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Local and Regional Economy in Theory and Practice ISSN 1899-3192

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UTILIZATION OF GEOTHERMAL ENERGY AS A RENEWABLE SOURCE

Summary: The paper analyses a renewable energy source – geothermal energy – from a world-wide and Slovak perspective. The world-wide view is focused on the installed capacity of electric and thermal energy production by continents and the comparison of the installed capacity of the thermal energy production of selected countries in the world. The world-wide view is applied also in the overview of the various categories of the direct use of geothermal energy. Two overviews of the results of the geothermal wells drilled in Slovakia by areas and by counties show the big potential for utilizing geothermal energy as an alternative source to fossil fuel consumption. Nowadays the task of research should be focused on the efficiency of the renewable energy sources exploitation and the diversification of the energy sources utilization.

Keywords: geothermal water, geothermal energy, thermo-energetic potential, geothermal source of energy, installed capacity, geothermal wells, yield.

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1. Introduction

A high concentration of geothermal energy in the crust of the Earth is found in areas of recent volcanism (Iceland, Italy, Japan, the Philippines, New Zealand, Indonesia, Chile, etc.) and young orogenous zones. In these areas the temperature at a depth of 100 to 1000m reaches more than 250℃. For example in Japan the measured reservoir temperatures in high heat regions range from 190 ℃ on Kyushu Island (localities Otake, Siginoi) to 350 ℃ in the Kakkonda region on Tahoku island. The value of the total amount of geothermal sources calculated from the volume of geothermal water with a temperature of more than 200 ℃, occuring up to a depth of 3 km, shows 24 600 MWe [Kawazoe, Shirakura 2005]. For these areas the accepted term is ‚geothermal field', which has an analogy in oil geology (crude oil or oil fields), just as the term ‚deposit of geothermal water' expresses the anomalous high value of temperatures latent to a relatively small geological area compared with the neighbourhood.

From the aspect of utilizing geothermal water, there is an important depth of ceiling and base of geothermal water reservoir underground, the nature of rocks,

their genesis, age, the chemical composition of substances dissolved in geothermal water, the content of gas, the hydraulic and thermo-physical characteristics of hydrogeological geothermal water collectors. From the economic point of view, we can define a reservoir with a minimal depth, which is the lowest temperature economically usable by the prospective user and with the maximum depth, which is the maximum accepted price of a geothermal well as a source of geothermal water.

The key problem of the research study is based on the need to pay more attention to renewable energy sources (RES). The purpose of the article is to approach a worldwide, regional, and national review of RES production by continents, countries, and the Slovak counties. The European context of the article is given by the Directive of the European Parliament and Council 2009/28/EC dated 23rd April, 2009 about the support of the utilization of Renewable Energy Sources. This is a strategic document which targets the period up to the year 2020. It creates a basis for the ongoing sustainable development of the utilization of RES even further. The EU member states have become obliged to develop their own legal acts complying with the above mentioned regulation and the consequent directives.

The article is a fundamental document of the research on the social-economic impact of renewable energy sources production and utilization. The research is carried out by project VEGA No.1/0787/11, supported by the Slovak Ministry of Education, entitled "Prospects of participation of the small and medium-sized enterprises in the diversification of energy infrastructure".

2. Geothermal energy in the world

From the global point of view, geothermal energy is at the forefront of renewable sources of energy. In the year 2000 its share in the generation of electricity and production of heat showed more than 50% of all RES [Rybach 2010]. In 2008, wind and solar energy, because of their exponential progress, overtook geothermal energy [Renewables…, 2009]. But one must realize that geothermal energy can be used permanently, whereas the production of electric energy from solar and wind energy is limited by weather conditions.

Geothermally fueled electric power is being generated in 21countries of the world [Huttrer 2000]. Installed capacity while generating electric energy from a geothermal source was 7974 MW_e in 2000 and 10 716 MW_e in 2010 (Table 1).

During the analysed ten years, the growth of electric energy production from these sources was 25.6%, whereas the shares of individual continents for the given period of years remained more or less the same. For example, the share of America in the production of electric energy from geo-thermal sources in 2000 was 42.6% and the same 42.6% was reached also in 2010. The largest producers of electric power in 2010 were – in America the USA (3093 MW_e), in Asia – the Philippines (1904 MW_e) and in Europe – Italy (843 MW_e).

Table 1. Installed capacity of electric energy production and heat in the world in 2000 and 2010

	Production of electric energy		Production of heat	
	2000/2010		2000/2010	
	MW(e)	%	MW(t)	%
Africa	54/174	0.7/1.6	121/130	0.7/0.3
America	3390/4561	42.5/42.6	5954/14293	34.7/28.3
Asia	3095/3661	38.8/34.2	5151/11555	30.0/22.8
Europe	998/1635	12.5/15.2	5630/24178	32.8/47.8
Oceania	437/685	5.5/6.4	318/427	1.8/0.8
TOTAL	7974/10716	100/100	17174/50583	100/100

Sources: [Huttrer 2000; Bertani 2010; Lund, Freeston 2000; Lund et al. 2010].

Power which is generated by geothermal steam is produced only in some European countries such as Iceland, Italy, Russia, Turkey, France (Guadeloupe), and Portugal (Azores). In 2010 the European production of geothermal power reached 15.2% of world production, which was an increase of 2.7% compared with the year 2000 [Huttrer 2000; Bertani 2010; Lund, Freeston 2000; Lund et al. 2010].

It is supposed that the generated electric power from geothermal sources can cover 8.3% of world electric energy consumption, thereby it meets the needs of 17% of the world population. In 31 countries of the world, mainly in Africa, Middle America, and Oceania, it is possible to cover the production of electric power up to 100% from geothermal sources [Dauncey, Mazza 2001].

In 2010 the geothermal energy was produced in 78 countries of the world. The installed thermal capacity for selected countries utilizing geothermal sources for heat production is displayed in Table 2. In 2000, the total installed capacity was 17 174 MW_t and in 2010 it reached already 50 583 MW_t, which means an increase in heat production from geothermal sources of 66% during the past 10 years. The biggest share in this growth was the utilization of heat pumps for space heating, which was not included in the statistics for the year 2000. We can illustrate this with the example of Germany and Sweden. When in 2000 the installed capacity for heat production in Germany was 397 MW_t, in 2010 it was already 2485 MW_t, whereas the share of heat pumps was 2230 MW_t, which was almost 90%. Similarly as in the case of Sweden, where there was in 2000 the installed capacity for heat production of 377 MW_t, while in 2010 it was already 4460 MW_t, whereas the share of heat pumps was 4230 MW_t, i.e. almost 95% of total production.

According to data presented at the World Geothermal Congress in 2000 [Lund, Freeston 2000], geothermal energy was utilized for heat production in 28 European countries. Geothermal sources in Europe are characterised, above all, by low temperature sources which are latent mainly on sedimentary formations. In 2000 the total installed capacity in Europe was 5630 MW_t, which represented 35% of the world production. The largest share from the European direct utilization of geothermal energy occurred in Iceland and Turkey (Table 2). Among the first 22

countries of the world from the aspect of installed capacity is the Slovak Republic with an installed heat capacity of 164 MW_t.

Table 2. Installed capacity for heat production in selected countries of the world in 2000 and 2010 in MWt

	Country	2000	2010
1.	USA	5 366	12 611
2.	China	2 814	8 898
3.	Iceland	1 469	1 826
4.	Japan	1 159	2 099
5.	Turkey	820	2 084
6.	Switzerland	547	1 061
7.	Germany	397	2 485
8.	Hungary	391	655
9.	Canada	378	1 126
10.	Sweden	377	4 460
11.	France	326	1 345
12.	Italy	326	867
13.	New Zealand	308	393
14.	Russia	307	308
15.	Austria	255	663
16.	Georgia	250	24
17.	Mexico	164	156
18.	Jordan	153	153
19.	Romania	152	153
20.	Slovak Republic	132	164
21.	Croatia	113	67
22.	Bulgaria	107	98

Source: [Fendek et al. 2011].

A development review of geothermal energy utilization in individual economic categories within the period of 1995 to 2010 is presented in Table 3.

Table 3. Categories of utilization of geothermal energy world-wide in the period1995 to 2010 (Capacity MWt)

	1995	2000	2005	2010
Heat pumps	1 854	5 275	15 384	35 236
Space heating	2 579	3 263	4 366	5 391
Greenhouses	1 085	1 246	1 404	1 544
Pond heating	1 097	605	616	653
Agricultural drying	67	74	157	127
Industrial uses	544	474	484	533
Bathing and swimming	1 085	3 957	5 401	6 689
Cooling and snow melting	115	114	371	368
Others	238	137	86	41
TOTAL	8 664	15 145	28 269	50 583

Source: [Fendek, Bágelová, Fendeková 2011].

3. Geothermal energy of Slovakia

The Country update report of the Slovak Republic presented at the 2010 World Geothermal Congress in Bali, Indonesia, approaches the situation of geothermal energy utilization, especially the direct use diversification, by counties and categories.

Geothermal direct-use is distributed in eight counties in the country with Nitra County (southwest of the centre of the country) having the highest number of locations (19), and Trnava County (western Slovakia) having the highest amount of thermal energy used. The smallest number of facilities is in Kosice County (eastern Slovakia) with five locations, however this area has the highest potential for geothermal use in the country, including the generation of electricity. Greenhouse heating is found in 11 locations, two of which receive heat at the end of a cascaded system. Vegetables and cut flowers are the main products grown in these greenhouses. These are 19 installations using geothermal energy for individual space heating and two locations for district heating. The main district heating system is for heating blocks of flats and a hospital in Galanta. There are 59 locations using geothermal water for swimming pools, both outside and inside. The combine utilization (cascaded use) of the energy is for greenhouse heating, district heating and, finally, for bathing – in Topolniky and Podhajska. Two locations use geothermal energy for fish farming. There are also 9 locations using geothermal heat pumps with a total of 16 units installed. The various direct-uses include: 16.7 MW_t and 381.1 TJ/yr for individual space heating; 10.8 MW_t and 232.0 TJ/yr for district heating; 17.6 MW_t and 461.1 TJ/yr for greenhouse heating; 11.9 MW_t and 271.0 TJ/yr for fish farming; 73.6 MW_t and 1708 TJ/yr for bathing and swimming; and 1.6 MW_t and 13.5 TJ/yr for geothermal heat pumps. The total for the country is 132.2 MW_t and 3067.2 TJ/yr [Fendek, Fendeková 2010].

Table 4. Geothermal water utilization in the Slovak Republic – diversification by counties

County	Number of exploited localities	Proven water yield		Installed heat capacity		
		Overall	Exploitable	Overall	Exploitable	Exploitable
		$l.s^{-1}$	$l.s^{-1}$	(MW_t)	(MW_t)	(%)
Bratislava	1	30.8	12.0	4.12	1.71	1.04
Trnava	13	369.2	199.7	83.01	45.84	27.98
Nitra	19	617.5	382.1	89.65	39.65	24.20
Trenčin	10	140.8	111.1	12.48	10.89	6.65
Zilina	14	388.3	268.4	39.91	32.12	19.6
BanskaBystrica	13	211.9	151.8	18.84	13.33	8.13
Prešov	7	267.8	172.3	36.09	19.08	11.64
Kosice	5	241.6	44.9	80.82	1.24	0.76
TOTAL	82	2 267.9	1 342.3	364.92	163.86	100

Source: [Fendek et al. 2011].

Table 4 shows that the highest installed exploitable heat capacity, 45,84 MW_t, is located in Trnava county. The most significant is Galanta with heating of a housing estate and hospital. This represents 27,98% of the total Trnava county exploitable heat capacity [Takács, Grell 2005].

According to available documentation, the first borehole, FGG-1, was drilled at Galanta in 1975 as a part of a survey on thermal water existence. At a depth of 1990 m water was found with a temperature of 62 ℃ and yield of 3.2 l/s. Therefore in 1983 and 1984 two more survey boreholes, FGG-2 and FGG-3, were drilled to prove geothermal water parametres. At depths of 2100 and 2102 m respectively, the temperature of the water was 80 ℃, and 77 ℃. The heat capacity of the wells is 6.8 and 6.29 MW_t.

In 1990, the political changes enabled the financial support of the North Environmental Finance Corporation Helsinky and Orkuveita Rejkjaviktur (Iceland) with the know-how to design and implement the successful project for the exploitation of geothermal energy. In 1996, the newly established local limited company Galantaterm Ltd., was a guarantee for sustainability of the project results.

As mentioned above, the smallest number of facilities is in Kosice County with five locations. However this area has the highest potential for geothermal use in the whole country. The parameters of the potential exploitation of geothermal water at Durkov (temperature 125 ℃, yield 65 l/s, and a total heat capacity of three wells of more than 70 MW_t) includes the prospect of heating 11 000 households in the nearby Kosice city (12 km) and furthermore, with an installed capacity 3.5 MW_e to generate 23 GWh/yr of electric energy. In doing so the Slovak Republic would become the 22nd country in the world utilizing geothermal energy for power generation.

4. Conclusion

In 2000 the total heat capacity was 17 174 MW_t and in 2010 it was 50 583 MW_t. During ten years the growth of heat production from geothermal sources was 66%. The largest share in this growth belongs to the utilization of heat pumps. This period of time showed the growth of power generation from a geothermal source of 25.6 %, whereas the share of individual continents during these years remained almost the same. What is important is that the Slovak Republic is among top 22 countries of the world with an installed capacity of 164 MW_t. According to Fendek, the new revaluated total heat-energetic potential of geothermal waters of Slovakia is 6653 MW_t. Of that, 5.48% was provided by geothermal boreholes and only 2.46% exploited by installed equipment. This means 44.9% of the proved potential. Still, 55.1% is available to use [Fendek et al. 2011].

The data presented in this article are mostly of a geological orientation, but they are a significant basis for the further social-economic research on the geothermal energy utilization and its possible inclusion in the diversification plans of the energy infrastructure of the Slovak Republic. Insufficient use of the proven heat-energetic potential creates business opportunities for SMEs' development, as well as the growth of municipal commitment of the affected regions. Utilization of geothermal heat in the Kosice basin also for power generation is a unique case, which will be closely examined in further research.

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UTYLIZACJA ENERGII GEOTERMALNEJ JAKO ŹRÓDŁA ODNAWIALNEGO

Streszczenie: Celem artykułu jest analiza odnawialnego źródła energii – energii geotermalnej – z punktu widzenia sytuacji na świecie i na Słowacji. Podejście globalne skupia się na mocach zainstalowanych wytwarzania energii elektrycznej i termalnej w odniesieniu do poszczególnych kontynentów oraz na porównaniu mocy zainstalowanych wytwarzanej energii termalnej z podziałem na wybrane kraje świata. Perspektywa globalna została również zastosowana do przeglądu różnych kategorii bezpośredniego wykorzystania energii geotermalnej. Dwie analizy wyników uzyskanych w przypadku odwiertów studni geotermalnych na Słowacji, z podziałem na obszary i kraje, wskazują na duży potencjał tkwiący w możliwościach wykorzystania energii geotermalnej jako alternatywnego źródła zużycia paliw kopalnych. Obecnie cel prowadzonych badań powinien skupiać się na efektywności wykorzystania odnawialnych źródeł energii oraz dywersyfikacji wykorzystania istniejących źródeł energii.

Słowa kluczowe: woda geotermalna, energia geotermalna, potencjał termalno-energetyczny, geotermalne źródło energii, moce zainstalowane, studnie geotermalne, wydajność.