the region of the Swiss Molasse Basin.

The potential of hydrothermal systems is limited in Switzerland. The local feasibility of heat and power production has to be evaluated by geophysical surveying and (slim hole) drilling. In contrast, the potential of petrothermal systems is assumed to be large in Switzerland. According to a study of the Paul Scherrer Institute PSI (Hirschberg et al., 2005), about 82'500 TWh_{el} could be produced in total from geothermal energy stored in the depth range between 3 and 7 km. The annual power consumption in Switzerland is about 60 TWh_{el}/year (2013).

The current project "GeoMol CH" assesses the subsurface potentials of the Swiss Molasse basin for sustainable planning and use of natural resources. "GeoMol CH" is a part of the transnational project "GeoMol", which takes place from September 2012 to June 2015. Not only the Swiss but also the Slovenian, Austrian, German, French and Italian parts of the alpine foreland basins were evaluated.

5. OPERATING GEOTHERMAL SYSTEMS

Until today, there has been no geothermal power generation in Switzerland. The first power project in the city of Basle was suspended after earthquakes occurred at the end of 2006 during a hydraulic stimulation. The second power project is located in the city of St.Gall. The flow rate is too low regarding geothermal power production. In summer 2013, induced seismicity occurred when cold water and drilling mud was injected into the fracture zone for well control. A long-term productivity test could evaluate the reservoir size of the found natural gas (methane).

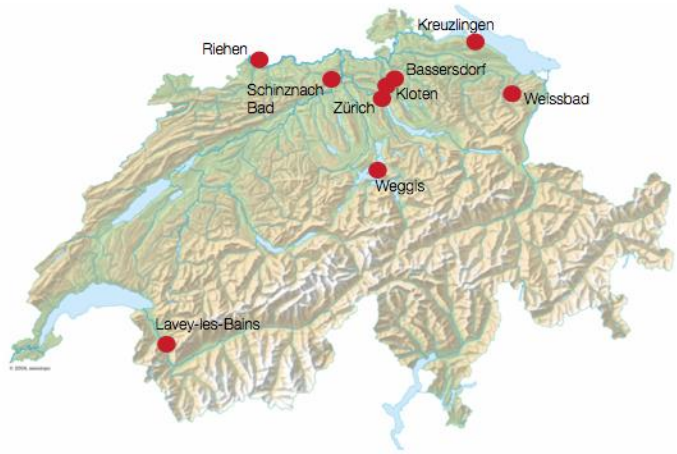

Figure 5: Overview of deep Geothermal projects in operation (2014).

Different kinds of geothermal direct use applications have been realised in Switzerland. Most of them are geothermal heat pump systems for space heating (Link et al. 2015). Deep aquifers have so far especially been used for thermal spas or for heating purposes (Figure 5). The Geothermal district heating system in Riehen by Basle is the only relatively large district heating system in Switzerland. It is successfully in operation since 1994 and was initiated in conjunction with the energy vision of the city. From 2010 to 2014, the Project "Riehen Plus" was realised to upscale the district heating system.

6. CURRENT DEEP GEOTHERMAL PROJECT DEVELOPMENTS

Several deep geothermal projects are in most different stages of development.

Since 2010, wells for three hydrothermal projects have been drilled. The first project is for direct use in agriculture and two wells were drilled for production. The start of operation is planned for the end of 2014. The second project is the already mentioned combined heat and power project of the city of St.Gall. The third implemented project is located in Davos and will use a 400 m deep aquifer for heating purposes (Groundwater heat pump system).

In total, 23 hydro- and petrothermal projects are investigated, seven of which are in a tangible stage (May 2014). Five projects, distributed over the Swiss Midlands, are petrothermal systems (EGS) planned by Geo-Energie Suisse AG (Avanches, Haute-Sorne, Etzwilen, Triengen and Pfaffnau; for details see Meier et al., 2015). One is a combined heat and power project (La Côte), and the last one a local heat only project (Oftringen).

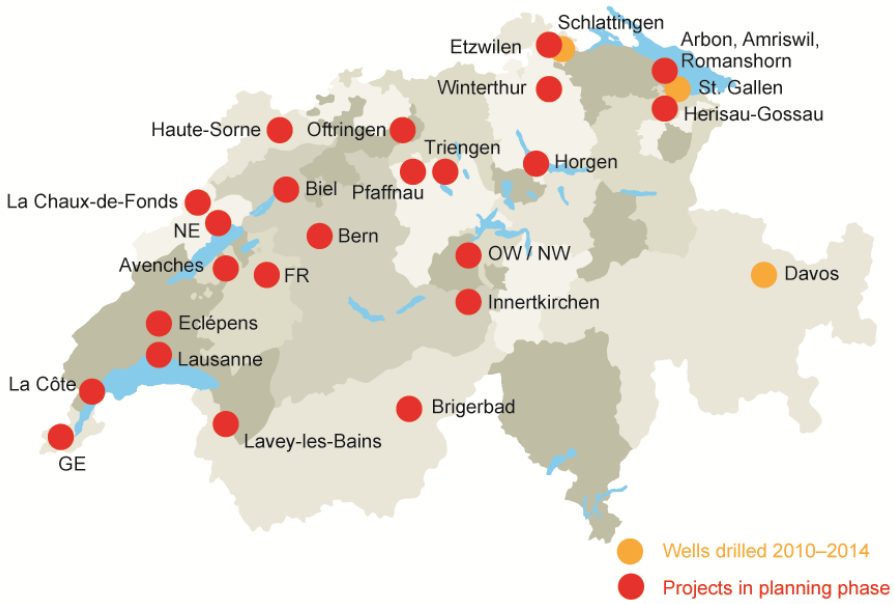

Figure 6: Deep geothermal wells drilled between 2010 and 2014 and geothermal projects in planning phase.

7. ACTUAL SITUATION AND CHALLENGES

Since 2008, deep geothermal energy for power production has been supported by a feed-in tariff (40 Rappen/kWh resp. 45 US Ct./kWh) and a geothermal exploration risk guarantee which covers as a maximum 50 % of the costs for drilling and testing. In 2010, two exploration companies were founded. The Axpo Power AG, division geothermal energy, planned to firstly develop hydrothermal projects, the Geo-Energie Suisse AG is pursuing petrothermal projects (EGS). Nonetheless, there has been no power production in Switzerland and although there are quite a lot of different projects in the planning phase (Figure 6), only the pioneer project in the city of St.Gall drilled a first well in 2013.

The reasons for the missing development of deep geothermal energy are manifold. One of the most urgent tasks is to improve the knowledge of the deep underground to be able to evaluate the technical and economic feasibility. To trigger private investments in the geothermal sector, the existence of deep aquifers or suitable rock formations for hydraulic stimulation has to be much more predictable. But to gain that knowledge and to be able to test and optimise the technics to enhance permeability and create efficient reservoirs, several pilot projects in different regions of Switzerland are necessary. In addition, the project owners such as power supply companies are suffering due to the current general price decline on the European electricity market. The know-how has to be imported in parts. Furthermore, as a consequence of the limited exploration and exploitation of resources in the past, the legal framework is insufficiently regulated and has to be aligned to recent needs to grant security of investment. Additionally, the knowledge of deep geothermal energy is at large relatively low in the general public which makes an early and comprehensive information and communication indispensable.

8. ENERGY STRATEGY 2050

According to the Swiss Energy Strategy 2050, about 4’400 GWh_{el}/year should be produced by deep geothermal energy in 2050.

In conjunction with the Energy Strategy 2050, a comprehensive package of measures has been planned and discussed since 2011 to stimulate the deep geothermal market and to achieve the objectives.

The following is included (amongst others):

- Increase in the geothermal exploration risk guarantee from 50 to 60 % and consideration of the costs for seismic campaigns etc. (not only for drilling and testing)
- Maintenance of the current feed-in tariff

- A feed-in bonus for petrothermal systems (EGS)
- Increase in the fund for “geothermal exploration risk guarantees”
- Consideration of deep geothermal energy as a main cornerstone in the Action Plan “Coordinated Energy Research Switzerland 2013 – 2016”
- Funding of especially applied research
- Information system and public availability of data from the deep underground
- Intensification of Public Relations & Communication

The new energy law will become effective in 2015. Some of the measures independent of the law are already implemented.

Beside the Energy Strategy 2050, many cantons started or even finished to work out a specific legal framework for the exploration and exploitation of deep geothermal energy or other resources.

Seven Swiss Competence Centres in Energy Research (SCCER) have been founded in 2013, one of these is located at the ETH Zurich and focuses on deep geothermal energy and hydro power.

To trigger private investments in exploration and pilot projects, the Swiss parliament demanded from the Swiss government in 2014 to develop an Action plan to promote geothermal exploration by seismics and drilling.

8. CONCLUSION AND FUTURE PROSPECTS

Deep geothermal power production is considered an important cornerstone in the Swiss Energy Strategy 2050. There are fast developments in all areas: cantonal and national politics, in the general awareness and among the power supply companies. If the challenges concerning the underground exploration and technology evolution are tackled and mastered, deep geothermal energy will play an important role in meeting the energy demand of Switzerland in the medium and long term.

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