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Country Update of the Slovak Republic

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ABSTRACT

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 essential feature of the Western Carpathians is their nappe structure composed of rock complexes ranging in age from the Precambrian to Tertiary. They are divided into several zones. Geothermal aquifers can be found only in the Inner Western Carpathians due to favorable geological conditions. 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. Up to today, 27 hydrogeothermal areas or structures have been identified in the Slovakian territory. Geothermal waters were proven by 171 geothermal wells with the depth of 9 m to 3,616 m. Three new wells were drilled and put into operation since the last World Geothermal Congress (2010). The temperature on the well head ranges from 18 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. The total amount of 2,453 l/s of geothermal water were documented by realized geothermal wells. 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. Geothermal waters are widely used for recreational purposes, mostly in very popular aquaparks in many places of Slovakia. Space heating, greenhouses and fish farming belong to other ways of geothermal energy utilization.

1. INTRODUCTION

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC set the national overall targets for the share of energy from renewable sources in gross final consumption of energy in 2020. The share of renewable energy resource on energy production in Slovakia should increase from 6.7% in 2005 up to 14.0% in 2020. In order to be able to achieve the national objectives set out in the Annex of the Directive, it is underlined that the State aid guidelines for environmental protection recognize the continued need for national mechanisms of support for the promotion of energy from renewable sources. Slovakia is obliged to ensure 14% of the share of RES on the gross final energy consumption in 2020. There is also a duty for each member state, given by the Directive, to adopt a national action plan for energy from renewable sources (NAP RES), which was adopted by the Slovak government in October 2010. According to the national action plan, 24% of the electric power should be produced from renewable energy sources, among them from geothermal sources, in 2020. The increase of renewable energy sources share on electric power and heat production with the goal to create adequate complementary sources necessary to cover domestic demand is one of the priorities of the Energetic policy of the Slovak Republic, adopted already in 2006. The use of RES as domestic energy sources increases in a certain measure the safety and partial diversification of the energy supply, and, at the same time it decreases the dependency of economics on instable prices of oil and natural gas. Their use is based on developed and 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.

Geothermal energy in Slovakia belongs to the most important renewable energy sources in Slovakia among biomass, solar, wind and water energy.

Geological setting of the Slovak Republic is favourable for occurrence of geothermal energy resources. Twenty-seven geothermal areas or structures, covering 16,750 km^2 which is 34% of the Slovak territory, have been identified as prospective areas for occurrence of potentially exploitable geothermal resources.

2. HYDROGEOTHERMAL CONDITIONS OF THE SLOVAK REPUBLIC

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 essential feature of the Western Carpathians is their nappe structure (Biely Ed., 1996). The geological structure is complicated; the rock environment consists of different types of aquifers, aquicludes and aquitards in very variable mutual position. Rock complexes range in age from the Precambrian to Tertiary, being arrayed into zones. Geothermal aquifers can be found only in the Inner Western Carpathians due to favorable geological conditions. Geothermal waters are largely bounded to Triassic dolomites and limestones of the Krizna and Choc nappes, less frequently to Neogene sands, sandstones, conglomerates, andesites and related pyroclastics (Figure 1).

The typical setting of geothermal structures in Mesozoic complexes, occurring mostly in the intramountainous depressions is as follows. The substratum consists of the Mesozoic Choc and Krizna Nappes, which often form elevated and sunken morphostructures due to tectonic disruption. Choc Nappe is a higher tectonic unit then the Krizna Nappe. The lowest tectonic unit is the Tatricum Envelope Unit with the same rock composition as Krizna Nappe. The vertical, tectonically derived superposition of Mesozoic successions gave arise to aquifer-aquitard stratification. Krizna Nappe is referred as a bottom, while Choc Nappe along with the Sub-Tatric Group of Palaeogene flysch sequence, or Neogene, mostly clayey sediments, and is referred as a top system. Bottom system includes base aquiclude represented by Early Triassic horizon typical in quartzites, sandstones and sandy shales (Werfenian shales) intercalated by anhydrite layers, beneath bottom aquifer of Middle Triassic carbonates - limestones and dolomites complex. Atop, a bottom aquitard corresponds to Late Triassic – Middle Jurassic organogene and detritic limestones, Carpathian Keuper´s shales and sandstones with anhydrite, overlapping to Middle Jurassic – Early Cretaceous pelitic limestones (clayey, marly) that alternate spatially with radiolarites, nodular limestones, claystones and marlstones. Top hydrogeological system involves base aquiclude represented by Early Triassic horizon typical in quartzites, sandstones and sandy shales (Werfenian shales) beneath top aquifer of Middle Triassic carbonates - limestones and dolomites complex of the Choc Nappe. Sometimes, the base aquiclude is missing. Triassic carbonates can be hydraulically connected to Sub-Tatric Group represented by Middle – Late Eocene Borove basal formation composed of breccias and conglomerates that pass to detritic carbonates and rare organogene limestones; beneath top aquifuge recognized as Late Eocene – Oligocene Huty (claystones dominated), Zuberec (flysch dominated) or Biely Potok (sandstones dominated) formations (Franko et al., 1995). Hydrogeological function of Neogene sequences and Quaternary cover varies regarding to the grainage. The maximal thickness of the Choc Nappe sequences in the intramountainous depressions is up to 1,200 m. Krizna Nappe sequence reaches the maximal thickness of 2,300 m.

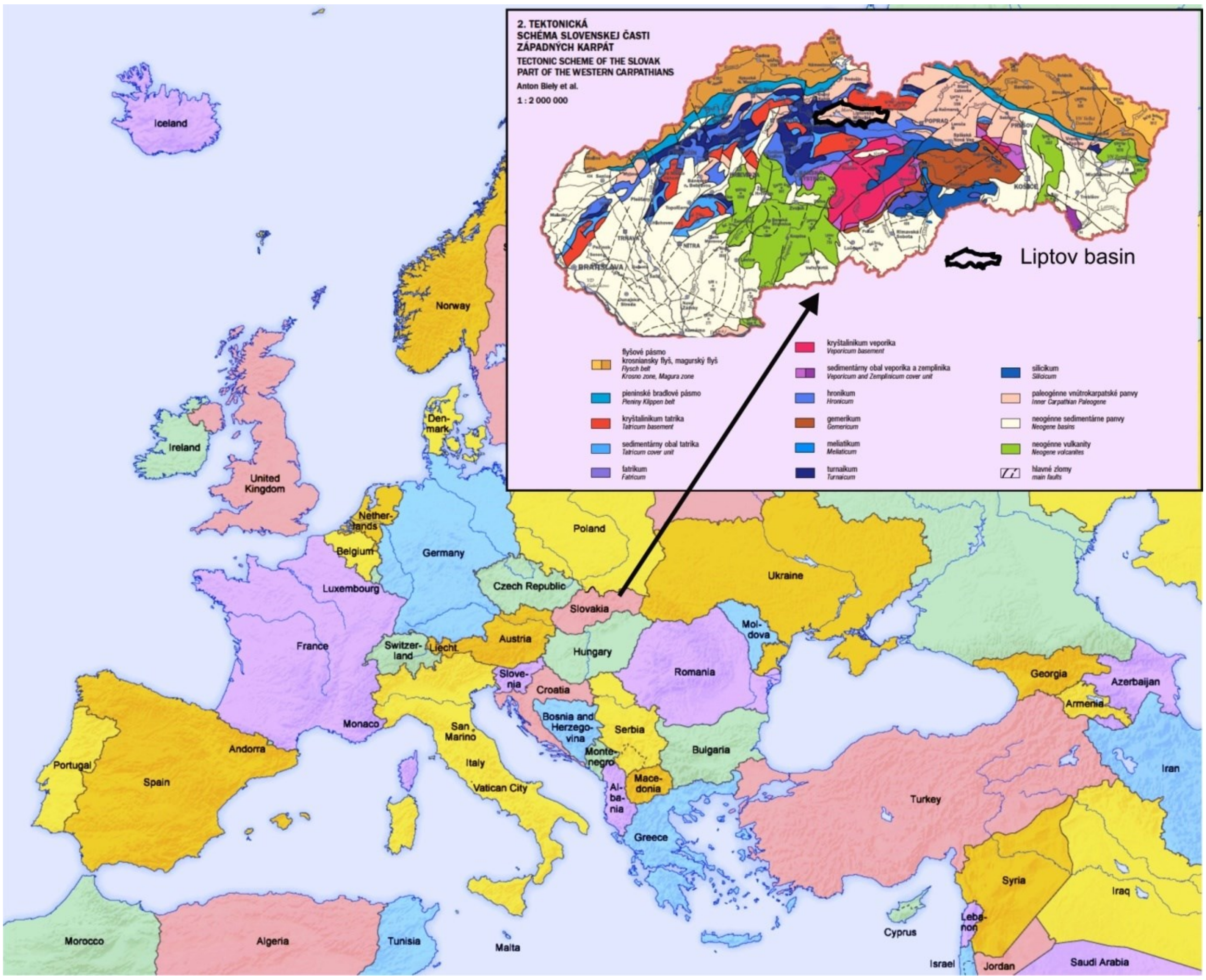

Figure 1: Location of the Slovak Republic and tectonic conditions of the Slovak part of the Western Carpathians

The typical setting of geothermal structure in Neogene complexes, occurring in the marginal lowlands in the southern part of Slovakia, consists of multiple aquifers and aquitards alteration. The aquifers consist mostly in layers of sands, the aquitards in clays, silts and marls. Up to eight different aquifers and aquitards were proven in the Central Depression of the Danube Basin. The overlying Quaternary sediments can create the hydraulically interconnected system with the Neogene aquifers, forming the huge thickness of sedimentary filling of the basin, reaching in the central part of the Central Depression of the Danube Basin (Gabcikovo area) up to 8,000 m, from which the thickness of Quaternary sediments reaches up to 500 m (Fendek et al, 2011).

Generally, the temperature on the well head ranges from 18 to 129°C in hydrogeothermal structures of Slovakia, 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. The effect of hydrogeochemical zoning is typical for Neogene hydrogeological structures where the chemical type of water changes from Ca-Mg-HCO_3 throughout Na-Ca-HCO_3-Cl and Na-HCO_3-Cl up to Na-Cl chemical type at the highest depths. The TDS increases in the same direction from less than 1 g/l up to 90 g/l at Marcelova (Central Depression of the Danube Basin). The geothermal water is enriched by dissolved gases, mostly by CO_2, CH_4 and H_2S.

3. PRESENT STATE-OF-ART IN GEOTHERMAL LEGISLATION IN THE SLOVAK REPUBLIC

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. The example of geothermal water bodies labelling is in Table 1, where the GWB means geothermal water body, SK is the Slovak Republic, No. 3 is the third groundwater body horizon (below the Quaternary and Pre-Quaternary water bodies), and M/N means Mesozoic/Neogene aquifer.

Table 1: Example of geothermal water bodies labelling

Labelling of the geothermal water body	Name of the geothermal water body
GWB SK 3-1/M	Geothermal waters of the Komarno high block structure
GWB SK 3-17/M	Geothermal waters of the Kosice Basin structure
GWB SK 3-25/N	Geothermal waters of the Dubnik depression structure

There are several amendments of acts regulating the research and use of geothermal energy sources. The Act No. 569/2007 Z.z. on geological works (Act on geology) as amended the Act No. 311/2013 Z.z, adopted on 1 November 2013, apply a provision on licensing of geothermal water withdrawals in category B. The withdrawals category must be approved by the Ministry of Environment and requires estimation of usable geothermal water amounts based on long-term hydrodynamic testing of the well, estimation of hydraulic properties of the rock environment, chemical composition of water and its physical properties. The way of source protection, quantitative and qualitative properties monitoring must also be proposed.

There were 82 localities approved by the Ministry of Environment for utilization of geothermal water in 2013. The total usable geothermal water amount approved was 1,287.1 l/s. Not all geothermal facilities are under the operation. As the example, there are 44 wells in the Central Depression of the Danube Basin, from which utilization of 27 wells has a valid approval by the ministry, but only 20 wells are used. Other examples are prospective areas as Komarno marginal block, Vienna Basin, Ilava Basin and Horne Strhare-Trenc graben where none of the wells are utilized at present.

Another important act regulating the use of geothermal waters is the Act No. 364/2004 Z.z. as amended by Acts No. 384/2009 Z.z., 134/2010 and 306/2012 Z.z. which defines the duty of reporting the amounts of withdrawals once a year and to pay for geothermal water withdrawals. Payments for withdrawals could be the reason for certain misinformation of reported withdrawal amounts. The state organization registering the data on withdrawals is the Slovak Hydrometeorological Institute as the governmental department of the Ministry of Environment.

In accordance with this Act, only 56 localities are under operation with the total withdrawals of 431.3 l/s, as it was reported to the Slovak Hydrometeorological Institute in the year 2013.

4. PRESENT STATE-OF-ART OF GEOTHERMAL SOURCES IN SLOVAKIA

The amended list of geothermal prospective areas/structures in Slovakia Republic, with the basic data on number of wells, well depths, discharged, geothermal water temperatures, thermal potentials and amounts of total dissolved solids is in Table 2.

Table 2: Basic characteristics of geothermal water in prospective areas/structures in Slovakia

Prospective area, structure	No.	Well depth (m)	Discharge (l/s)		Temperature (°C)	Thermal power	TDS (g/l)
	of wells	min. – max.	min. – max.	total	min. – max.	(MW_t)	min. – max.
Central depression of the Danube Basin	44	306 – 3,303	0 .1 – 25.0	480.6	19 – 91	100.72	0.5 – 20.1
Komarno high block	10	160 – 1,021	5.5 – 70.0	268.7	20 – 40	18.86	0.7 – 0.8
Komarno marginal block	4	1,060 – 1,763	3.3 – 6.0	18.8	42 – 56	2.95	3.1 – 90.0
Vienna Basin	2	2,100 – 2,605	12.0 – 5.0	37.0	73 – 78	9.50	6.8 – 10.9
Levice block	4	1,470 – 1,900	28.0 – 53.0	181.0	69 – 80	47.94	17.6 – 19.6
Banovce Basin and Topolcany embayment	8	102 – 2,106	1.7 – 18.8	71.8	20 – 55	5.32	0.6 – 5.9
Upper Nitra Basin	5	150 – 1,851	2.5 – 22.0	57.9	19 – 59	7.05	0.4 – 1.9
Skorusina Basin	2	600 – 1,601	35.0 – 65.0	100.0	28 – 56	12.24	0.8 – 1.3
Liptov Basin	11	50 – 2,500	6.0 – 32.0	251.5	26 – 66	28.85	0.5 – 4.7

Prospective area, structure	No. of wells	Well depth (m) min. – max.	Discharge (l/s) min. – max.	total	Temperature (°C) min. – max.	Thermal power (MW_t)	TDS (g/l) min. – max.
Levoca Basin (W and S parts)	14	9 – 3,616	0.0 – 61.2	251.5	20 – 62	34.92	0.6 – 4.0
Kosice Basin	8	160 – 3,210	3.0 – 65.0	214.9	18 – 134	79.26	0.7 – 31.0
Turiec Basin	4	97 – 2,461	0.0 – 12.4	27.4	41 – 54	3.79	1.4 – 2.5
Komjatice depression	1	2,572	8	8.0	51	1.21	56.8
Dubnik depression	4	350 – 1,927	1.5 – 15.0	36.0	18 – 75	3.70	1.6 – 30.0
Trnava embayment	1	118	14.5	14.5	24	0.55	2.52
Piestany embayment	2	30 – 1,200	2.0 – 10.0	12.0	19– 69	0.87	1.3 – 1.4
Central Slovakian Neogene volcanic (NW part)	12	92 – 2,500	0.0 – 30.0	115.2	27 – 57	13.95	0.4 – 5.0
Ilava Basin	4	100 – 1,761	0.0 – 10.0	18.1	22 – 40	1.43	1.7 – 2.6
Zilina Basin	7	105 – 2,258	0.0 – 22.0	66.4	24 – 42	3.63	0.4 – 0.8
Central Slovakian Neogene volcanic (SE part)	7	40 – 85	2.1 – 25.0	72.5	24 – 42	4.30	1.0 – 5.9
Horne Strhare – Trenc graben	4	320 – 625	1.5 – 10.5	16.0	21 – 38	1.04	0.4 – 3.1
Rimava Basin	6	158 – 1,100	0.0 – 45.0	61.4	18 – 33	1.76	1.7 – 31.5
Levoca Basin (NE part)	3	3,500	4.0 – 5.0	13.5	51 – 65	2.29	8.7 – 12.3
Humenne ridge	3	250 – 823	0.7 – 4.0	6.9	23 – 33	0.44	4.4 – 11.9
Besa-Cicarovce structure	0	-	-	-	-	-	-
Lucenec Basin	1	1,501	11.2	11.2	37	1.04	12.1
Total	171	9 – 3,616	0.0 – 70.0	2,435.4	18 – 129	387.60	0.4 – 90.0

Total number of existing geothermal wells reached 171 with the depth ranging from 9 to 3,616 m, discharge reaching up to 70 l/s, geothermal water temperature at the well head between 18 and 129°C and TDS values of 0.4 – 90 g/l.

At present, research of geothermal conditions includes also application of geothermometers in several prospective areas of geothermal water occurrence.

New results were reached by hydrogeothermal investigation in the Central Depression of the Danube Basin, in the Upper Nitra Basin, Liptov Basin and the Central Slovakian Neogene volcanic (NW part), where six new geothermal wells were drilled since the last reporting. There are three new geothermal wells in the Central Depression of the Danube Basin: SEG-1 in Sered, GTS-1 in Sala and GN-1 in Nesvady; one new geothermal well in the Upper Nitra Basin: RH-1 in Handlova, one well in the Liptov Basin: FGTB-1 in Besenova and one new well in the Central Slovakian Neogene volcanic (NW part): HGV-3 in Vyhne. Geothermal water in Sered and Sala are used for district heating, waters in Besenova and Vyhne for bathing, in Nesvady for greenhouse heating. The geothermal water in Handlova is not used yet; the project for bathing utilization is being prepared. Selected parameters of new geothermal wells are in Table 3.

Currently, there are three geothermal district heating systems in the territory of Slovakia. All of them are located in the Central Depression of the Danube Basin. The first one is located in the Galanta city and it is in operation for more than 18 years. Two others – in Sala and Sered cities, were built within the last five years.

In 1996, the first geothermal heating plant, with capacity of 8 MW_t, in the Galanta town was put on line. Galantaterm Ltd. – a legal entity has been formed to supply the 1,236 flats of the "Sever" residential area - together with its public service sector and the hospital of Galanta - with heat and hot service water. Geothermal power is used to provide the heat and hot service water. A natural-gas boiler house is used to heat the water when average daily temperature drops below -2°C (Takacs and Grell, 2005).

In the year 2011, almost 15 years after Galanta, operation of geothermal district heating system in the town of Sala was commenced. New geothermal well GTS-1 was drilled to the depth of 1,800 m, pipelines were laid and a heat exchanger station was built. Geothermal energy is being utilized in large boiler plant CK31, where four natural gas boilers of 20.7 MW total thermal outputs are installed. The installed capacity is strongly overdesigned in relation to recent heat and significantly lower heat outputs are needed even in extremely cold period. Designed temperature gradient of heating loop is 100/50°C but most of the year lower return heating water temperature is being achieved. The distribution network supplies by heat 82 pressure independent heat exchanger stations situated in apartment and public service buildings. Geothermal well GTS-1 is located approximately 200 m west of the boiler plant. Geothermal water is transported via pre-insulated pipeline to heat exchanger station placed in the boiler plant site. Two stages of direct geothermal water utilization via plate heat exchanger are implemented: in the first stage return heating water is being warmed up; in the second stage water of heat pump evaporator loop is being warmed up while the heat pump warms up the return heating water. Geothermal energy combined with heat pump presents base load heat source, while natural gas boilers are used as a peak load source or back up source. Geothermal energy covers in average 27.6% of the overall heat production. Installed heat pump covers in average 6.0% and the natural gas boilers are still the most important heat source with contribution of 66.4% in average (Halas, 2014).

Table 3: Parameters of new geothermal wells

Location and labeling	Year	Discharge (l/s)	Temperature at the well head (°C)	Thermal power (MW_t)	T.D.S. (g/l)
Sered SEG-1	2011	9.0	66.0	1.94	5.10
Sala GTS-1	2010	15.0	69.0	3.39	4.90
Nesvady GN-1	2008	2.7	60.0	0.50	2.90
Handlova RH-1	2010	15.0	37.5	1.41	1.06
Besenova FGTB-1	2011	32.0	66.0	6.83	3.00
Vyhne HGV-3	2009	5.5	29.0	0.32	0.90

In the town of Sered, the advantage of geothermal energy is taken since 2012 (Halas, 2014). New geothermal well SEG-1 was drilled to the depth of 1,800 m. Geothermal heat exchanger station was built in medium size boiler plant K5, where four natural gas boilers of 8.7 MW total thermal output are originally installed. The installed capacity is similarly as in Sala overdesigned and substantially lower heat outputs are needed throughout whole year. Designed temperature gradient of heating water is 65/45°C. The distribution network supplies by heat 20 pressure dependent heat exchanger stations situated in apartment and public service buildings with more than 960 apartments. Geothermal well SEG-1 is located approximately 300 m south of the boiler plant. Geothermal water is transported via pre-insulated pipeline to the heat exchanger station placed in boiler plant site. Two stages of direct geothermal water utilization are implemented: in the first stage return heating water is being warmed up; in the second stage water of heat pump evaporator loop is being warmed up while the heat pump warms up the return heating water. In addition, natural gas fired cogeneration unit producing heat for the network and electricity mainly for own consumption is installed. Altogether four types of heat sources are installed. Geothermal energy and heat pump present base load heat source, while the natural gas boilers are used as a peak load source or back up source. Contribution of geothermal energy to the overall annual heat production in K5 boiler plant is in average 37.7%, the heat pump covers 26.6% and the cogeneration unit 11.0%. Rest of the annual heat production (27.0%) is supplied by the original gas boilers (Miklos, 2014).

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

5. CONCLUSIONS

The legislation has changed lately in Slovakia. One of the important duties for geothermal energy users is to ask for approval of usable geothermal water amounts prior to request for withdrawals permission. The special commission for classification of natural amounts of groundwater, including geothermal water, is working at the Ministry of Environment.

There is a duty to pay for the withdrawn geothermal water. This duty has the influence on registered geothermal water amounts. This is the reason, why the registration does not reflect the real utilized amounts of geothermal water.

Since the last reporting, six new geothermal boreholes were drilled in Slovakia; five of them are already utilized for district heating, greenhouses heating and for bathing purposes. New projects are being prepared for district heating of Presov, Michalovce and Velky Meder cities.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014			1,398	5,36	2,584	5,207	1,95	15,72	510	1,63	6,442	27,917
Under construction in December 2014					77	229	470	3,78	122	364	669	4,373
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	4	30	1,89	7,25	2,728	5,68	2,85	22,9	930	2,57	8,402	38,43

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

	Type	Maximum utilization			Capacity (MWt)	Annual utilization		
		Flow Rate (l/s)	Temperature (°C) T inlet	Temperature (°C) T outlet		Ave flow (l/s)	Energy (TJ/yr)	Capacity factor
Senec	B/H	12.0	49	28	1.05	8.9	24.763	0.745
Piestany	B	39.5	69	30	6.45	21.6	111.113	0.547
Diakovce	G/H	12.0	68	26	2.11	7.5	41.770	0.628
Galanta	D/B	25.0	77	28	5.13	9.2	59.719	0.369
Galanta	D/B	25.0	80	25	5.75	6.7	48.750	0.269
Galanta	B	10.8	62	28	1.54	2.5	11.077	0.229
Cilizska Radvan	G	6.0	82	32	1.26	2.5	16.488	0.417
Velky Meder (Calovo)	B/H	10.0	79	26	2.22	8.0	55.926	0.800
Velky Meder (Calovo)	B/H	18.2	57	26	2.36	7.0	28.622	0.384
Topolniky	G/H/B	23.0	74	18	5.39	18.6	137.387	0.808
Dunajska Streda	B	23.0	55	22	3.18	3.9	16.932	0.169
Dunajska Streda	G/H	15.2	91	35	3.56	5.0	37.154	0.331
Cilistov	B	15.0	52	16	2.26	3.5	16.619	0.233
Belusske Slatiny	B	6.0	22	15	0.18	3.8	3.509	0.633
Trencianske Teplice	B	12.1	40	27	0.66	3.0	5.144	0.248
Banovce n. Bebravou	B	17.0	40	21	1.35	7.9	19.848	0.466
Chalmova	B	13.4	33	18	0.84	7.6	15.037	0.567
Chalmova	H	5.0	39	20	0.40	0.8	1.980	0.158
Kos	H	22.0	59	38	1.93	9.9	27.311	0.448
Partizanske	B	18.8	20	15	0.39	9.6	6.331	0.510
Male Bielice	B	8.5	40	22	0.64	4.5	10.684	0.529
Velke Bielice	G	8.3	39	19	0.69	0.5	1.319	0.060
Topolcany	B	2.0	55	33	0.18	0.8	2.321	0.400
Zeliezovce	G	13.5	18	15	0.17	6.7	2.651	0.496
Santovka	B	15.5	27	18	0.58	14.0	16.572	0.900
Kalinciakovo	B	36.0	25	19	0.90	18.6	14.720	0.516

Vlcany	G/H	10.0	68	38	1.26	3.2	12.662	0.320
Diakovce	B	4.0	38	18	0.33	1.0	2.664	0.252
Diakovce	B	15.0	19	15	0.25	2.6	1.377	0.174
Obid	B	5.8	21	15	0.15	1.6	1.266	0.276
Sturovo	B/H	70.0	40	22	5.27	13.4	31.791	0.191
Podhajska	B/H/G	53.0	80	34	10.20	35.0	212.359	0.660
Tvrdosovce	G	20.0	70	38	2.68	5.0	21.104	0.250
Surany	B	3.5	49	35	0.21	0.5	0.923	0.143
Patince	B	103.5	26	17	3.90	6.6	7.799	0.063
Virt	B	10.0	26	18	0.33	7.2	7.597	0.720
Virt	B	18.3	24	15	0.69	13.0	15.432	0.710
Zlatna na Ostrove	G	7.5	51	21	0.94	0.5	1.979	0.067
Oravice	B/H	65.0	56	26	8.16	25.6	101.299	0.394
Rajecke Teplice	B/H	9.0	37	22	0.56	5.7	11.277	0.633
Stranavy	B	22.0	24	18	0.55	3.5	2.770	0.159
Liptovsky Jan	B	30.0	29	15	1.76	12.3	22.713	0.410
Liptovsky Trnovec	B/H	31.0	60	28	4.15	27.8	117.338	0.896
Besenova	B	32.0	26	15	1.47	19.3	28.002	0.603
Besenova	H/B	27.0	62	26	4.07	26.4	125.358	0.977
Lucky	B	13.9	32	18	0.81	11.6	21.347	0.831
Turcianske Teplice	F/H	12.4	54	18	1.87	6.0	28.490	0.484
Turcianske Teplice	B	10.5	44	18	1.14	6.0	20.576	0.571
Tornala	B	45.0	18	15	0.56	9.8	3.878	0.218
Vyhne	B	5.0	36	22	0.29	1.4	2.604	0.282
Sklene Teplice	B	16.0	57	21	2.41	13.0	61.729	0.812
Kremnica	B	23.2	47	23	2.33	11.4	36.088	0.491
Kovacova	B/H	25.0	48	18	3.14	12.0	47.484	0.480
Sliac	B	11.0	33	15	0.83	5.0	11.871	0.454
Sielnica	B	3.0	33	15	0.23	1.5	3.561	0.500
Dudince	B	15.0	28	15	0.82	7.0	12.003	0.467
Vinica	B	10.0	21	15	0.25	4.6	3.640	0.460
Dolna Strehova	B	5.0	29	15	0.29	2.5	4.598	0.498
Vysne Ruzbachy	B/H	20.0	23	12	0.92	1.8	2.554	0.088
Poprad	B/H	48.2	48	15	6.66	27.6	120.047	0.572
Vrbov	F/B	22.0	56	22	3.13	22.0	98.616	0.999
Vrbov	F/B	27.5	59	15	5.06	22.7	131.626	0.824
Nesvady	G	2.7	60	12	0.54	1.0	6.331	0.370
Sala	D	15.0	69	15	3.39	10.4	74.360	0.696
Sered	D	9.0	66	15	1.92	3.4	22.737	0.375
Veľky Slavkov	B	27.0	21	15	0.68	0.8	0.657	0.031
Nove Zamky	B	2.7	21	15	0.07	1.3	1.021	0.478
Kosice (Tahanovce)	B	4.9	26	15	0.23	2.3	3.337	0.469
Sobrance	B	4.0	29	15	0.23	3.5	6.463	0.875
TOTAL		**1,327.4**			**135.89**	**591.4**	**2,185.1**	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

Locality	Ground or water temp. (°C)	Typical Heat Pump Rating or capacity (kW)	Number of Unites	Type	COP	Equivalent Full Load Hr/Year	Thermal Energy Used (TJ/yr)
Podhajska	40	20	1	W	3.8	3,360	0.153
Bojnice	38	40	1	W	4.2	4,350	0.273
V.Ruzbachy	19	778	2	W	3.7	8,250	6.845
Gbelany	9	23	1	W	4.0	4,550	0.115
Raj. Teplice	34	489	3	W	4.5	7,600	4.725
Piestany	45	43	2	W	5.4	5,600	0.208
Senec	40	106.8	2	W	5.5	7,900	0.729
Cilistov	38	43	2	W	5.6	4,750	0.176
Rabca	19	81.2	2	W	5.9	3,800	0.266
TOTAL		1,624	16			50,160	13.490

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

	Installed Capacity [MW_t]	Annual Energy Use (TJ/yr)	Capacity Factor
Individual Space Heating	16.6	367.1	0.562
District Heating	16.2	198.1	0.693
Air Conditioning (Cooling)			
Greenhouse Heating	15.4	224.7	0.414
Fish Farming	11.9	271.0	0.722
Animal Farming			
Agricultural drying			
Industrial Process Heat			
Snow Melting			
Bathing and Swimming	87.7	1,395.2	0.542
Other Uuses [specify]			
Subtotal	147.8	2.456.1	0.510
Geothermal Heat Pumps	1.6	13.5	0.267
Total	149.4	2,469.6	0.507

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINET USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014.

Purpose	Wellhead temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration	(all)	-	2	-	-	2,150
Production	>150 °C	-	-	-	-	-
	150-100 °C	-	-	-	-	-
	< 100 °C	-	4	-	-	6,900
Injection	(all)	-	-	-	-	-
Total		-	6	-	-	9,050

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (restricted to personnel with University degrees

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	2	4	5	-	-	22
2011	2	5	6	-	-	28
2012	2	5	5	-	-	25
2013	2	6	7	-	-	32
2014	2	7	8	-	-	41
Total	10	27	31	-	-	148

(1) Government (4) Paid Foreign Consultants
(2) Public Utilities (5) Contributed Through Foreign Aid Programs
(3) Universities (6) Private Industry

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (1999) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1995 – 1999	6.25	0.75	3.00	-	95	5
2000 – 2004	3.72	1.32	3.60	-	82	18
2005 – 2009	4.27	14.4	48.59	-	95	5
2010 – 2014	3.96	11.61	5.73	-	93	7