Geothermal Energy Use, Country Update for Switzerland

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Keywords: Geothermal, direct use, heating, cooling, heat pumps, borehole heat exchangers, spas, tunnel water, agriculture, feed-in tariff, risk coverage, petrothermal, EGS, Switzerland.

ABSTRACT

So far there is no power generation in Switzerland. On the other hand, Switzerland is an internationally prominent player in shallow geothermal energy technology, thanks to the widespread geothermal heat pump installations. These systems, providing space heating, cooling, and/or domestic hot water, are growing steadily. In 2014, the total drill-length of borehole heat exchangers was about 2,500 km. The areal density is still highest worldwide.

In 2014, the total installed capacity of all heat pump systems was 1816.8 MW (Figure 6), whereof 84.3 % (1531.7 MW) were installed in borehole heat exchangers, 14.1 % (256.5 MW) in groundwater systems, 1.0 % (19 MW) in geostructures, 0.3 % (5 MW) in deep aquifer systems, 0.2 % (3.8 MW) in tunnel water systems and <0.1 % (0.8 MW) in deep borehole heat exchangers.

In 2014, the heat production amounted to 3037.3 GWh (real operating data), with a geothermal and thus renewable energy part of 2277.5 GWh. Geothermal heat pump systems for space heating provided the main part of heat production (2790.1 GWh). Of this, about 85 % came from systems with borehole heat exchangers (2385.3 GWh). The remaining heat pump-based utilisation was made up by groundwater systems (344.3 GWh), geostructures (39.5 GWh), deep aquifers (13.5 GWh), tunnel water (5.8 GWh) and deep borehole heat exchangers (1.7 GWh). Direct geothermal heat use without heat pumps was applied mainly for thermal bathing (242.1 GWh) and a doublet system for district heating (3.1 GWh) in Riehen near Basel. At the tunnel of "Lötschberg" a large part of the geothermal heat (2 GWh) was used directly for fish farming (Tropenhaus Frutigen).

Since 2008, geothermal power production has been supported by a national geothermal exploration risk guarantee and by a feed-in tariff. In contrast, there is no national direct incentive scheme for utilising geothermal energy for heating and/or cooling purposes, but a number of Switzerland's 26 cantons provide investment subsidies for ground source heat pumps.

1. INTRODUCTION

With an area of approximately 41'000 km^2, Switzerland is located in central Europe. Most of the 8 Million inhabitants (in 2014) live in the Swiss Midlands north of the European Alps. The Swiss demographic growth is one of the largest in Europe with about 1% per year (last 5 years).

Direct use of geothermal energy has had a long tradition in Switzerland. The oldest utilisations are the still popular thermal spas. Geothermal heat pump applications have been for more than a century an unabated success story with annual growth rates of up to 12 %. Switzerland has the highest density of ground source heat pump systems (GSHP) in the world. The deployment of shallow geothermal energy applications is mainly restricted by water protection regulations but not constrained by its natural potential.

2. SWISS ENERGY POLITICS

The efficiency increase and energy saving measures are the most important goals of the current Swiss Energy Policy. Nonetheless, in the energy scenario for 2050 the power demand is forecasted to only stabilize or even grow slightly (Figure 1). In contrast, high saving potentials characterize the transportation and heating sectors.

The Swiss Federal Assembly decided on May 25th, 2011 to realign their energy politics and to back out stepwise of the nuclear energy program. Because nuclear power plants are currently the second largest electricity producer in Switzerland (35.8 % in 2012 according to BFE, 2014), power production by renewable energies has to be enhanced simultaneously. An increased deployment of renewable energy technologies is therefore another very important pillar of the Swiss Energy politics.

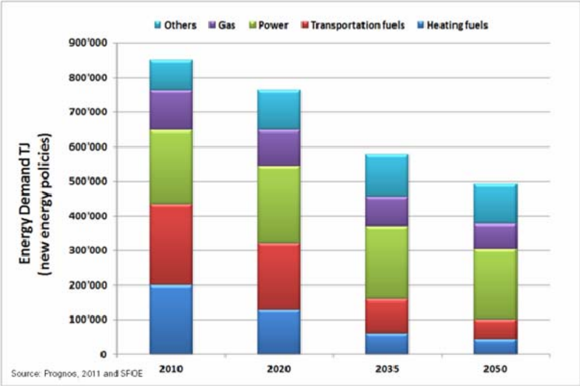

Figure 1: Energy demand of Switzerland: Expected development from 2010 up to 2050 according to Prognos and the Swiss Federal Office of Energy (SFOE).

In the context of the search for alternative energy sources, the great future potential of deep geothermal energy has been realised by the Swiss Federal Office of Energy (SFOE) and has been 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 2). 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.

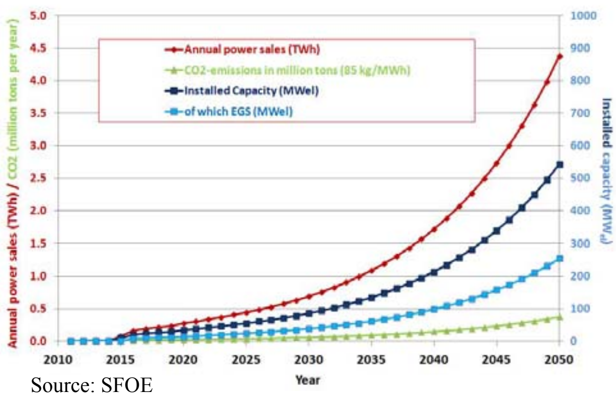

Figure 2: Development of the installed electrical capacity and geothermal power production according to the Energy Strategy 2050 (Source: Swiss Federal Office of Energy SFOE).

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.

Regarding (geothermal) heat, no specific national or cantonal goals are defined for 2050.

3. GEOLOGICAL BACKGROUND AND GEOTHERMAL POTENTIAL

Switzerland is roughly divided into the Tabular and the Folded Jura in the West and North (blue units in Figure 3), the Swiss Molasse Basin (Swiss Midland) (yellow unit) and the alpine orogen in the central and southern parts (other colours, Figure 3).

The Swiss basement (purple units) consists of crystalline rocks containing troughs with permo-carboniferous sediments. The basement is exposed immediately north of the Swiss-German border («Schwarzwald» in Figure 3). 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 4).

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.

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”), the 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.

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 by 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 57.5 TWh_{el}/year (2014).

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”. Not only the Swiss but also the Slovenian, Austrian, German, French and Italian parts of the alpine foreland basins were evaluated.

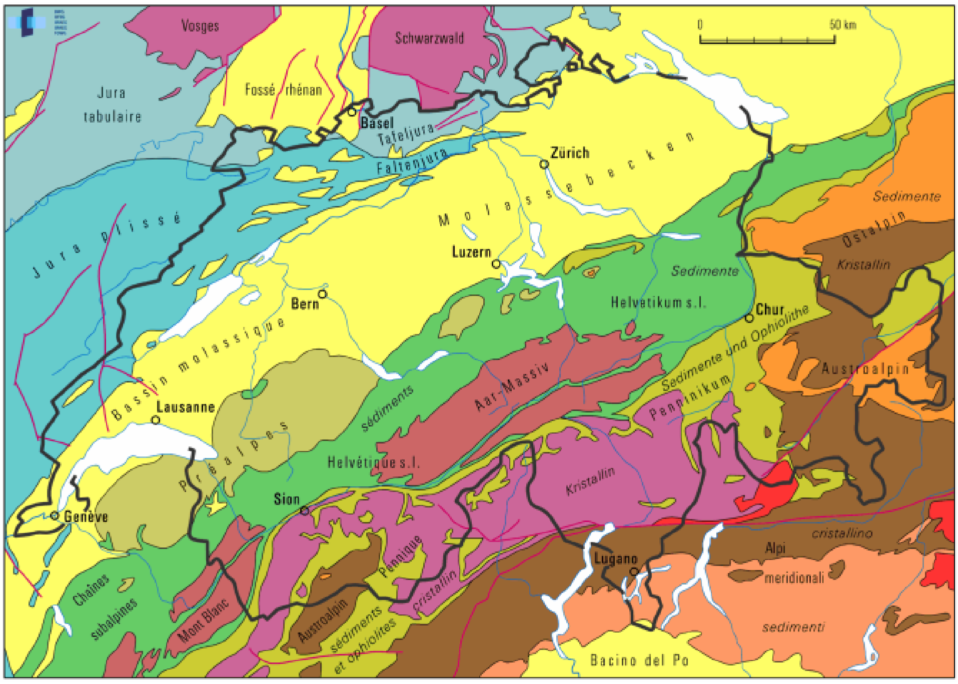

Figure 3: Rough geological classification of Switzerland (Source: Federal Office of Topography swisstopo).

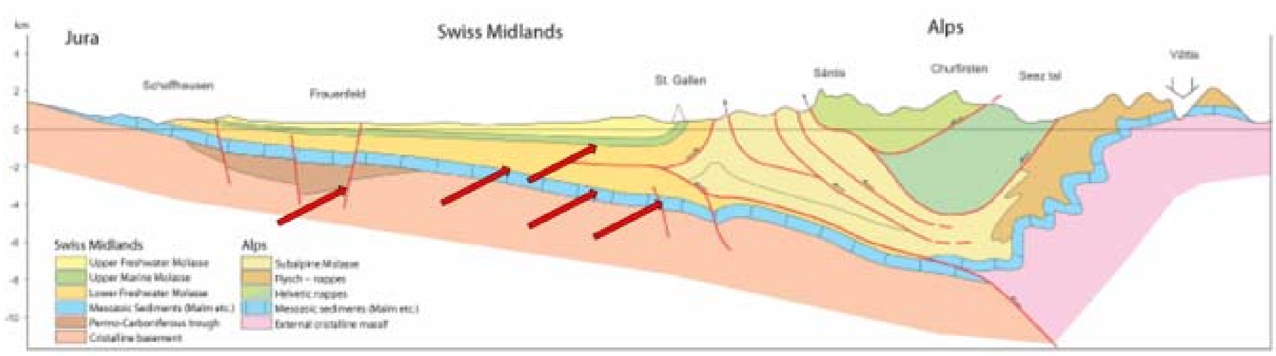

Figure 4: Possible hydrothermal target horizons and/or target areas along fault zones (red arrows) in the region of the Swiss Molasse Basin.

4. GEOTHERMAL UTILISATION

4.1 Electric power generation

The first Swiss geothermal power project in the City of Basel was suspended after earthquakes occurred at the end of 2006 during a hydraulic stimulation. In 2012, two geothermal pioneer projects (AGEPP in Lavey-les-Bains and the St.Gall project) obtained the Swiss national geothermal exploration risk guarantee. Regarding the AGEPP project, the project progress has stagnated since then and the start of the drilling is still uncertain. In 2013, the first well of the project St.Gall was completed and the supposed water bearing fault zone area was reached. The productivity tests revealed that the water flow is too low (about 5 instead of the expected > 50 l/s) and the geothermal project was stopped in May 2014.

As a consequence, there has been no geothermal power generation in Switzerland until today.

4.2 Geothermal direct use

Different kinds of geothermal direct use applications have been realised in Switzerland (e.g. Figure 5, Tables C to E). Details regarding installed capacity, produced energy etc. are comprehensively compiled and the individual figures and trends elucidated in detail in the annual Swiss geothermal energy statistics (Imhasly et al. 2015).

The trends of the individual geothermal direct use applications show a steady increase in deployment, installed capacity and produced heat. By far, ground source heat pumps are still the most important application in Switzerland, followed by near-surface groundwater utilisations and balneology (Figure 5). Other systems including the use of deep aquifers have been of less relevance up to 2014.

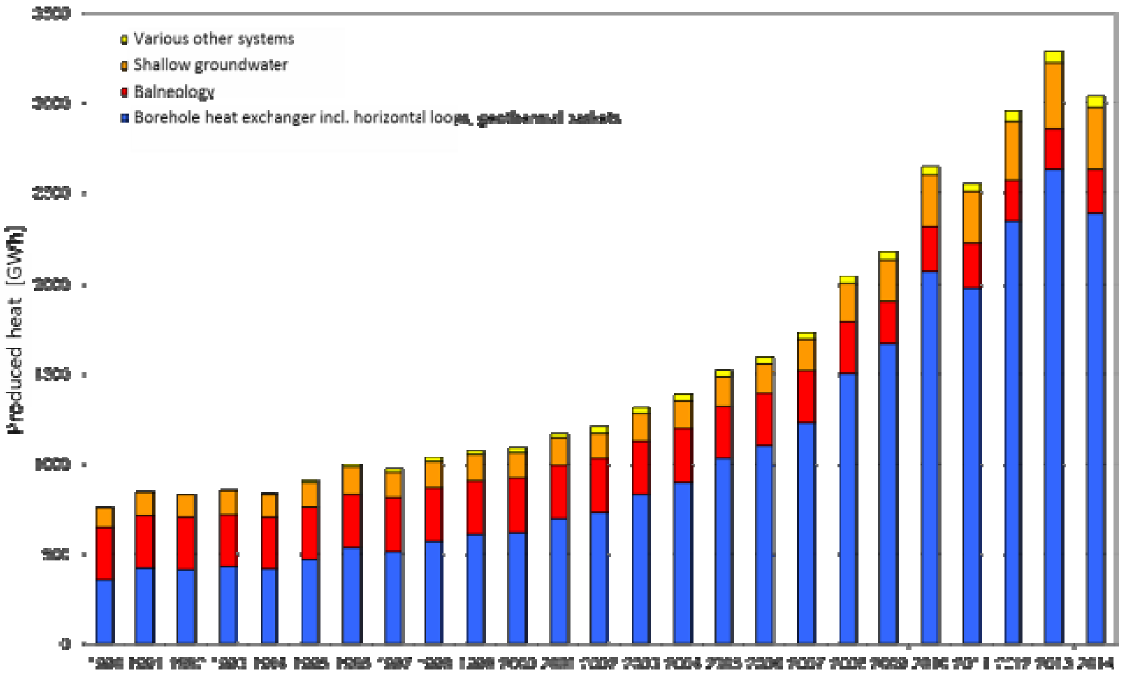

Figure 5: Annual Heat Production with geothermal energy in Switzerland until 2014 (after Imhasly et al., 2015). The data are based on the Swiss Heat Pump Statistics (official sales figures) or on the report of the operator and represent real operating data. The annual variations are due to the dependence on the heating degree days.

The decrease in heat production relative to 2013 is due to a warm winter and thus low number of heating degree days.

In 2014, about 6’477 brine/water (35 %) and 463 water/water (2.5 %) heat pumps had been sold. The heat pumps sold most are air/water (62.5 %), the fewest are air/air heat pumps (Source: Fachvereinigung Wärmepumpen Schweiz FWS).

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In 2014, the heat production amounted to 3037.3 GWh (Figure 7), with a geothermal and thus renewable energy part of 2277.5 GWh.

Geothermal heat pump systems for space heating provided the main part of heat production (2790.1 GWh). Of this, 85 % came from systems with borehole heat exchangers (2385.3 GWh). The remaining heat pump-based utilisation was made up by groundwater systems (344.3 GWh), geostructures (39.5 GWh), deep aquifers (13.5 GWh), tunnel water (5.8 GWh) and deep borehole heat exchangers (1.7 GWh).

Geothermal heat pump applications, now increasingly used in combined heating and cooling, are growing steadily. In 2014, the total drill-length for BHEs was about 2'500 km (Source: Fachvereinigung Wärmepumpen Schweiz FWS). The areal density is still highest worldwide (Lund and Boyd, 2015).

Direct geothermal heat use without heat pumps is applied mainly for thermal bathing (242.1 GWh) and a doublet system for district heating (3.1 GWh) in Riehen near Basel. At the tunnel of “Lötschberg” a large part of the geothermal heat (2 GWh) is used directly for fish farming (Tropenhaus Frutigen).

4.2.1 Geothermal DH plants

The only large geothermal DH plant is the one in Riehen by Basel. It has been in operation since 1994. The thermal water is produced from an approximately 1.5 km deep aquifer (Middle Triassic Muschelkalk formation) in the area of a fault zone at the Southern End of the Upper Rhine Graben. The 65 °C warm water was originally produced with a flow rate of 20 l/s. In 1997, the district heating grid was extended to Stetten (Lörrach), Germany. This system represents the first transboundary direct use facility worldwide. From 2010 to 2014, the Project “Riehen Plus” was realised to upscale the district heating system. Due to the installation of a new pump, the flow rate increased to 23 l/s (May 2014; with the future aim of reaching 25 to 28 l/s) and the temperature rose to 66 °C. After the geothermal energy is transferred at a heat exchanger, the thermal water is additionally cooled down to a temperature of 30–25 °C by three heat pumps with a COP of about 6.5.

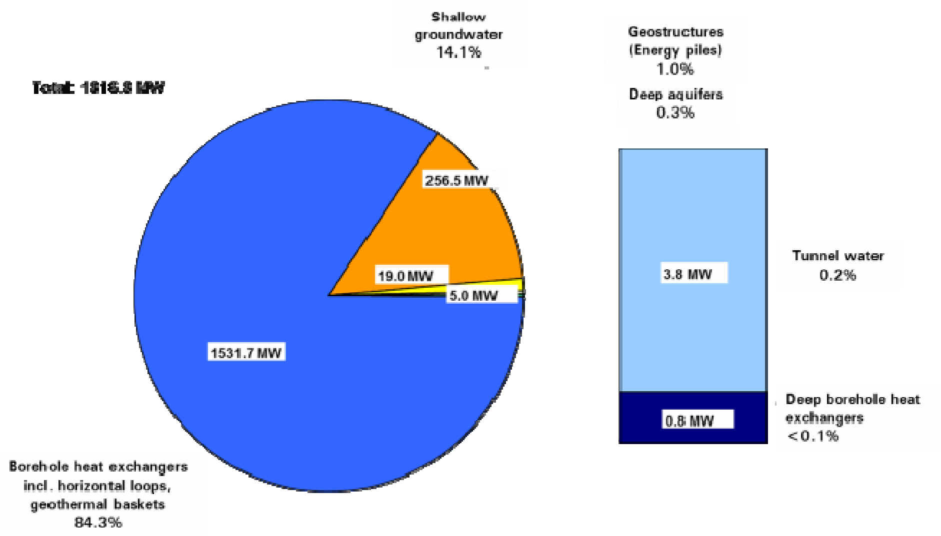

Figure 6: Installed capacity of heat pump systems in Switzerland in 2014 (after Imhasly et al., 2015).

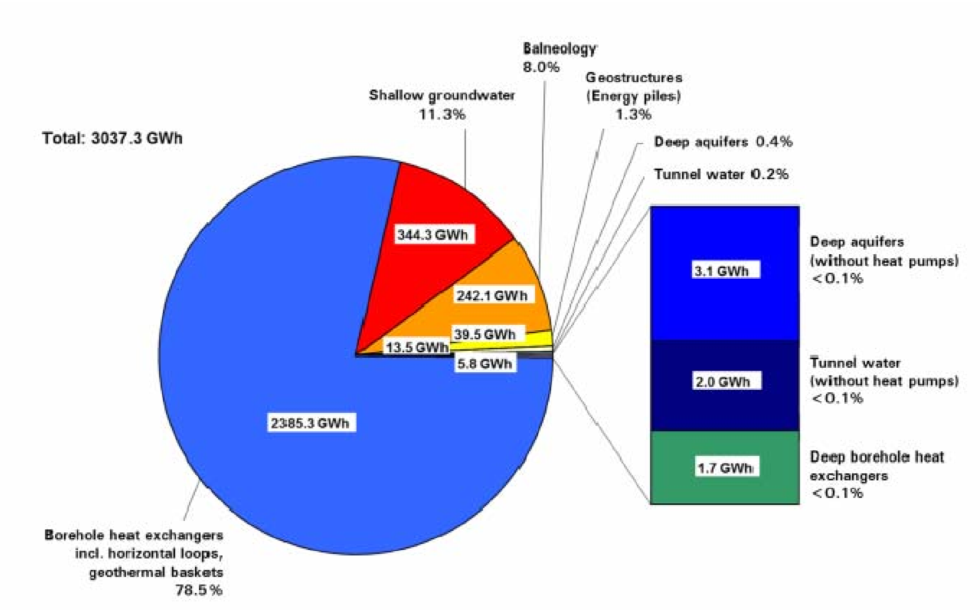

Figure 7: Relative contributions to the heat production [in GWh] of the various direct use categories in 2014 (real operating data; after Imhasly et al., 2015).

4.2.2 Geothermal heat in agriculture and industry

There has been no geothermal heat use in the agriculture and industry sector yet. The first project in Schlattingen is realised, but is not in operation yet. One of the two wells has a nearly 800 m long and almost horizontal section in the 1.5 km deep aquifer and produces about 10 l/s. The water temperature is about 63 °C. For further project details see e.g. Frieg et al., 2015.

4.2.3 Geothermal heat for individual buildings

The interest in geothermal heat pump applications is still very high in Switzerland. After an exponential growth until 2011, the growth rates stabilized at a high level. Those systems are not only relevant for new buildings but are also a favourite solution when renovating the heating system. In two cases, even tunnel water is used alternatingly for heating and cooling, depending on the season.

4.2.4 Tunnel water for heating and cooling

In Switzerland, many tunnels exist in the alpine orogen and the hilly foreland. The tunnels in the Swiss Alps have a length of up to 34.6 km (Lötschberg base tunnel). The new Gotthard base tunnel has a length of 57 km. Tunnels drain the water from the surrounding rock zones and, as a result, a considerable amount of warm water flows in the tunnel towards the portals. Water with a temperature up to 50 °C can be utilised.

The strict environmental regulation forbids discharging the warm water into nearby rivers. Instead of using energy to cool the water down, this energy reserve can be used for various applications. In Switzerland many different types of applications are deployed: space heating, greenhouses, balneology, fish farming etc.

Figure 8: The "Tropenhaus Frutigen" at the northern portal of the Lötschberg base tunnel uses the geothermal heat of the tunnel water for space heating, for raising tropical plants in greenhouses and for producing caviar in a fish farm (source: Tropenhaus Frutigen).

The most straightforward and cheapest form of tunnel heat usage is to collect and transport inflowing waters via ducts to the portals, with as little temperature drop as possible. When the temperature level of the tunnel water outflows is too low for direct applications (e.g. for district heating), heat pumps are used.

In 2014, geothermal tunnel water applications (with heat pumps) produced 5.8 GWh, of which 4.1 GWh were of geothermal origin. At the Lötschberg base tunnel additional 2 GWh of heat were used directly without heat pumps for fish farming ("Tropenhaus Frutigen", Figure 8). The Lötschberg Tunnel water has a flow rate of about 100 l/sec and is characterised by a fairly constant temperature of 17°C.

In two cases, at the Gotthard and the Mappo Morettina road tunnels, the water is also used for cooling during summer time.

5. 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 (Schlattingen project) and two wells were drilled for production. The start of operation is planned for spring 2016. The second project is the combined heat and power project of the city of St.Gall, which failed due to an insufficient flow rate of about 5 l/sec. 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, 9 hydro- and petrothermal projects are currently under investigation. Five projects, distributed over the Swiss Midlands, are petrothermal systems (EGS) planned by Geo-Energie Suisse AG (Avenches, Haute-Sorne, Etzwilen, Triengen and Pfaffnau; for details see Meier et al., 2015). Another project is a combined heat and power project (project AGEPP), two are local heat only projects (Oftringen, Energeô Vinzel) and the last one is a large exploration project in the canton of Geneva.

6. INCENTIVE SCHEMES

In Switzerland, there is no national direct incentive scheme for utilising geothermal energy for heating and/or cooling purposes. A number of Switzerland's 26 cantons provide investment subsidies for ground source heat pumps but the amounts and requirements differ from canton to canton. The canton of Thurgau provided a geothermal exploration risk guarantee for the drilling of the deep geothermal project in Schlattingen. This is remarkable for two reasons: 1. there is no legal obligation to grant such a guarantee and 2. although the application was submitted during summer vacation, it took the cantonal parliament only a few days to authorise the guarantee credit.

Since 2008, geothermal power production has been supported by a national geothermal exploration risk guarantee covering as a maximum 50 % of the drilling and testing costs and by a feed-in tariff (Table 1), by which payment is guaranteed for a duration of 20 years. The funds required for financing the feed-in tariffs and the guarantees derive from a surcharge of 0.6 Rappen/kWh (which is about the same in US Ct., Dec 2015) that end customers pay for power transmitted via the high voltage grid. The Swiss feed-in tariffs are higher than in most other countries.

A national feed-in tariff or exploration risk guarantee for deep geothermal direct use projects is not possible, because the money for the fund is derived from the power sector.

Table 1: Feed-in tariffs for electricity from geothermal energy

Installed Capacity (el)	Feed-in tariff (Rappen resp. US Ct./kWh)
≤ 5 MW	40.0
≤ 10 MW	36.0
≤ 20 MW	28.0
20 MW	22.7

6. MARKET DEVELOPMENT

6.1 Shallow geothermal energy

Market conditions for industry players in the ground source heat pump sector are increasingly challenging. There is a tendency towards larger, complex, combined heating & cooling systems, applying up to several hundred borehole heat exchangers. Due to the success of ground source heat pump systems, many players have entered the market which now shows early signs of consolidation. Most shallow geothermal drilling companies compete on price.

6.2 Deep geothermal energy

Since 2008, deep geothermal energy for power production has been supported by a feed-in tariff and a geothermal exploration risk guarantee. In 2010, two exploration companies were founded. The Axpo Power AG, division geothermal energy, planned to first 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, only the pioneer project in the city of St.Gall drilled a first well in 2013. The Axpo Power AG stopped their activities in the deep geothermal sector in 2015.

The reasons for the missing development of deep geothermal energy are manifold (Wyss and Link, 2015). 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.

7. RESEARCH AND DEVELOPMENT

Several shallow geothermal projects (< 400 m) were supported by national funding, but no specific master plan exists as the technique is highly mature. Important aspects are quality assurance, efficiency enhancement and innovative thermal grids.

Geothermal power production is a main issue of the Action Plan "Coordinated Energy Research Switzerland 2013–2016". It supports research and development regarding petrothermal Systems (EGS) by focusing especially on the four main topics: reservoir exploration, reservoir generation (stimulation), reservoir monitoring and efficiency enhancement of energy conversion. In this context, a Swiss Competence Center for Energy Research (SCCER), focusing on the supply of electricity (SoE), was established in 2013/14. It will concentrate on deep geothermal power production (petrothermal or EGS) and hydropower.

Regarding fundamental research, the GEOTHERM project (2008–2012) received a larger proportion of the available funding. It analysed in depth the data of the Basel EGS project and derived important learnings with respect to e.g. the underground behaviour during the hydraulic stimulation. Managing induced seismicity is an important aspect in Switzerland due to the framework conditions in the underground and the importance of EGS. Therefore GEOBEST, a project which is implemented by the Swiss Seismological Service (SED), is also one of the main pillars of current R&D (Table 2). Regarding pilot projects, the geothermal direct heat project in Schlattingen received national funding for e.g. the novel approach to explore the aquifer (Frieg et al., 2015).

Geothermal Education was strengthened in the last years and is offered at the University of Neuchâtel, the Swiss Federal Institute of Technology (ETHZ) in Zurich and the "École Polytechnique Fédérale de Lausanne" (EPFL) in Lausanne.

Table 2: Some of the most important R&D and pilot projects in Switzerland (Source: modified after Minder and Siddiqi, 2014).

Nr.	R&D Projects (1–5) and Pilot Projects (6+7)	Issue
1	GEOSIM	Real time assessment of seismic risks
2	Thermal spallation drilling: rock-flame interaction	Revolutionary drilling technique
3	GeoMol – CH	Delineate the geothermal potential of the sedimentary basins of CH
4	COTHERM	Better understanding of high-temperature geothermal systems: test bed for numerical modelling techniques
5	GEOTHERM	Novel observation techniques for understanding induced seismicity
6	Direct heat project in Schlattingen (Canton of Thurgau)	Direct use of geothermal energy for agribusiness
7	GEOBEST	Managing induced seismicity risk: methodology for permitting and regulatory bodies

8. FUTURE DEVELOPMENTS AND INSTALLATIONS

Shallow geothermal energy applications will remain popular in Switzerland. Innovative applications including cooling, heat storage, reservoir management, smart thermal grids (“anergy grids”) etc. will become very important. The exploration and exploitation of hydrothermal deep aquifers (> 400 m depth) could be important for heating purposes. Regarding geothermal power production, future developments will be related to EGS as it has highest potential in Switzerland. Recent R&D, geothermal education and some industry work is already focused on that issue.

9. CONCLUSIONS

The use of geothermal energy for spas and residential heating purposes is still very popular in Switzerland. This sector, and especially ground source heat pumps, has enjoyed annual compound growth rates of about 12% per year for about a decade. Since 2011, the growth rates have slowly consolidated. The market conditions for industry players in the GSHP sector are increasingly challenging. Due to the success of and high demand for this application, many companies had entered the market and are now competing on price. Quality assurance has been maintained at a high level. Several of the Swiss cantons support shallow geothermal energy (< 400 m) by financial contributions for ground source heat pumps. Regarding Research and Development, there is no specific master plan, but funding of specific projects is common. The main interest is in enhancing efficiency and quality, thermal grids and heat storage.

In Switzerland, no electricity has been produced by geothermal energy yet. Geothermal power production plays an important role in the Swiss Energy Strategy 2050. Up to 2050, geothermal power plants should provide 4.4 TWh_{el} per year. The potential of hydrothermal resources for power production is limited in Switzerland, therefore, the mid- to long-term goal is to improve petrothermal systems (or Enhanced or Engineered Geothermal Systems, EGS) to be able to exploit a significant proportion of the resource.

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ACKNOWLEDGEMENTS

We would like to take the opportunity to thank the Swiss Federal Office of Energy (SFOE) and all involved players for their great commitment to support and promote geothermal energy and to improve the related technologies.

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

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total electric power generation	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production ** (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2015 *				62’954*		
Under construction end of 2015						
Total projected by 2018	2.5	15-20				
Total expected by 2020	2.5	15-20				
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2015 (indicate exploration/exploitation, if applicable):					3 (exploration; only one for electricity)	

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Final electric power consumption in Switzerland in 2014: 57'466 GWh_e

<u>Explanation to tables C, D1 and D2:</u> ‘Geothermal district heating or district cooling’ (Geothermal DH plants) is defined as the use of one or more production fields as sources of heat to supply thermal energy through a network to multiple buildings or sites, for the use of space or process heating or cooling, including associated domestic hot water supply. If greenhouses, spas or any other category is among the consumers supplied from such network, it should be counted as district heating and not within the category of the individual consumer. In case heat pumps are applied in any part of such a network, the also should be reported as district heating and not as geothermal heat pumps. An exception is for distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings; systems of this kind should be reported in table E. For table D2, please give information on large systems only (>500 MW_{th}); installations with geothermal source temperatures <25 °C and depth <400 m should be reported in table E.

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 for individual buildings		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)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2015 *	11.1*	26.1*	–	–	1807.2*	2769.1*	29.1*	242.1*
Under constru-ction end 2015	–	–	2-2.5	15-20			–	–
Total projected by 2018	13	30	2-2.5	15-20	2318	4341	29.1	242.1
Total expected by 2020	17	38	2-2.5	15-20	2489	4677	29.1	242.1

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Note: spas and pool are difficult to estimate and are often over-estimated. For calculations of energy use in the pools, be sure to use the inflow and outflow temperature and not the spring or well temperature (unless it is the same as the inflow temperature) for calculating the energy parameters, as some pool need to have the geothermal water cooled before using it in the pools.

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commis-sioned	CHP **	Cooling ***	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
Bassersdorf					0.24		0.47*	
Itingen					0.08		0.18*	
Kloten					0.24		0.58*	
Kreuzlingen					0.06		1.75*	
Riehen					4.5	32.3	11.32*	
Seon					1.35		2.28*	
Oberwald (VS)	Furka railway tunnel				1.37		2.74*	
Airolo (TI)	Gotthard road tunnel			yes	0.72		0.86*	
Kaltbrunn (SG)	Ricken railway tunnel				0.16		0.25*	
Frutigen (BE)	Lötschberg base tunnel, North portal				1.08		3.44*	
Trimbach (SO)	Hauenstein Base railway tunnel				0.37		0.34*	
Bourg St Pierre (VS)	Grand-St-Bernard road tunnel				0.04		0.1*	
Minusio/Tenero (TI)	Mappo Morettina, road tunnel			yes	0.07		0.12*	
Weggis (LU)					0.10		0.54*	
Weissbad (AI)					0.08		0.23*	
Triemli (ZH)					0.6		0.92*	
total					11.06		26.12*	

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** If the geothermal heat used in the DH plant is also used for power production (either in parallel or as a first step with DH using the residual heat in the brine/water), please mark with Y (for yes) or N (for no) in this column.

*** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Table D2: Existing geothermal direct use other than DH, individual sites

Not applicable

<u>Explanation to table E:</u> 'Shallow geothermal' installations are considered as not exceeding a depth of 400 m and (natural) geothermal source temperatures of 25 °C. Installations with geothermal source temperatures >25 °C and depth >400 m should be reported in table D1 or D2, respectively. Distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings are not considered geothermal DH *sensu strictu*, and should be reported in table E also.

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

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2015 *		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015 *	88'215*	1'531.7*	2385.3*	4'075*	97.8*	240.8*
Projected total by 2018	101'240	1'900	3'614			

* If 2014 numbers need to be used, please identify such numbers using an asterisk

Table F: Investment and Employment in geothermal energy

	in 2015 *		Expected in 2018	
	Expenditures ** (million €)	Personnel *** (number)	Expenditures ** (million €)	Personnel *** (number)
Geothermal electric power	–	–	–	–
Geothermal direct uses				
Shallow geothermal	150*		150	
total				

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Expenditures in installation, operation and maintenance, decommissioning

*** Personnel, only direct jobs: Direct jobs – associated with core activities of the geothermal industry – include "jobs created in the manufacturing, delivery, construction, installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration". For instance, in the geothermal sector, employment created to manufacture or operate turbines is measured as direct jobs.

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 (could be provided in some cantons on a voluntary basis, not national)	DIS (in some cantons, not national)
Financial Incentives – Operation/Production	FIT	–	–
Information activities – promotion for the public	Yes (e.g. Swiss Geothermal Society)	Yes (e.g. Swiss Geothermal Society)	Yes (e.g. Swiss Geothermal Society)
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	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)