Geothermal Energy Use, Country Update for Slovak Republic

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ABSTRACT

Geothermal waters in Slovakia were proven by 172 geothermal wells with the depth of 9 m to 3,616 m. After 2013, two new wells were drilled, none of them being put into operation yet. The total amount of 2,487 l/s of geothermal water were documented by realized geothermal wells. A total of 61 locations throughout the country use geothermal water for heating. The individual applications for installed capacity and annual energy use include: 16.6 MW_{th} and 1,321.6 GWh_{th}/yr of individual space heating, 16.2 MW_{th} and 740.1 GWh_{th}/yr for district heating, 27.3 MW_{th} and 1,784.5 GWh_{th}/yr of geothermal heat in agriculture and industry, 87.7 MW_{th} and 5,022.7 GWh_{th}/yr for bathing and swimming, and 78.1 MW_{th} and 2,374.2 GWh_{th}/yr for geothermal heat pumps. The total for the country is then 225.9 MW_{th} and 11,243.1 GWh_{th}/yr. The total amount of geothermal water utilized in the last period was 441 l/s in average per year. This utilization makes only 18 % of approved amounts of geothermal water.

1. INTRODUCTION

One of the priorities of the Energetic policy of the Slovak Republic, adopted already in 2006, is the increase of renewable energy sources (RES) share on electric power and heat production with the goal to create adequate complementary sources necessary to cover domestic demand. The use of RES as domestic energy sources increases, in a certain measure, the safety and partial diversification of the energy supply. At the same time, use of RES decreases the dependency of the economics on instable prices of oil and natural gas. Their use is based on environmentally friendly technologies and comprises to decrease of greenhouse gases and noxious agents.

The Act No. 309/2009 on support of renewable energy sources and highly efficient combined production was adopted by the Slovak government in 2009. The act is being continuously amended. The act optimizes the functioning of the market with the electric power in the area of renewable energy sources and combined production of electric power and heat, and creates the stable economic and administrative environment. The latest goals in RES utilization were set by the 2009/28/EC Directive aiming to get 20 % of the EU energy from renewable sources by 2020.

Geothermal energy is environmentally friendly, local and stable renewable energy resource which is independent on climatic and market conditions.

Up to present day, 27 hydrogeothermal areas or structures have been identified in the territory of Slovakia (Fig. 1). Low enthalpy (temperature in the range 15 °C – 100 °C), medium enthalpy (100 °C – 150 °C) and high enthalpy (higher than 150 °C) geothermal resources occur in territory of the Slovak Republic. The most frequent of these are low enthalpy and the least are high enthalpy geothermal resources. The low temperature geothermal sources are located in all 27 delineated geothermal areas or structures; in 16 of them the medium temperature was detected and only in five out of 27 areas the high-temperature geothermal energy sources are present.

The Slovak Republic is one of the countries in which geothermal water bodies were defined according the Water Framework Directive No. 2000/60/EC of the European Parliament and of the Council. Geothermal water bodies are labelled by number composed of general labels SK 300(0) (Slovakia, third groundwater body horizon), number of the groundwater body itself and label(s) for permeability type of the geothermal aquifer. For example, code SK300240PF means Danube Basin central depression geothermal water body where aquifers are of porous-fissure permeability.

Seven out of 27 prospective areas are the transboundary geothermal water bodies. One, namely Vienna Basin, is shared by Slovakia and Austria. Three other geothermal water bodies: Komarno high block, Komarno Marginal Block and Danube Basin Central Depression are shared by Slovakia and Hungary, the last one partially also by Austria. Skorusina depression and Levoca basin (S and W parts) are shared by Slovakia and Poland, and the last one – Humenne ridge is shared by Slovakia and Ukraine.

The comprehensive list of geothermal wells with geothermal installations up to the year 1994 was given in Geothermal Atlas of the Slovak Republic (Franko, Remsik, Fendek Eds. 1995). Occurrence of geothermal water sources in Slovakia in cartographic form is given in the map Geothermal and mineral water sources in the scale 1:500,000, published in the Landscape Atlas of the Slovak Republic (Fendek et al. 2000). The latest overview of geothermal wells as geothermal water sources in Slovakia was done by Fendek and Fendekova (2015).

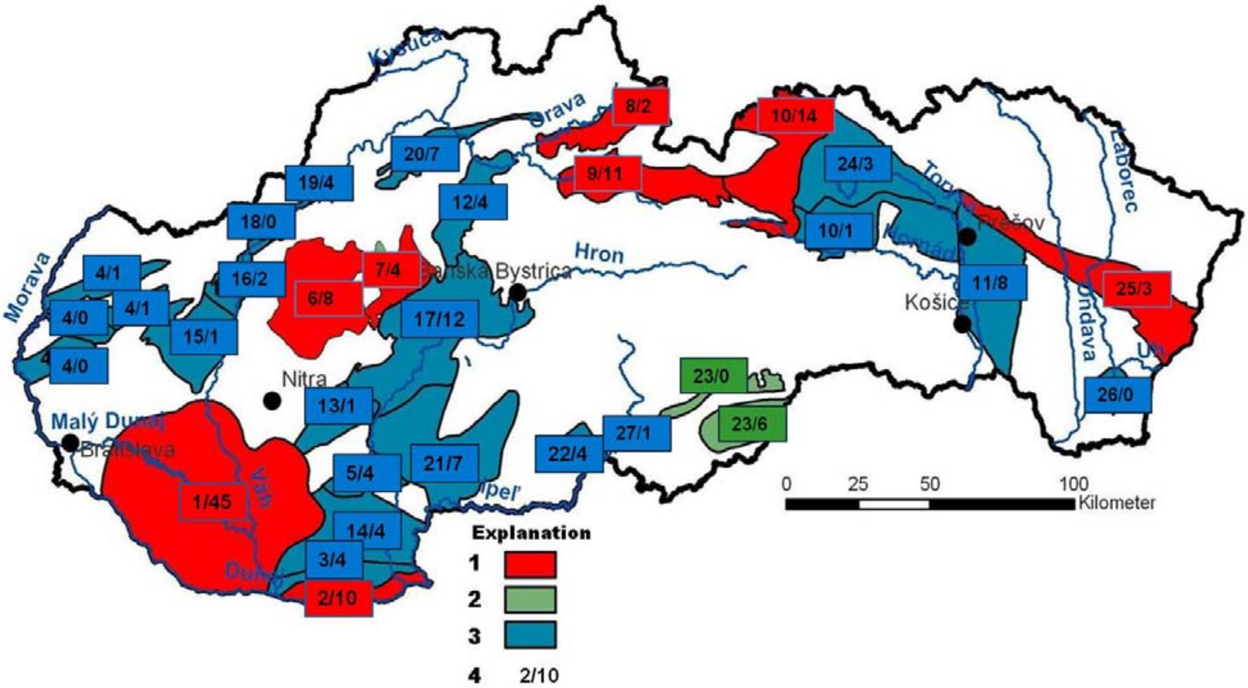

Figure 1: Distribution of potential geothermal areas and structures in the territory of Slovak Republic: Explanation: 1 – prospective areas with geothermal water verified by geothermal wells, 2 – prospective areas geologically assessed for the purpose of prospecting and exploration of geothermal waters, 3 – prospective area with assumed occurrence of geothermal waters (based on general knowledge of geological conditions) 4 – serial number of the prospective area or structure/number of drilled geothermal wells. List of prospective areas: 1-Danube Basin central depression, 2-Komarno high block, 3-Komarno marginal block, 4-Vienna Basin, 5-Levice marginal block, 6-Banovce Basin and Topolcany embayment, 7-Upper Nitra Basin, 8-Skorusina Basin, 9-Liptov Basin, 10-Levoca Basin (W and S parts), 11-Kosice Basin, 12-Turiec Basin, 13-Komjatice depression, 14-Dubnik depression, 15-Trnava embayment, 16-Piestany embayment, 17-Central Slovakian Neogene volcanics (NW part), 18-Trencin Basin, 19-Ilava Basin, 20-Zilina Basin, 21-Central Slovakian Neogene volcanics (SE part), 22-Horne Strhare – Trenc graben, 23-Rimava Basin, 24-Levoca Basin (N part), 25-Humenne ridge, 26-Besa – Cicarovce structure, 27 – Lucenec

2. OVERVIEW OF HYDROGEOTHERMAL CONDITIONS AND GEOTHERMAL RESOURCES IN SLOVAKIA

The majority of the Slovak territory is occupied by the Western Carpathian mountain system, only part of the eastern Slovakia is assigned into the Eastern Carpathians. The Western Carpathians are the Alpine mountain range stretching across the Slovak territory. According to the age of development of the Alpine nappe structure they are classified as the Outer – with Neo-Alpine nappes and the Inner with Paleo-Alpine – Pre-Paleogene nappe structure. The essential feature of the Western Carpathians is their nappe structure.

The geological structure and favorable geothermic conditions create a suitable setting for the occurrence of geothermal energy resources in the Slovak territory. However, the geological setting is favorable for the occurrence of geothermal waters with temperature higher than 20 °C only in the Inner Western Carpathians. Geothermal aquifers are largely associated with Triassic dolomites and limestones of the Krizna, Choc and Silicikum Nappes, less frequently with Neogene sands, sandstones, conglomerates, andesites and related pyroclastics. Geothermal wells are located mostly in the intra-mountainous depressions or in lowlands bordering the Slovak territory in its southern part.

The Inner Western Carpathians can be divided into two parts, which vary widely in their geothermal activity and spatial distribution of the Earth's heat. Relatively low temperatures and densities of surface heat flux are characteristic for the central and northern part (30-40 °C at a depth of 1,000 m; 50-60 mW/m^2). High subsurface temperatures and high heat flux densities are typical for the Neogene sedimentary basins and volcanic mountains (40 – 70 °C at a depth of 1,000 m; 70 – 120 mW/m^2). The highest heat fluxes in the Western Carpathian were estimated for the Eastern Slovakian Neogene Basin – in the central and SE parts the temperatures reach 60 – 70 °C at a depth of 1,000 m and the heat flux varies between 100 – 120 mW/m^2 (Franko et al. 1995).

Geothermal waters were already proven by 172 geothermal wells with the depth of 9 m to 3,616 m. The temperature on the well head ranges from 18 °C to 129 °C, yields reach up to 70 l/s. Water is mostly of Na-HCO_3-Cl, Ca-Mg-HCO_3 and Na-Cl chemical type with the TDS value of 0.4 – 90.0 g/l.

More detailed description of five out of 27 prospective areas follows.

2.1 Danube Basin central depression

The highest number of geothermal wells was drilled in the Danube Basin central depression (prospective area No. 1, Fig. 1). The Danube Basin central depression is enclosed by the Danube River in the southwest between the cities of Bratislava and Komarno, by the Male Karpaty Mts. in the northwest, by the Dobra Voda fault (a branch of the Ludina fault) in the northeast, and approximately by the Nitra River in the southeast. A crystalline complex (schists, granitoids) has been identified in the pre-Tertiary base of its northwestern and southeastern part. The depression is filled with the Quaternary and Ruman gravels and sands, and mixtures of clays or sandy clays and sands to sandstones (Dak, Pont and Panon). The depression developed between the Panon and Pliocene stages and is of a brachysynclinal shape, with the deepest part in the area of Gabcikovo.

The geothermal conditions in the basin were lately studied by Svasta et al. (2014). Thermal groundwater flow was simulated by a finite element model. The aim of the transient coupled flow and heat simulation was to test the proposed well configuration and estimate the operating life of the system by prediction of thermal breakthrough.

Altogether 45 boreholes were drilled in the area with the depths from 306 to 3,303 m. Water temperature reaches from 19 °C to 91 °C and the discharges from 0.1 to 25.0 l/s. The total discharge amounts 488.6 l/s and the thermal power was estimated on 102.39 MW_t.

2.2 Upper Nitra Basin

The Upper Nitra Nitra Basin (prospective area No. 7, Fig. 1) represents the intra-mountainous depression surrounded by core mountains of Strazovske vrchy Mts., Tribec Mts., Ziar Mts. and a volcanic mountains of Vtacnik. The depression is filled with Paleogene, Neogene and Quaternary sediments. Maximum temperature values in the Upper Nitra Basin are reached in the central part of the basin between Novaky and Prievidza towns.

Altogether four boreholes were drilled in the basin; a new borehole is being drilled close to Novaky city these days. The boreholes reached the depth from 150 to 1,851 m and temperatures from 19 °C to 59 °C. The total discharge amounts 57.9 l/s and the thermal power makes 7.05 MW_t.

2.3 Liptov Basin

The Liptov Basin (prospective area No. 9, Fig. 1) represents an intramontaneous depression in the core mountain belt of the Western Carpathians. Geothermal water aquifers in Liptov basin are represented by Triassic dolomites and limestones with the fissure-karst permeability, which were documented by geothermal boreholes at depths of 48 – 2,336 m. Thickness of aquifers varies between 300 – 1,000 m. Results from eleven geothermal boreholes with the depth of 50 – 2,500 m were used for evaluation of geological structure, geothermic and pressure conditions, hydraulic parameters of aquifers, spatial distribution and chemical composition of geothermal waters and their thermal-energy potential. Geothermometry was also applied to estimate the geothermal reservoir temperature.

Eleven boreholes were drilled in the Liptov Basin up to present. Discharges of geothermal boreholes range from 6.0 to 32.0 l/s, amounting totally 251.5 l/s. Geothermal water temperature varies from 26 °C to 66 °C and the thermal power was estimated on 28.85 MW_t.

2.4 Poprad Basin

The Poprad Basin is a part of the Levoca Basin – W and S parts (prospective area No. 9, Fig. 1). It is filled by Paleogene sediments of the podtatranska unit (alternation of sandstones and claystones, with basal conglomerates on the base of the unit). Mesozoic carbonatic rocks of the Choc and Krizna nappe are developed under the Paleogene filling of the basin. The deepest geothermal borehole in the territory of Slovakia was drilled here up to the depth of 3,616 m at Stara Lesna (FGP-1, Fendek, Blanarova 2014). This was the only case where the entire profile of Quaternary sediments, Palaeogene sediments of the podtatranska unit, two nappes (Choc, Krizna) and the envelope unit was drilled through up to the crystalline basement in the Poprad Basin.

Altogether 14 boreholes were drilled in the area with the depths from 9 to 3,616 m. Water temperature reaches from 20 °C to 61.2 °C and the discharges from 0.1 to 25.0 l/s. The total discharge amounts 251.5 l/s and the thermal power was estimated on 34.92 MW_t.

2.5 Kosice Basin

The Kosice Basin (prospective area No. 11, Fig. 1) is the prospective area where the hottest geothermal water with the temperature of 134 °C was drilled in the territory of Slovakia up to present. This area is one of the most prospective areas of Slovakia with possibilities to accumulate geothermal waters with the highest temperature to be used for electricity production by Rankin cycle in the future. The prospective part of Kosice basin with geothermal waters favourable for electric power production occupies 200 km^2. It is the area around the village Durkov.

The area stretches in the west between the cities of Presov and Kosice up to the Slovak-Hungarian border. The western border is created by Slovenske Rudohorie Mts., the eastern border by Slanske vrchy Mts. The basin is filled by Quaternary sediments. Underlying Neogene sediments are of Sarmatian to Karpathian ages. Sarmatian clays have the thickness of about 500 – 1,000 m, Badenian calcareous sandy clays up to 1,300 m and Karpathian calcareous claystones with, conglomerates on base have the thickness of about 400 m. Thickness of Mesozoic rocks which form the underlying layers for Neogene sediments rise eastwards from 300 to 1,000 m. Depths at which Mesozoic dolomites occur in the western part is much shallower than that one in the eastern part of the basin.

Altogether eight boreholes were drilled in the basin. The boreholes reached the depth from 160 to 3,210 m and temperatures from 18 °C to 134 °C. The total discharge amounts 214.9 l/s and the thermal power makes 79.26 MW_t.

3. CURRENT STATE OF GEOTHERMAL WATER UTILIZATION

Currently, there are three geothermal district heating systems under operation in the territory of Slovakia. All of them are located in the Danube Basin central depression. The first one is located in the Galanta city and it is in operation for more than 20 years. Two others – in Sala and Sered cities, were built within the last five years. Experiences obtained over the years of operation prove significant geothermal heat production and natural gas savings while the heat price is lower and more stable than in case of conventional gas boiler plants. Existing geothermal projects in Galanta, Sala and Sered confirm that well designed and implemented projects are economically feasible without any subsidy. As a response of the positive experiences, new geothermal district heating systems in different locations are in preparation phase and two of them are planned to be built soon (Halas 2015).

Besides of the district heating, the geothermal water is also utilized for heating of service buildings in Galanta, Senec, Diakovce, Topolniky, Dunajska Streda, Komarno, Chalmova, Kovacova, Oravice, Rajecke Teplice, Besenova, Liptovsky Trnovec, Poprad and Vysne Ruzbachy, for hotels heating in Besenova, Velky Meder, Podhajska and Sturovo. For sport hall heating it is used in Topolniky, in Novaky-Kos it is utilized for heating of miner's dressing rooms and air heating in brown coal mine.

Geothermal water is utilized for fish farming on Vrbov, Turcianske Teplice and Handlova.

In 38 localities geothermal water is used for recreational purposes, mainly in swimming pools.

There is only one locality in the Slovak territory, where the thermally utilized geothermal water is re-injected into the geothermal reservoir. The first geothermal project of reinjection plant construction in Podhajska (Levice marginal block, prospective area No. 5, Fig. 1), finished in 1994 is under operation for more than 20 years. The reinjection plant is based on use of the reinjection well GRP-1 Podhajska (Fendek et al. 1989).

The individual applications for installed capacity and annual energy use include: 16.6 MW_{th} and 1,321.6 GWh_{th}/yr of individual space heating, 16.2 MW_{th} and 740.1 GWh_{th}/yr for district heating, 27.3 MW_{th} and 1,784.5 GWh_{th}/yr of geothermal heat in agriculture and industry, 87.7 MW_{th} and 5,022.7 GWh_{th}/yr for bathing and swimming, and 78.1 MW_{th} and 2,374.2 GWh_{th}/yr for geothermal heat pumps. The share of individual applications for annual energy use is in Fig. 2. The total for the country is then 225.9 MW_{th} and 11,243.1 GWh_{th}/yr.

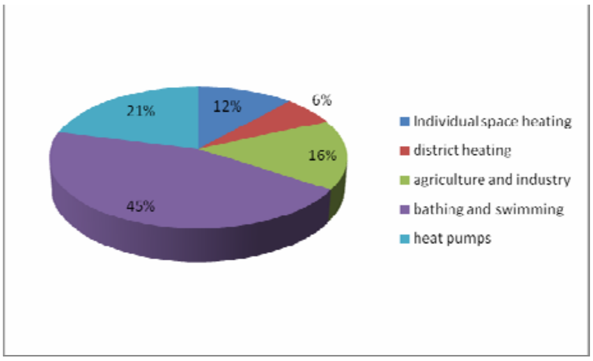

Figure 2: Share of individual application for annual energy use

The total amount of geothermal water utilized in the last period was 441 l/s in average per year. This utilization makes only 18 % of approved amounts of geothermal water.

The market for domestic heat pumps in Slovakia is quite limited primarily due to the existence of a dense gas network. The technology is however slowly reaching a level of recognition and acceptance amongst the general public. Heat pumps present an interesting alternative in the new build sector, but are less attractive in the retrofit segment where gas network already exists. As with many other markets, the general economic downturn adversely affected the rate of new construction in the building sector in recent times, and so the Slovak heat pump market stagnated in 2011. It did however grow from this position in the years 2012 – 2014.

Currently, sales are not stimulated by any form of subsidy scheme. New incentive scheme for small energy sources, where heat pumps are included, is in preparation. The current challenge for the Slovak heat pump market is to overcome the barriers set by the economic situation and a general resistance to any changes in heating systems. Economically profitable investment to HPs are for multi-dwelling buildings after disconnecting to central heat supply, what is in lot of cases forbidden by local authorities according to

EE regulation. Other applications are in supermarkets, cogeneration units or in aqua parks.

4. USE OF GEOTHERMOMETRY IN GEOTHERMAL WATER RESEARCH

Geothermic conditions of geothermal aquifers can be either characterized by temperature of geothermal water measured in existing deep wells or estimated using geothermometers based on the chemical composition of geothermal water. Use of geothermometers is one of the methods for estimation of geothermal water formation and circulation depth.

Both, silica geothermometers and conventional cation geothermometers were used in the study to estimate the reservoir conditions in the Liptov Basin and Poprad Basin.

The best agreement between measured and theoretical values for most of the boreholes was obtained using the Arnorsson et al. (1983) equation for chalcedony (steam loss):

$$T\ (°C) = [1264 / (5.31 - \log cSiO_2)] - 273.15 \qquad [1]$$

In a few cases the best agreement between measured and theoretical values was obtained using the equation for K-Mg geothermometer (Giggenbach 1988):

$$T\ (°C) = [4410 / (14.0 + \log (K/\sqrt{Mg})] - 273.15 \qquad [2]$$

Silica geothermometers give better results in the Poprad basin where results of five wells with suitable data were processed. The best results were obtained by chalcedony geothermometer of Arnorsson et al (1983), with the difference between the real values and the estimated ones in the range of -6.5 to 4.9 °C (Fendek, Blanarova 2014). Geothermometers based on cations did not give satisfactorily results, because of oversaturation of geothermal waters by main minerals present in the rock environment.

Application and interpretation of silica geothermometry provides tool to study reciprocal SiO_2-K-Mg relations in terms of formation temperature assessment and definition of unrevealed processes. Fricovsky et al. (2015) studied the Besenova structure (Liptov Basin) in more details. While at the Bešeňová elevation, the chalcedony controls aqueous SiO_2 content, concentration of K^+ and Mg^{2+} refers to water-rock equilibrium with dolomite, illite, chlorite, chalcedony or adularia. Thermal waters associated with the structure are immature in essence, consequent to various filtration velocities and several mixing contacts. Use of chalcedony geothermometry provided reliable results for deep reservoir only, (Krizna nappe Triassic carbonates) inferring (T_{med}=75 °C). Basal temperature determined from silica-enthalpy model reaches T = 84 °C, affine to thermal models. K-Mg geothermometer calculated according to equation [2] works well for shallow aquifers (Choc nappe Triassic carbonates) at Lucky area.

5. CONCLUSIONS

The Slovak Republic is one of the countries in which geothermal water bodies were defined according the Water Framework Directive No. 2000/60/EC of the European Parliament and of the Council. Seven out of 27 prospective areas are the transboundary geothermal water bodies.

The geological structure and favorable geothermic conditions create a suitable setting for the occurrence of geothermal energy resources in the Slovak territory. The most frequent resources are of low enthalpy and the least are those of the high. Geothermal waters were already proven by 172 geothermal wells with the depth of 9 m to 3,616 m. The temperature on the well head ranges from 18 °C to 129 °C, yields reach up to 70 l/s. Water is mostly of Na-HCO_3-Cl, Ca-Mg-HCO_3 and Na-Cl chemical type with the TDS value of 0.4 – 90.0 g/l.

Silica geothermometers and conventional cation geothermometers were used to estimate the reservoir temperature conditions in the Liptov Basin and Poprad Basin. The best agreement between measured and theoretical values for most of the boreholes in the Poprad Basin was obtained using the equation for chalcedony (steam loss). Geothermometers based on cations did not give satisfactorily results, because of oversaturation of geothermal waters by main minerals present in the rock environment. At Besenova (Liptov Basin) use of chalcedony geothermometry provided reliable results for deep reservoir only.

The individual applications for installed capacity and annual energy use include: 16.6 MW_{th} and 1,321.6 GWh_{th}/yr of individual space heating, 16.2 MW_{th} and 740.1 GWh_{th}/yr for district heating, 27.3 MW_{th} and 1,784.5 GWh_{th}/yr of geothermal heat in agriculture and industry, 87.7 MW_{th} and 5,022.7 GWh_{th}/yr for bathing and swimming, and 78.1 MW_{th} and 2,374.2 GWh_{th}/yr for geothermal heat pumps. The total for the country is then 225.9 MW_{th} and 11,243.1 GWh_{th}/yr.

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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 *	-	-	8,074	25,669		
Under construction end of 2015		-	547	4,009		
Total projected by 2018	-	-	10,014	31,206		
Total expected by 2020	4	30	12,089	38,431	0.03	0.08
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):						

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 *	16.2	740.1	27.3	1,784.5	16.6	1,321.6	87.7	5,022.7
Under constru-ction end 2015	-	-	-	-	-	-	-	-
Total projected by 2018	18.4	722.5	30.7	2,006.7	19.3	1,506.6	98.6	5,647.2
Total expected by 2020	75.9	972.5	36.4	2,379.3	24.8	1,757.7	125.3	7,176.1

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 * (GW_{th}/y)	Geoth. share in total prod. (%)
Galanta	Galantaterm Ltd.	1996	N	N	10.9	13.1	390.5	94.5
Sala	MeT Sala Ltd.	2011	N	N	3.4	20.7	260.7	27.6
Sered	Energetika Sered Ltd.	2012	N	N	1.9	8.7	81.9	37.7
total					16.2	42.5	740.1	

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

Locality	Plant Name	Year commis-sioned	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
Senec		1971	No	1.05		89.15	
Piestany		2002	No	6.45		400.01	
Diakovce		1962	No	2.11		150.37	
Galanta		1975	No	1.54		39.88	
Cilizska Radvan		1986	No	1.26		59.36	
Velky Meder (Calovo)		1972	No	2.22		201.33	
Velky Meder (Calovo)		1983	No	2.36		103.04	
Topolniky		1975	No	5.39		494.59	
Dunajska Streda		1971	No	3.18		60.96	
Dunajska Streda		1985	No	3.56		133.75	
Cilistov		1979	No	2.26		59.83	
Belusske Slatiny		1978	No	0.18		12.63	
Trencianske Teplice		1984	No	0.66		18.52	
Banovce n. Bebravou		1984	No	1.35		71.45	
Chalmova		1992	No	0.84		54.13	
Chalmova		1983	No	0.40		7.13	
Kos		1980	No	1.93		98.32	
Partizanske		2000	No	0.39		22.79	
Male Bielice		1974	No	0.64		38.46	
Velke Bielice		1983	No	0.69		4.75	
Topolcany		1985	No	0.18		8.36	
Zeliezovce		1972	No	0.17		9.54	
Santovka		1982	No	0.58		59.66	
Kalinciakovo		1986	No	0.90		52.99	
Vlcany		1982	No	1.26		45.58	
Diakovce		1972	No	0.33		9.59	
Diakovce		1983	No	0.25		4.96	
Obid		1979	No	0.15		4.56	

Table D2 continued

Locality	Plant Name	Year commis-sioned	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
Sturovo		1975	No	5.27		114.45	
Podhajska		1973	No	10.20		764.49	
Tvrdosovce		1978	No	2.68		75.97	
Surany		1989	No	0.21		3.32	
Patince		1982	No	3.90		28.08	
Virt		1973	No	0.33		27.35	
Virt		1976	No	0.69		55.56	
Zlatna na Ostrove		1990	No	0.94		7.12	
Oravice		1991	No	8.16		364.68	
Rajecke Teplice		1974	No	0.56		40.60	
Stranavy		1990	No	0.55		9.97	
Liptovsky Jan		1963	No	1.76		81.77	
Liptovsky Trnovec		1992	No	4.15		422.42	
Besenova		2006	No	1.47		100.81	
Besenova		1987	No	4.07		451.29	
Lucky		1962	No	0.81		76.85	
Turcianske Teplice		1966	No	1.87		102.57	
Turcianske Teplice		1988	No	1.14		74.08	
Tornala		1985	No	0.56		13.96	
Vyhne		1967	No	0.29		9.37	
Sklene Teplice		1981	No	2.41		222.23	
Kremnica		1967	No	2.33		129.92	
Kovacova		1983	No	3.14		170.94	
Sliac		1996	No	0.83		42.74	
Sielnica		2004	No	0.23		12.82	
Dudince		1997	No	0.82		43.21	
Vinica		1990	No	0.25		13.11	
Dolna Strehova		1956	No	0.29		16.55	

Table D2 continued

Locality	Plant Name	Year commis-sioned	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
Vysne Ruzbachy		1958	No	0.92		9.19	
Poprad		1994	No	6.66		432.17	
Vrbov		1982	No	3.13		355.02	
Vrbov		1989	No	5.06		473.85	
Nesvady		2008	No	0.54		22.79	
Velky Slavkov		2007	No	0.68		2.36	
Nove Zamky		1983	No	0.07		3.68	
Kosice (Tahanovce)		1982	No	0.23		12.01	
Sobrance		1975	No	0.23		23.27	
total				**119.71**		**7,126.24**	

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 *	3,012	78.1	2,374.2			
Projected total by 2018	3,765	112.9	3,433.7			

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	3.2	165		
Shallow geothermal	3.1	170		
total	**3.6**	**335**		

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	no	O – grants by R&D grant agency	O – grants by R&D grant agency
Financial Incentives – Investment	no	yes	REQ
Financial Incentives – Operation/Production	no	yes	REQ
Information activities – promotion for the public	yes	yes	yes
Information activities – geological information	yes	yes	yes
Education/Training – Academic	no	yes	yes
Education/Training – Vocational	no	yes	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)