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Geothermal Energy Use, Country Update for Switzerland

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ABSTRACT

In the last decades, several geothermal projects for district heating or balneological usage were realised in Switzerland. In contrast, «deep geothermal power» has not been produced yet. Through the events in Fukushima and the enacted nuclear phaseout, the perspectives of deep geothermal energy have been distinctively improved and the development has accelerated. The acceptance is currently high, but the expectations related to deep geothermal energy increased simultaneously. 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.

Geothermal heat pumps, on the other hand, represent continuously a success story in Switzerland, with annual growth rates of 20 %.

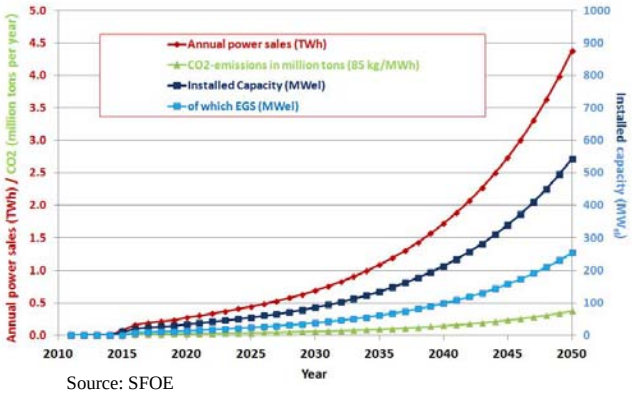
1. INTRODUCTION

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 (Fig. 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.



Source: SFOE

Fig. 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.

2. GEOLOGY AND GEOTHERMAL POTENTIAL

2.1 Geological Background

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

The Swiss basement consists of crystalline rocks containing troughs with permo-carboniferous sediments. The basement is exposed immediately north of the Swiss-German border («Schwarzwald» in Fig. 1). 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.

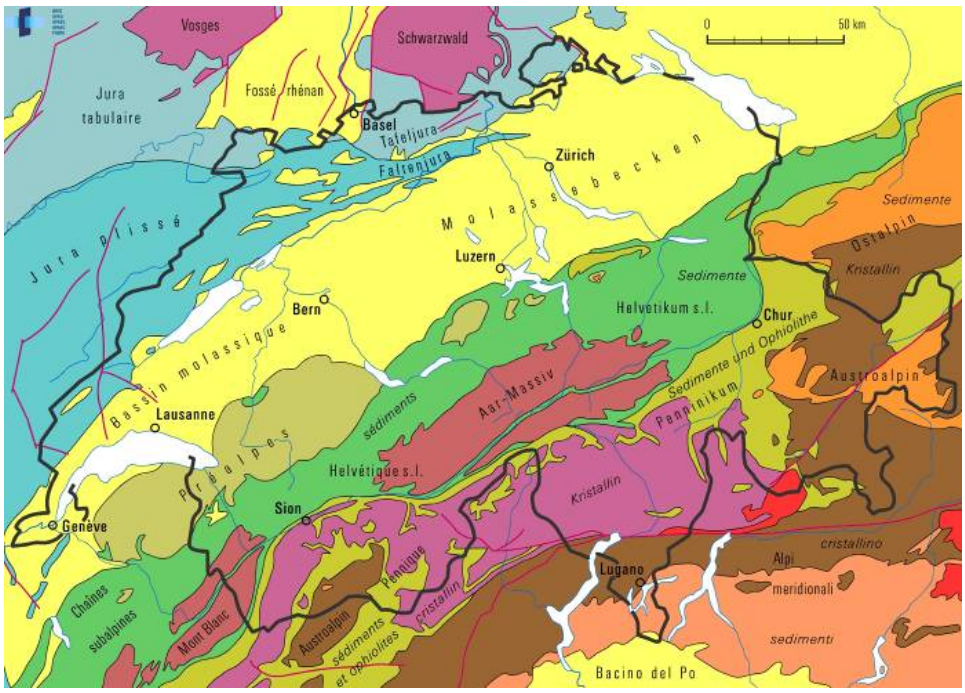


Fig. 2: Rough geological classification of Switzerland.

The surface of the Swiss Midland is structured by Quaternary glaciations and subsequent alluvial and colluvial processes.

Compared to many other countries, the deep underground of Switzerland has been scarcely investigated.

2.2 Geothermal gradients and heat flow

In the Swiss Molasse basin, the geothermal gradients are considered to be normal, with values between 25 and 40°C. 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).

2.3 Knowledge about the deep underground

The deep underground of Switzerland is not very well known yet. In the 1960–1980's, seismic lines were shot for the exploration of oil and gas («SEAG», Fig. 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.Gallen», in the northeastern part of Switzerland, with the aim to define the drilling targets of a geothermal project.

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, power production requires a drilling depth of more than 3 km. Until today (spring 2013), only 10 deep wells have reached down into that depth zone (Fig. 4). The data basis for the geothermal resource evaluation and the development of geothermal heat and power projects is poor.

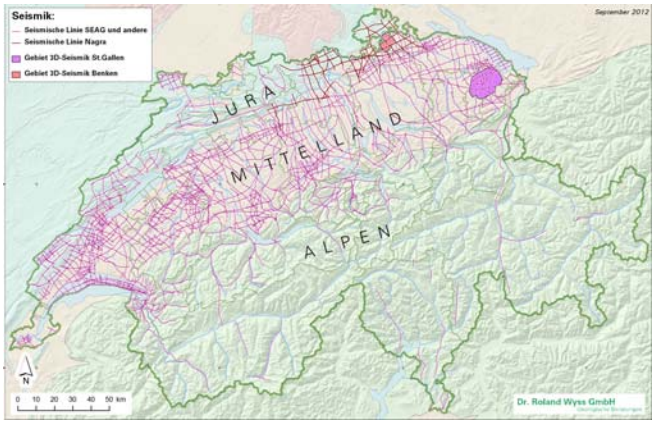


Fig. 3: Existing seismic lines in Switzerland.

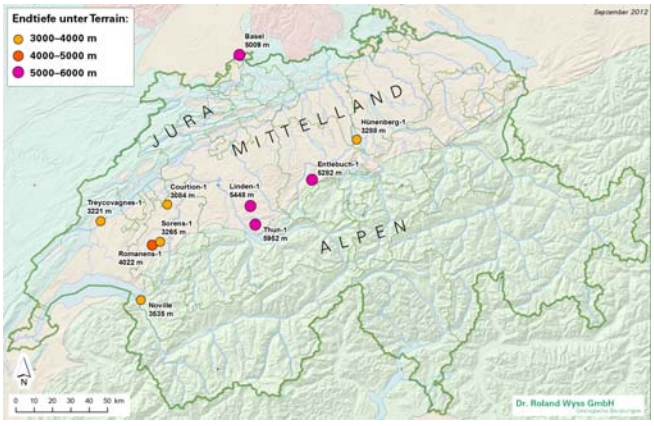


Fig. 4: Existing deep wells in Switzerland with depths > 3000 m.

2.4 Potential targets for geothermal projects

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 (Fig. 5).

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.

2.5 Geothermal 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 by the different cantons.

The potential of hydrothermal systems is limited in Switzerland. The local feasibility of heat and power production has to be evaluated by chemical and 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 (2010).

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.

3. GEOTHERMAL UTILIZATION

3.1 Geothermal power generation

Until today, there has been no geothermal power generation in Switzerland. The first power project in the City of Basel was suspended after earthquakes occurred at the end of 2006 during a hydraulic stimulation.

3.2 Geothermal direct use

Different kinds of geothermal direct use applications have been realised in Switzerland (Figure 6, Table 1 and 2). Geothermal heat pump systems for space heating provide the main part of heat production (2.3 TWh). Of this, 86 % comes from systems with borehole heat exchangers. The remaining heat pump-based utilization is made up by groundwater systems (288 GWh), geostructures (30.7 GWh), deep aquifers (6 GWh), tunnel waters (3.9 GWh) and deep borehole heat exchangers (0.5 GWh).

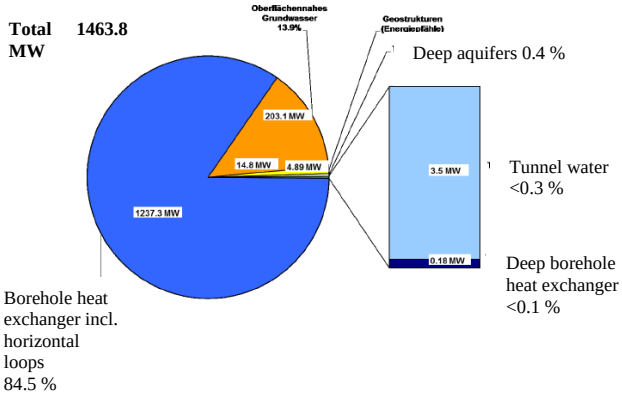


Fig. 6: Relative contributions of the various direct use categories in 2011 (after Imhasly et al., 2012).

Geothermal heat pump applications, now increasingly used in combined heating/cooling mode, are growing steadily with 20 % annually. In 2011 the total drill-length for BHEs was >2'000 km. The Areal density, with about 3 standard 12 kW units per km^2, is highest worldwide.

Direct geothermal heat use without heat pumps is applied mainly for thermal bathing (240 GWh) and a doublet system for district heating (0.3 GWh) in Riehen near Basel. The decline in direct heat generation in 2011 was due to the reconstruction of the heating station in Riehen.

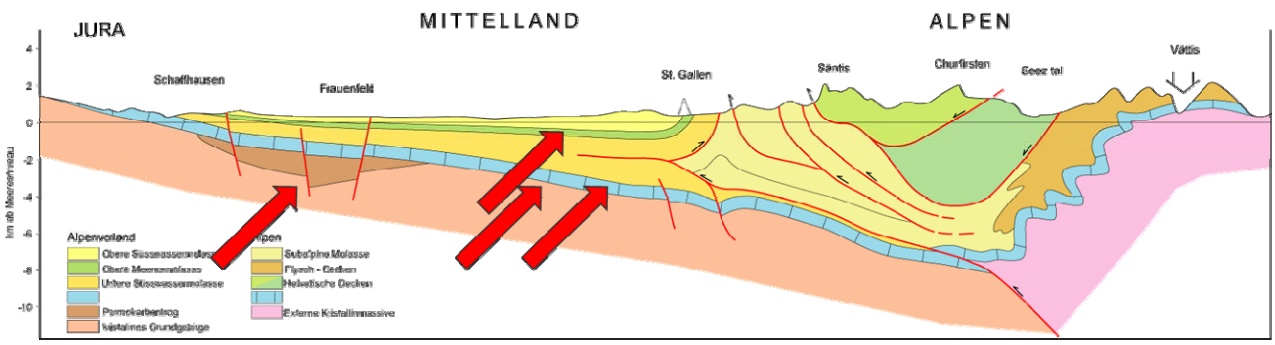


Fig. 5: Possible hydrothermal target horizons and/or target areas in the region of the Swiss Molasse Basin.

Table 1: Development of total thermal capacity (MW_{th}) 2008-2011 of systems using heat pumps. Thermal spas are not included (after Imhasly et al., 2012).

System	2008	2009	2010	2011	% in 2011
BHE*s	861.2	981.2	1122.8	1237.3	84.5
NSGW**	143	159.7	183.2	203.1	13.9
Geo-structures	10.4	11.9	12.2	14.8	1.0
Deep aquifers	5.0	4.9	4.9	4.9	0.3
Tunnel water	2.4	2.4	3.5	3.5	0.2
Deep BHEs	0.2	0.2	0.2	0.2	<0.1
Total	**1022.1**	**1160.3**	**1326.8**	**1463.8**	

*BHE: Borehole heat exchanger incl. horizontal loops and geothermal baskets
**NSGW: Near surface groundwater heat pumps

Table 2: Development of total heating energy (GWh_{th}) 2008-2011 (effective operating data, after Imhasly et al., 2012).

System	2008	2009	2010	2011	% in 2011
BHE*s	1493.4	1642.2	2068.1	1979.1	77.7
Thermal bathing	290.4	238.3	240.2	240.2	9.4
NSGW**	209.8	224.1	290.7	285.4	11.2
Geo-structures	21.5	24.7	25.3	30.7	1.2
Deep aquifers	13.4	15.5	13.3	6.1	0.2
Deep aquifers (no heat pumps)	2.1	1.8	0.7	0.3*	<0.1
Tunnel water	4.3	4.1	4.6	5.7	0.2
Deep BHEs	0.8	0.7	0.7	0.5	<0.1
Total	**1022.1**	**1160.3**	**1326.8**	**1463.8**	

*BHE: Borehole heat exchanger incl. horizontal loops and geothermal baskets
**NSGW: Near surface groundwater heat pumps

4. CURRENT DEEP GEOTHERMAL PROJECT DEVELOPMENTS

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

Two hydrothermal systems are under construction. The first project is for direct use in agriculture and the second well is drilled in spring 2013. The second project is the power and district heating project of the City of St.Gallen and the first well will most probably be finished in early summer 2013.

23 hydro- and petrothermal projects are investigated, whereas 10 projects are in a tangible stadium (Table 3).

Tab. 3: Deep geothermal energy projects in Switzerland for power production (selection).

Project venue	Project developers	Phase
Lavey-les-Bains (VD)	Diverse municipalities and power supply companies	Drilling in preparation
Arbon, Romanshorn, Amriswil (TG)	Electric power company of the Canton Thurgau EKT, Axpo Power AG	Preliminary studies, 3D seismic 2013/14
Avenches* (VD)	Geo-Energie Suisse AG	Planning phase, Public relations
Bassecourt* (JU)	Geo-Energie Suisse AG	Planning phase, Public relations
Eclépens (VD)	BKW / sol-E Suisse AG and others	Planning phase
Etzwilen* (TG)	Geo-Energie Suisse AG	Planning phase, Public relations
St.Gallen (SG)	Sankt Galler Stadtwerke	Start of drilling 4th of March 2013
Herisau-Gossau (SG)	Axpo Power AG, Sankt Galler Stadtwerke, St. Gallisch-Appenzellische Kraftwerke AG	Preliminary studies, feasibility study in preparation
Sursee-Mittelland* (LU)	Geo-Energie Suisse AG	Planning phase, Public relations

* Petrothermal projects (EGS)

5. CURRENT INCENTIVE SCHEMES

5.1. Shallow geothermal energy sector

Financial support or tax credits of different kind and size can be obtained when installing geothermal heat pumps, depending on the site location. This explains at least partly the rapid development of the Swiss geothermal heat pump market.

5.2 Deep geothermal energy sector

Since 2008, deep geothermal projects for power production have been supported by a feed-in tariff (highest in Europe) and a risk guarantee which covers max. 50 % of the costs for drilling and testing.

6. 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.

Up to now, there has been no power production in Switzerland although there have been a feed-in remuneration and a risk guarantee since 2008. Only one pioneer project started drilling in spring 2013.

The reasons for the missing deep geothermal development are manifold. The geothermal exploration risk is quite high in Switzerland due to the insufficient knowledge of the deep underground. There is no experienced industry and the know-how has to be imported in parts. The knowledge about deep geothermal energy is at large quite low in the general public.

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

The following is included (amongst others):

- Increase of the 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
- Increase of the «risk guarantee funds»
- Consideration of deep geothermal energy as a main cornerstone in the «Federal Energy Research Masterplan 2013 – 2016»
- Funding of especially applied research
- Public availability of the information system about the deep underground
- Intensification of public relations

The consultation of the Swiss Energy Strategy 2050 ended in January 2013 and the new energy law will become effective in 2015. Some of the measures can be implemented before.

Very important is also that there is no specific legal framework for the exploration and usage of deep geothermal energy. Many cantons are just working out the statutory basis for that.

7. CONCLUSIONS

Geothermal heat pumps are continuously a success story in Switzerland, with annual growth rates of 20 %. The areal density with about 3 standard 12 kW units per km^2 is highest in the world.

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 solved, deep geothermal applications will play an important role in meeting the energy demand of Switzerland in the medium and long term.

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Acknowledgements

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TABLES A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2012	–	–	–	~62'900	–	–
Under construction end of 2012	–	–	–	–	–	–
Total projected by 2015	2.5 MW*	14.5	–	–	–	–

*netto

Table B: Existing geothermal power plants, individual sites*

*Geothermal power plants are not yet available in the country.

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH Plants*		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2011	8.4	10.3	–	–	28.9	240
Under construction end of 2012	–	–	one project (agriculture) no figure	one project (agriculture) no figure	-	–
Total projected by 2015**	26.4	104.3	no figure	no figure	28.9	240

*) Geothermal fluids: deep aquifers and outflowing tunnel waters
**) Uncertain

Table D: Existing geothermal district heating (DH) plants, individual sites

Locality	Thermal water source	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geothermal capacity (MW_{th})	2011 geo-thermal heat production (GWh_{th}/y)
Bassersdorf/ZH	Deep aquifer	no	no	0.24	0.24
Kloten/ZH	Deep aquifer	no	no	0.24	0.41
Kreuzlingen/TG	Deep aquifer	no	no	0.06	0.12
Riehen/BS	Deep aquifer	no	no	3.00	1.79
Seon/AG	Deep aquifer	no	no	1.35	1.62
Oberwald/VS	Tunnel water	no	no	1.11	1.65
Airolo/TI	Tunnel water	no	no	0.72	0.65
Kaltbrunn/SG	Tunnel water	no	no	0.16	0.17
Frutigen/BE	Tunnel water	no	no	1.08	3.45
Trimbach/SO	Tunnel water	no	no	0.37	0.15
Minusio/TI	Tunnel water	no	no	0.07	0.07
Total				**8.40**	**10.32**

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012**		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number*	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2011	~120’000*	1’455	2’295	~10’000	120	20
Projected by 2015**	160’000	2’000	3’000	–	–	–

*) 12 kW_{th} equ. Units
**) estimated numbers

Table F: Investment and Employment in geothermal energy

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power				
Geothermal direct uses				
Shallow geothermal				
total				

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	DIS	DIS	DIS (in some cantons, not national)
Financial Incentives – Investment	RC (50 %, national)	RC (100% in Canton Thurgau)	DIS (in some cantons, not national)
Financial Incentives – Operation/Production	FIT	–	–
Information activities – promotion for the public	Yes (Swiss Geothermal Society, main activity sector)	Yes (Swiss Geothermal Society, but less compared to geothermal electric power production)	Yes (Swiss Geothermal Society, but less compared to the deep geothermal sector because shallow geothermal applications are already well known)
Information activities – geological information	Yes (publicly available cantonal potential studies and Project «GeoMol CH»)	Yes (publicly available cantonal potential studies and Project «GeoMol CH»)	Yes (cantonal websites)
Education/Training – Academic	Yes	Yes	Yes
Education/Training – Vocational	No	No	Yes

Key for financial incentives:					
DIS	Direct investment support	RC	Risc coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota