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Geothermal Update for Bulgaria (2010-2014)

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ABSTRACT

Thermal waters in Bulgaria have only direct use applications as about 72% of the total discovered flow rate has a temperature up to 50°C. Geothermal activity is mainly concentrated in the southern part of the country due to the higher water temperature combined with low water salinity (TDS), mostly below 1g/l. The current installed capacity amounts to about 83.1 MWt, excluding the low grade energy use by ground source heat pumps (GSHP). Towards 2014 the greatest thermal water quantity is used for balneology – 60.5% and direct water supply – 27.3 %. The total share of water used for individual space heating and greenhouses is low and amounts to about to 3.6%. GSHP are installed in family houses, blocks of flats, office and industrial buildings in different regions in the country. An innovative pilot system using CO_2 earth heat pipe ($GECO_2$) has been recently installed aiming at providing heating to an industrial building located in southern Bulgaria. In order to promote geothermal development about 70 state-owned reservoirs are currently granted to the local Municipalities for a period of 25 years by the Ministry of Environment and Water, 2014. A reduction of the fees for thermal water use about 3-4 times is expected to boost geothermal application in the country.

1. INTRODUCTION

According to the latest published data by the National Statistical Institute (2014), coal and nuclear energy maintain their leading role, respectively with 49.55% and 35.51 % shares of the total produced primary energy (Fig.1).

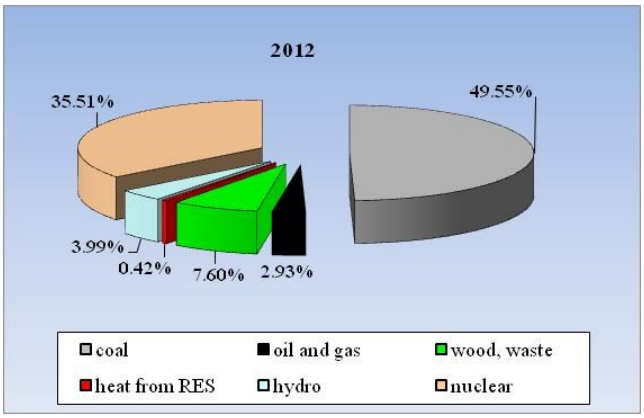

Figure 1: Share of primary energy sources in the energy balance (National Statistical Institute)

The Renewable Energy Sources (RES) share in the gross produced energy amounts to 12.3% towards 2012 including hydro power plants with installed capacity above 10 MW and 2.9% excluding them, Public Energy Council, Ministry of Energy and Economy, 2012.

A trend of a small increase of the gross produced primary energy is observed after 2009 (Fig.2). The period 2010-2012 is marked by growing coal production by 12% to 20% as well as by rapid rise of installed capacity for electricity generation from wind and photovoltaic.

The construction of new renewable installations drastically deceased in 2013 when only 6.1 MW were additionally installed (Fig.3). Among the small renewables (excl. hydro power plants >10 MW) wind and solar electricity generation have the largest share, respectively 29.3% and 21.6% (Public Energy Council, Ministry of Energy and Economy, 2013)(Fig.4).

Biomass (wood and wood waste) is mostly used for heat production. Geothermal waters have only direct use application as their temperature is less than 100°C.

Feed-in tariffs are applicable only to solar, photovoltaic, biomass and small hydro (less than 10MW installed capacity). Two factors, retroactive measures taken by the Government regarding already signed contracts, and the 20% tax imposed on the produced RES energy will significantly slow down the future development of this sector.

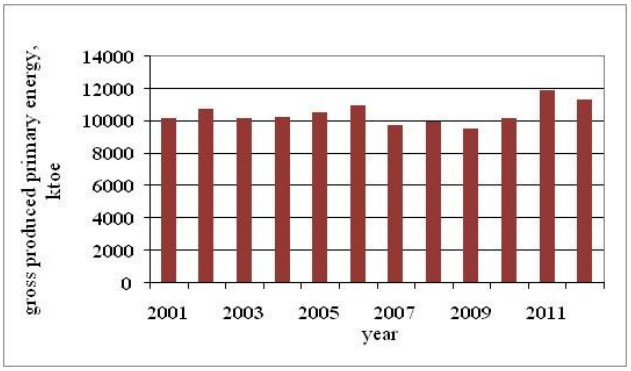

Figure 2: Gross primary energy within the period 2001 – 2012, National Statistical Institute

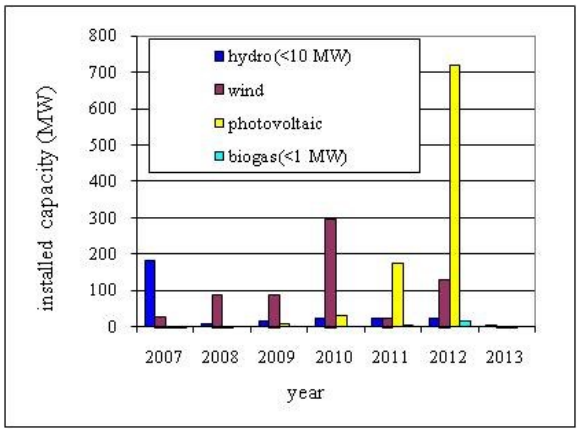

Figure 3: New RES installed capacity within the period 2007-2013, Public Energy Council

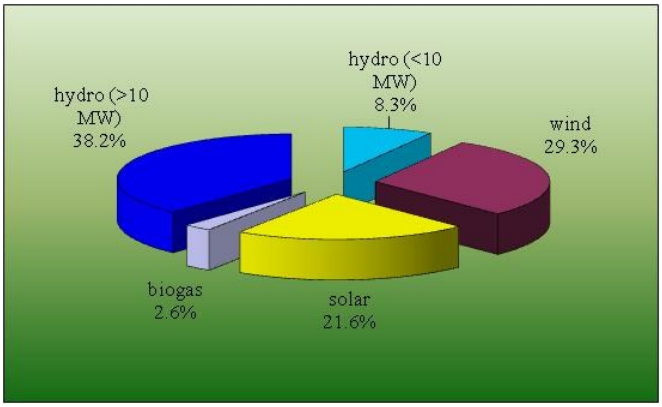

Figure 4: Electricity generation by RES towards 2013 (Public Energy Council)

The government setting and leading agencies involved in geothermal development discussed in Bojadgieva et al. (2005) haven't changed during the reported period 2009-2014. In the last two years some promoting steps have been taken like alleviating administrative regulation, reducing fees for thermal water use and normative requirement for cascade systems of exploitation. According to the latest amendments of the Water Act in 2010 many state-owned reservoirs are made available for use by the Municipalities.

2. GEOLOGY AND HYDROGEOLOGY BACKGROUND

Bulgarian territory is characterized by a complex and diverse geological structure. It is built of rocks of different origin, various lithologic and petrologic compositions and of Quaternary to Archean and Proterozoic age (Y.Yovchev, 1971).

Bulgaria is divided into three major hydrogeological units – Low Danubian basin, Intermediate region and Rila-Rhodopes region (Fig.5). The Low Danubian Artezian basin encompasses Moesian plate, Balkan Foreland tectonic zone and northern part of Balkan tectonic zone. Intermediate region covers southern part of Balkan zone and Sredna gora tectonic zone. Rila-Rhodopes region

comprises Rila-Rhodopes massif. Three types of reservoirs are found in the country - stratified, fractured and mixed (water from a fractured reservoir is secondarily accumulated in a younger sediment reservoir).

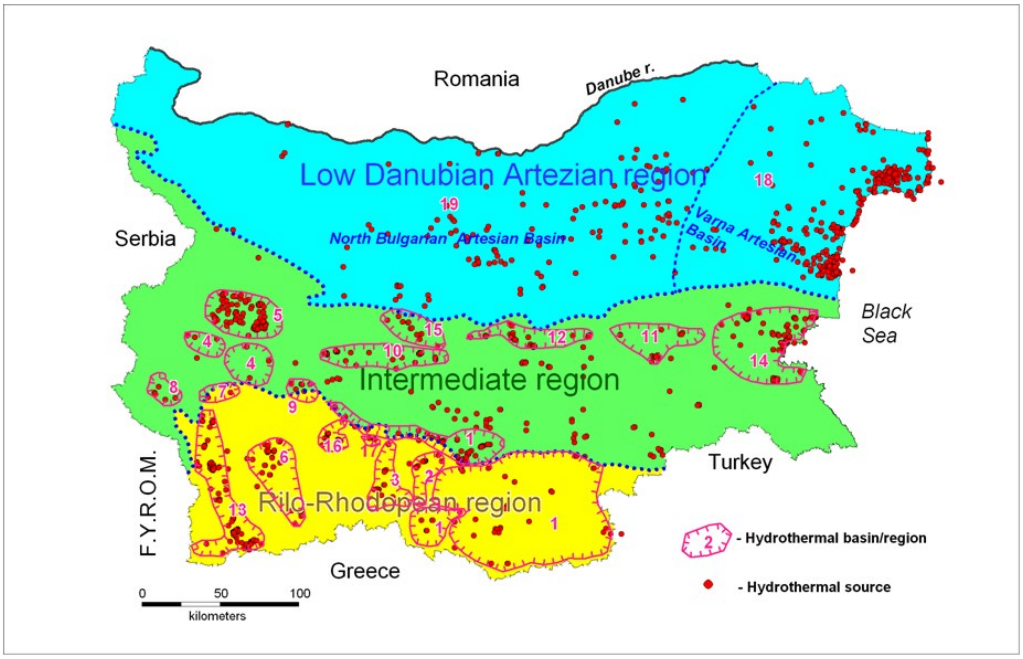

Figure 5: Hydrothermal regions in Bulgaria. ***Legend: Basins with mostly utilized thermal water – Sandanski (13), Razlog (6), Chepino (16), South Sredna Gora (11), North –East-Bulgarian basin (Varna Artesian Basin) – (18)***

The Moesian plate has a Caledonian-Hercynian basement and a cover of Upper Paleozoic and Mesozoic sediments. The main geothermal reservoirs in the platform area are situated in the carbonate strata of Malm-Valanginian, Middle Triassic and Upper Devonian age.

The Sredna gora zone is a heterogeneous hydrothermal region where unstratifed (fault-fractured), stratified and mixed hydrothermal systems are present. Hydrothermal circulation takes place in the fractured massif of granite and metamorphic rocks and in the Upper Cretaceous volcano - sedimentary deposits. Thermal reservoirs are formed also in many postorogenic Neogene – Quaternary grabens filled up with terrigenious deposits.

Only the western part of Rila-Rhodopes massif is rich in thermal water. It is built of Precambrian metamorphic and granite rocks, fractured by a dense set of seismically active faults. Unstratified hydrothermal systems with thermal waters of low salinity, meteoric origin and of highest temperature up to 100^{o}C are found in this area. The metamorphic basin contains some large bodies of marble that act as hydrothermal reservoirs. Permeable terrigenous-clastic rocks in the deep Neogene and Paleogene grabens also contain thermal waters.

3. RESOURCE CHARACTERISTICS

According to the Water Act (1999), 102 geothermal fields from all over the country are specified as exclusive state property. The most perspective of them are located in North-East Bulgaria (Moesian plate) and in South Bulgaria (Rila-Rhodopes massif)(Bojadgieva et al., 2010). The mostly utilized thermal waters are in five hydrothermal basins, defined by Petrov et al. (1998): North-East Bulgarian basin and those in South Bulgaria - Chepino, Sandanski, South Sredna Gora and Razlog (Fig. 5). They account for 47% of the total thermal water flow rate in use in Bulgaria.

Thermal water temperature varies within the interval 20-100^{o}C and the majority of the reservoirs have a flow rate between 1 and 20 l/s (Bojadgieva et al., 2005). Some 72% of the total discovered flow rate has temperature up to 50^{o}C (Petrov et al., 1998). Higher temperatures of about 150^{o}C are expected for the deeper seated sedimentary reservoirs of Devonian and Triassic age in the Moesian plate (North Bulgaria) and for Sapareva banja and Velingrad geothermal fields (South Bulgaria) (Hristov et al., 2000).

Established chemical water content (TDS) varies respectively, in: - Southern Bulgaria from 0.1g/l up to 1.0 g/l (only for a few sites it is between 1 g/l and 15 g/l) and in Northern Bulgaria - from 0.1 g/l up to (100 g/l – 150 g/l). About 70% of the thermal waters are slightly mineralized (<1 g/l) with fluoride concentration ranging from 0.1 to 25 mg/l, various metasilicic acid concentrations (up to 230 mg/l) and of mostly low alkalinity (Vladeva and Kostadinov, 1996). These chemical properties made possible the wide application of thermal waters for bottling of potable water and direct supply for everyday necessities.

The quantity of currently exploited thermal water amounts to 28% of the discovered resource. Of them, 5% are utilized under concession regime (mainly for bottling of mineral water) and 23% are placed to users for all other applications by permit regime (Fig. 6). The official registers of issued permits and concessions for thermal water use have been uploaded in the Internet site of the Ministry of Environment and Water and currently updated.

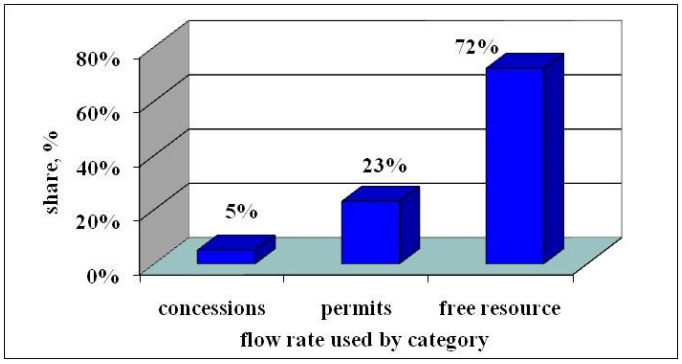

Figure 6: Exploited and free resource of state-owned reservoirs towards 2014 (Ministry of Environment and Water, Sofia).

4. GEOTHERMAL UTILIZATION

Direct thermal water use nowadays is for balneology, space heating and air-conditioning, greenhouses, ground source heat pumps, direct thermal water supply, bottling of potable water and soft drinks and for some technological processes. All uses such as prevention, treatment and rehabilitation, relaxation, swimming pools, sanitary needs and drinking water out of taps belong to one category – balneology.

The Water Act defines three categories for thermal water utilization: water supply (when no alternative is available), treatment and rehabilitation in specialized medical centers and the third category combines all other applications - balneology and energy.

The fees for water use are defined according to the above-mentioned three categories. They vary according to the temperature and are the lowest for water supply (0.015 – 0.016 EUR/m^3), followed by treatment and rehabilitation (0.02 - 0.03 EUR/m^3) and 0.08 – 0.26 EUR/m^3 for all other applications (State Gazette, 2011).

The utilized water quantities are calculated on the basis of updated register of issued permits (Ministry of Environment and Water) and concessions (Council of Ministers).

The share of water quantity used by different types of applications towards 2014 is presented in Fig. 7. Balneology and water supply retain their leading role respectively by 60.5% and 27.3%. Two of the applications in balneology are dominant – relaxation and sanitary needs (59.2%) and treatment and rehabilitation (21.5%) (Fig. 8). Utilized water for relaxation and sanitary needs has the highest share in balneology due to the intensive application in spa hotels located on the mountain and seaside resorts. Permits for relaxation and sanitary needs as well as for prevention are issued for users that are not registered according to the Medical Establishments Act.

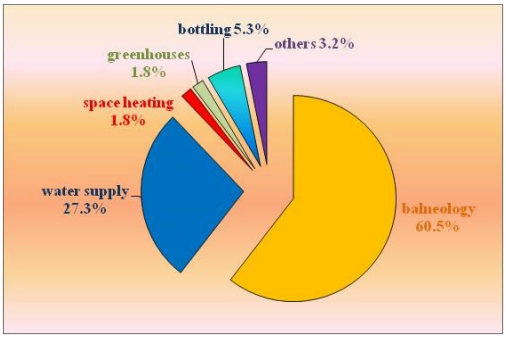

Figure 7: Water use by application towards 2014

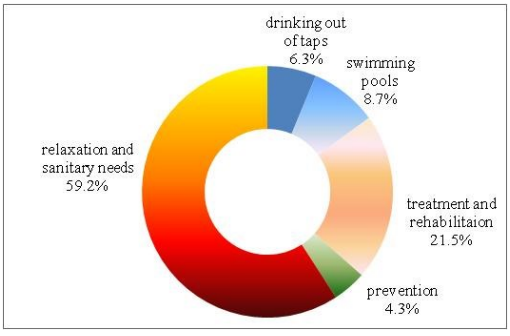

Figure 8: Water use in balneology towards 2014

The capacity and energy use for balneology are estimated based on the information on inlet temperature and permitted annual water quantity. The outlet temperature is assumed based on the experience with similar facilities. Permissions for water use are received for about 67 sites all over the country.

Direct supply with mineral water is taking place in regions where no other alternative is available. This application is typical for several resorts on the northern Black Sea coast. Drinking mineral water out of taps in spa resorts is free of charge.

The share of water used for space heating, air-conditioning and greenhouses is small and accounts totally for 3.6%. Heating is provided only to individual buildings not connected in a district heating system. According to the published information by the Ministry of Environment and Water (2014), geothermal energy for individual space heating is presently used in 4 sites. The installed capacity for heating and air-conditioning is 6.6 MW and produced energy is 99.86 TJ/yr.

Geothermal greenhouses are currently in operation in 6 sites located in South Bulgaria. These cover an approximate area of 10 ha and produce vegetables and flowers for the local market. The installed capacity is 1.65 MW and produced energy is 25.45 TJ/yr.

Applications such as small industrial uses for clothes driers and washer, for technological needs in different enterprises (oil, food and soft drinks production), and for plant irrigation are combined in one category called “others”. The installed capacity is 9.17MW and produced energy is 57.83TJ/yr.

The trend of thermal water quantity used by application for the period 2009-2014 is presented in Fig. 9. Balneology remains a leading application and shows a small trend of increasing towards 2014 (Fig. 9). The share of water supply is unevenly growing after 2009. Water used for space heating and greenhouses is significantly reduced after 2009 and is almost the same in the period 2012-2014. Bottling of potable water remains nearly constant during the past 5 year’s period.

Relaxation and sanitary needs takes the highest share among balneology for the whole period, as a small decrease is marked in 2012 compared to the 2009 (Fig. 10). Aside from prevention, the share of the other three applications has increased 2-3 times within the discussed period.

The implementation of heat pumps using renewable energy has been growing during the years. The published data concern the total energy produced by air to water and water to water heat pumps. The number of air to water heat pumps systems is far more prevalent but no official information on their total installed capacity is available so far.

According to the information published in some Bulgarian Internet sites GSHP systems are assembled in family houses, blocks of flats, offices and industrial buildings in different regions of the country. They provide heating, cooling and domestic hot water and the installed capacity varies from 5-6 to 590 kW.

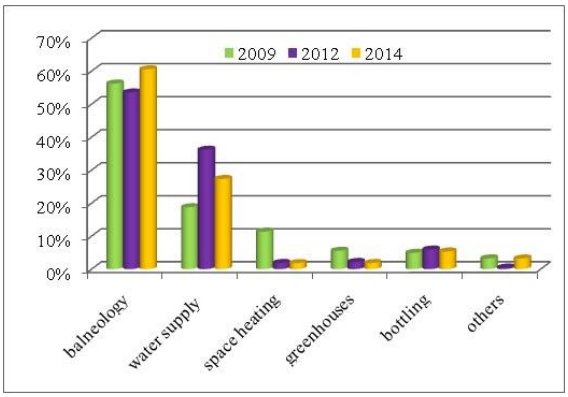

Figure 9: Water quantity used by application for the period 2009-2014

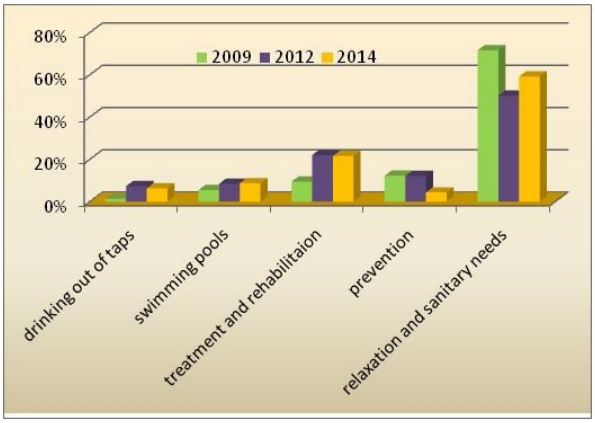

Figure 10: Water quantity used for balneology for the period 2009- 2014

The price of produced thermal energy estimated for 8 geothermal stations assisted by GSHP is about 2 Eurocents/kWh. These systems are partially financed by the Bulgarian Energy Efficiency Agency and Renewable Energy Credit Line (BEERECL) (Detailed project statistics, 2014).

The total installed capacity for direct heat use in Bulgaria (excl. GSHP) runs up to 83.10 MWt, which is slightly increased in comparison with that in 2009. Annual energy use is estimated to 1,177.12 TJ/yr for 2014.

An innovative pilot system using CO_2 earth heat pipe (GECO2) has been recently installed aiming at providing heating to an industrial building located in Brani pole village, 5 km south of the town of Plovdiv, S. Bulgaria (Small Grants Program of the Global Environment Fund, 2010-2012). Condensed CO_2 is flowing down along the wall of a flexible, corrugated stainless steel pipe (German patent) and as a result of the heat exchange with the surrounding rocks a vaporized CO_2 is moving up the same pipe to a heat pump system. The pipe is fixed in a well at a depth of 110 m. The system is of 3 kW installed capacity and provides only heating. It has been in operation since the beginning of 2012.

5. DISCUSSION

The growth of RES energy production during the past 10 year's period is due to the rapid development of wind and solar energy (Fig. 11). Data are taken from Table 1, included in the three geothermal update reports for Bulgaria respectively in 2004, 2009 and 2014.

Thermal waters are not used for electricity generation due to the low temperature of less than 100°C. Small RES - hydro plants (<10MW), photovoltaic, wind and biomass installations produce about 8% of the electricity generation in the country.

The investments made in this sector exceeded 3 billion EUR and were entirely private (Public Energy Council, 2013).

The average prime cost of electricity generation by renewables is estimated within the interval (8.84-14.93) Eurocents/kWh (VAT excluded) and is about 3-4 times higher, compared to electricity produced by fossil fuel installations (State Energy and Water Regulatory Commission, 2012)(Fig. 12).

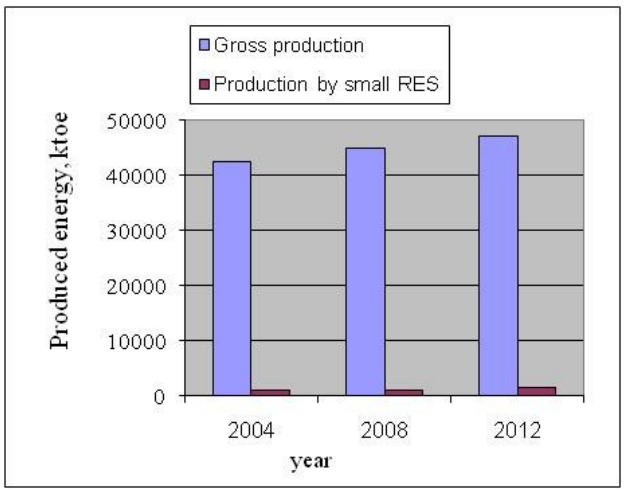

Figure 11: Primary electricity production (2004-2014), State Energy and Water Regulatory Commission

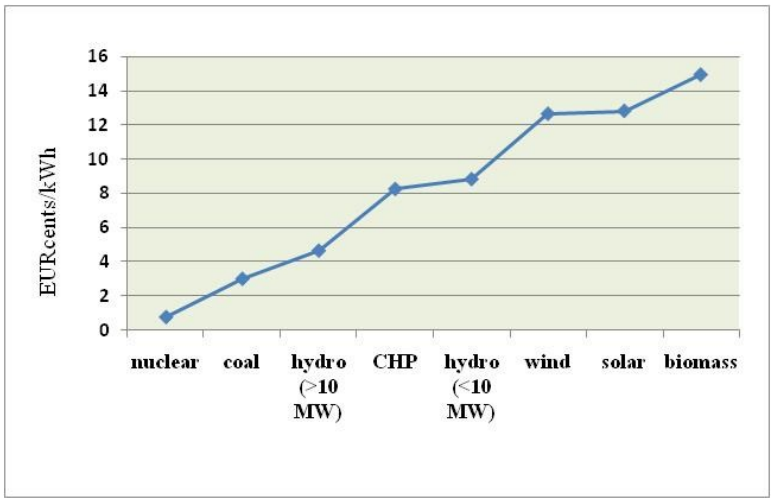

Figure 12: Average primary costs of produced electricity

The average prime cost of produced thermal energy by CHP plants is estimated to be 3.8 Eurocents/kWh based on the data for 37 plants. The newly built geothermal installations are few and the reported primary cost for them is about 6-7 Eurocents/kWh, (Prefeasibility study, 2011).

The trend of geothermal energy development for direct use within the period 2004-2014 is presented in Fig. 13 and 14. The total capacity has decreased after 2004 by 29% and remained almost unchanged during the past 10 years. Data are taken from Table 3, included in the county update reports – 2004, 2009 and 2014 (Fig. 13). Many of the heating installations have been closed since 2004 for poor technical conditions and some of the systems in operation reduced their activity as well.

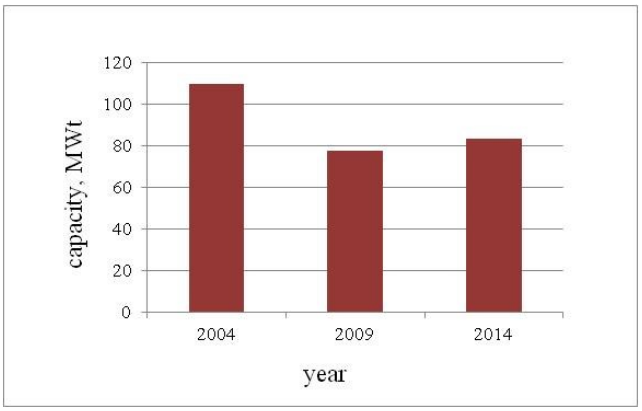

Figure 13: Total capacity change during the period 2004-2014

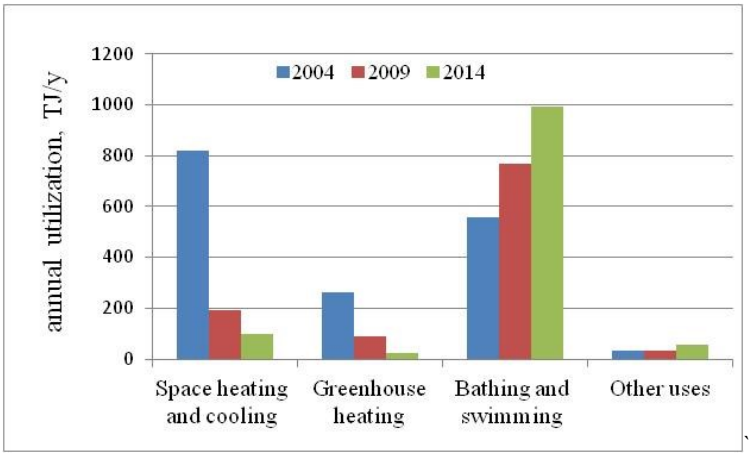

Figure 14: Annual utilization by application during the period 2004-2014

The trend of annual energy use for the past ten years is presented in Fig. 14. Space heating and greenhouses has been steadily declining, while balneology (bathing and swimming) has marked a progress for the entire ten years period.

Thermal waters could be administrated on the spot by legal entities and individuals. Up to date about 70 state-owned fields have been identified for being granted to the Municipalities. The Municipalities are entitled to adopt their own tariffs for water use in order to attract developers of renewable energy sources.

Another significant change that occurred after 2011 was the sharp decrease of about 3-4 times of the fees for water use. For example, the tax for water use for treatment and rehabilitation was reduced from minimum 8 Eurocents/m^3 in 2009 to 2-3 Eurocents/m^3 in 2014.

The main barriers for thermal water use are mainly related to the lack of:

- Administrative capacity and funds of the municipalities for water management;

- State support needed to improve the poor condition of the water sources granted to communities and to provide further studies for resource assessment;

- Local investment interest and strategic partners.

The application of ground source heat pumps would continue to grow and balneology will preserve its leading role. The legislative changes are expected to provoke greater interest in the direct geothermal energy.

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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	0	0	6205	25447.4*	1755** (>10 MW) excl.PSHPP	2198.8**	2000*	15798.2*	1887**	3562.8**	11847	47007.2
Under construction in December 2014												
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020												

*buletin_energy_2013_bg.pdf

**http://www.mi.government.bg/files/useruploads/files/obshtestven_syvet/res.pdf
Installed capacity (MWe): hydro (<10MW) - 192, wind - 751, biomass - 21, photovoltaic - 923
Produced energy (GWh/y): hydro(<10 MW) - 480, wind - 1689.75, biomass - 147, photovoltaic - 1246.05

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

[1] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
1. Montana district	B	32.43	36.04	25			1.50	15.57	22.67	0.48
2. Lovech and Tarnovo districts	B,O	51.64	42.41	29			2.90	23.76	42.03	0.46
3. Varna and Shumen districts	B,H,G,O	522.51	33.98	27			15.26	318.84	293.54	0.61
4. Kjustendil and Pernik districts	B,H,O	28.64	77.85	38			4.78	10.89	57.24	0.38
5. Sofia city and Sofia district	B,H,G,O	121.9	45.27	35			5.24	54.87	74.33	0.45
6. Blagoevgrad district	B,H,G,O	159.08	61.28	38			15.49	55.70	171.03	0.35
7. Smoljan district	B,O	20.74	51.62	38			1.18	8.09	14.53	0.39
8. Pazardjik district	B,H,G,O	168.11	56.51	29			19.35	70.63	256.29	0.42
9. Plovdiv district	B	94.22	46.14	26			7.94	41.47	110.16	0.44
10. Stara Zagora district	B	64.70	52.17	25			7.36	29.77	106.69	0.46
11. Sliven and Haskovo districts	B,G	28.17	51.98	38			1.65	12.40	22.87	0.44
12. Bourgas district	B,G,O	17.05	36.54	30			0.47	6.65	5.74	0.39
TOTAL		1309.19					83.10	648.64	1177.12	0.45

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

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat

[1] Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

[2] Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

[3] Report the COP = (output thermal energy/input energy of compressor) for your climate

[4] Report the equivalent full load operating hours per year, or = capacity factor x 8760

[5] Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or Water Temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Bulgaria	10-20	6 - 590*		V,H,W				
TOTAL								

* installed capacity range

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

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^{6} W)
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	3.30	49.90	
District Heating [4]			
Air Conditioning (Cooling)	3.30	49.96	
Greenhouse Heating	1.65	25.45	
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	65.69	993.98	
Other Uses (specify)	9.17	57.83	
Subtotal	83.11	1177.12	
Geothermal Heat Pumps	10.00	47.30	
TOTAL	93.11	1224.42	

[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.04		0.091			
2000-2004	0.77					
2005-2009	0.091		3.817			
2010-2015			3.599			