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Geothermal Update for Bulgaria (2014-2018)

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ABSTRACT

The main aim of the article is to represent geothermal situation in the country over the period 2014-2018. Bulgarian territory covers an area of approximately 111,000 sq.km and it is a part of two regional tectonic structures - the Moesian plate (Northern Bulgaria) and the Alpine-Himalayan belt (Southern Bulgaria). Almost all natural geothermal springs are situated in Southern Bulgaria as the latter has a complex geological structure. Most of the known geothermal waters in Northern Bulgaria are reached by deep drilling works at depths between 2,000 and 6,000 m. The total flow-rate of geothermal sources in the country is estimated to be about 3,000 L/s with temperature range of 25-100ºC. Geothermal waters have only direct utilization due to the fact that 72% of them are with temperature up to 50ºC. The installed capacity amounts to 99.37 MWt (2018), excluding the low grade energy use by ground source heat pump (GSHP). Traditionally, most of the geothermal potential is used for balneology (including bathing and swimming) is about 60% and up to 23% for other purposes and 17% for direct water supply, air-conditions, greenhouse heating and bottling. Most of the hydrothermal sites are developed in the framework of mountain or sea resorts. Due to the relatively low geothermal temperature, electricity generation from geothermal water is not currently available in the country.

1. INTRODUCTION

Bulgaria is located in SE Europe and covers 23% of the Balkan Peninsula (Fig. 1). The territory of the country is approximately 111,000 square kilometres and it has a population of about 7,150,000 (2015).

Thermal waters in Bulgaria are treated separately by the legislation. They are owned by the State Government (the Ministry of Environment and Water) and part of them belong to the Municipalities according to the Water Act (1999). The Ministry of Environment and Water approves the exploitable thermal water resources and hydrothermal energy and sets up the wellhead protection zones of all reservoirs (state and municipal ones). The Ministry of Health controls chemical composition and general state of all water sources.

State-owned thermal waters are administered by the Council of Ministers according to the Concessions Act through concession regime and by the Ministry of Environment and Water according to the Water Act using permission regime.

The Municipalities are responsible to carry out the management of local thermal waters according to the Municipality Property Act (1996).

There is not any specialized company in Bulgaria operating only in the field of geothermal resources and energy.

Bulgarian energy includes the following installed capacities:

- Nuclear Power Plant (NPP) "Kozloduy": Total capacity 2,000 MWe (Block V - 1,000 MWe and Block VI - 1,000 MWe);

- 30 Hydro Power Stations (HPS and PHPS) with a total installed capacity of 3,161 MWe. All of them belong to the National Electrical Company of Bulgaria;

- Several Thermo Power Stations (TPS) with a total installed capacity of 6,888 MWe. Six of the biggest ones are: "Maritsa East 1" (690 MWe), "Maritsa East 2" (1630 MWe), "Maritsa East 3" (908 MWe), "Maritsa" (690 MWe), "Varna" (1260 MWe), "Ruse" (400 MWe);

- Renewable Energy Sources (RES): Solar Stations (1040 MWe), Wind Turbines (751 MWe), Biomass (46 MWe).

The total installed capacity for Bulgaria is 13,889 MWe in the end of 2018 according to the National Electrical Company (https://nek.bg/index.php/bg/za-nas/organizacionna-struktura)

Using the latest published data by the National Statistical Institute (2017), coal or natural gas and nuclear energy maintain their leading role, respectively with 57% and 28% shares of the total produced electrical energy and the share of the Renewable Energy Sources (RES) is 7% (Fig.2).

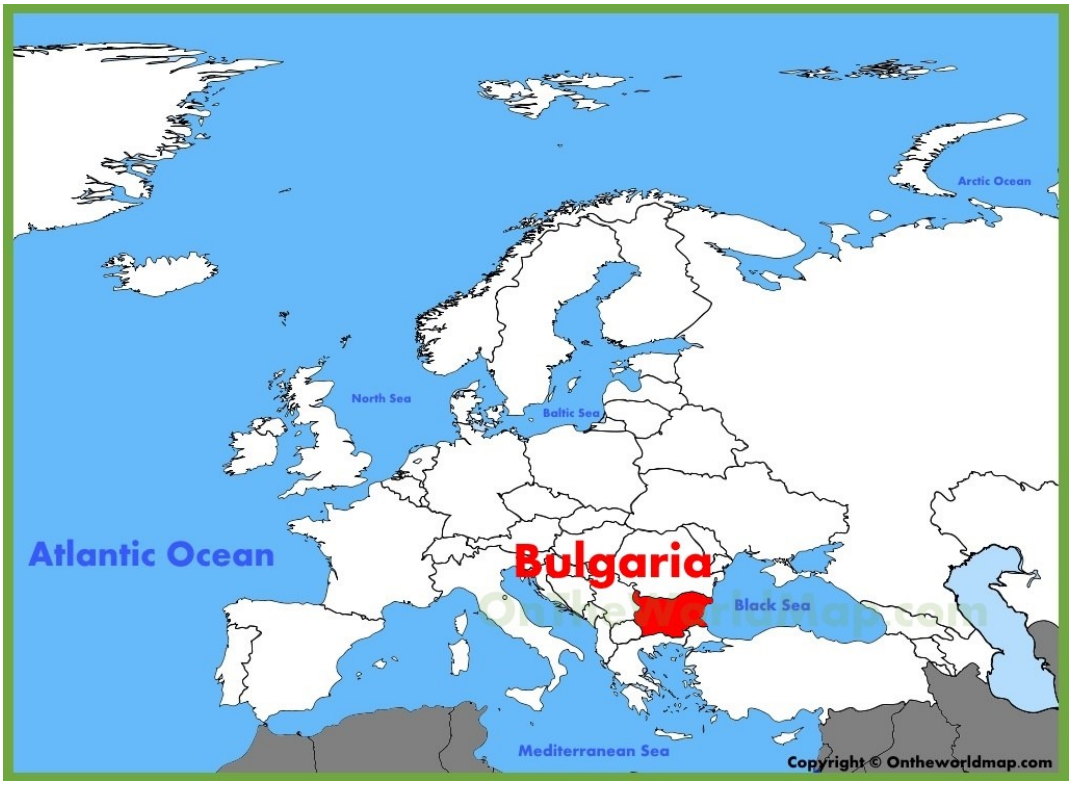


Figure 1: Bulgaria location on the Europe map

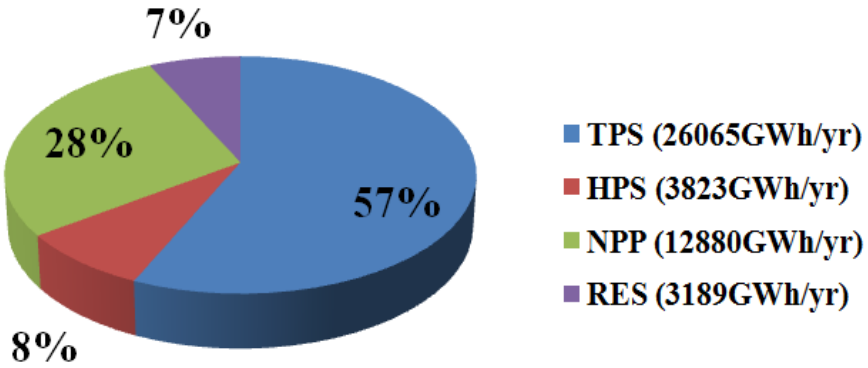


Figure 2: Electricity production in Bulgaria (2018)

*(**TPS-**Thermo Power Station, **HPS-**Hydro Power Station, **NPP-**Nuclear Power Plant, **RES-**Renewable Energy Sources)*

2. GEOLOGY BACKGROUND

The geology of Bulgaria comprises sediments, intrusive and metamorphic rocks of different origin with various lithologic and petrologic compositions - with Precambrian to Quaternary ages (Yovchev, 1971, Dabovski et al., 2002, Zagorchev, 2009). The area of the country covers parts of two major tectonic units: the northern part of the Alpine thrust belt in the Balkans, and its foreland - the Moesian plate (Zagorcev, 1992, 1994). The Alpine belt is subdivided into three zones (Balkan, Sredna Gora, Rila–Rhodope massif). Part of the Moesian plate completely covers Northern Bulgaria. Up to 1,000 m thick artesian aquifers (Upper Jurassic-Lower Cretaceous) are found in the plate composed of extensively fractured and highly permeable limestones and dolomites. It is the biggest geothermal reservoir in the country.

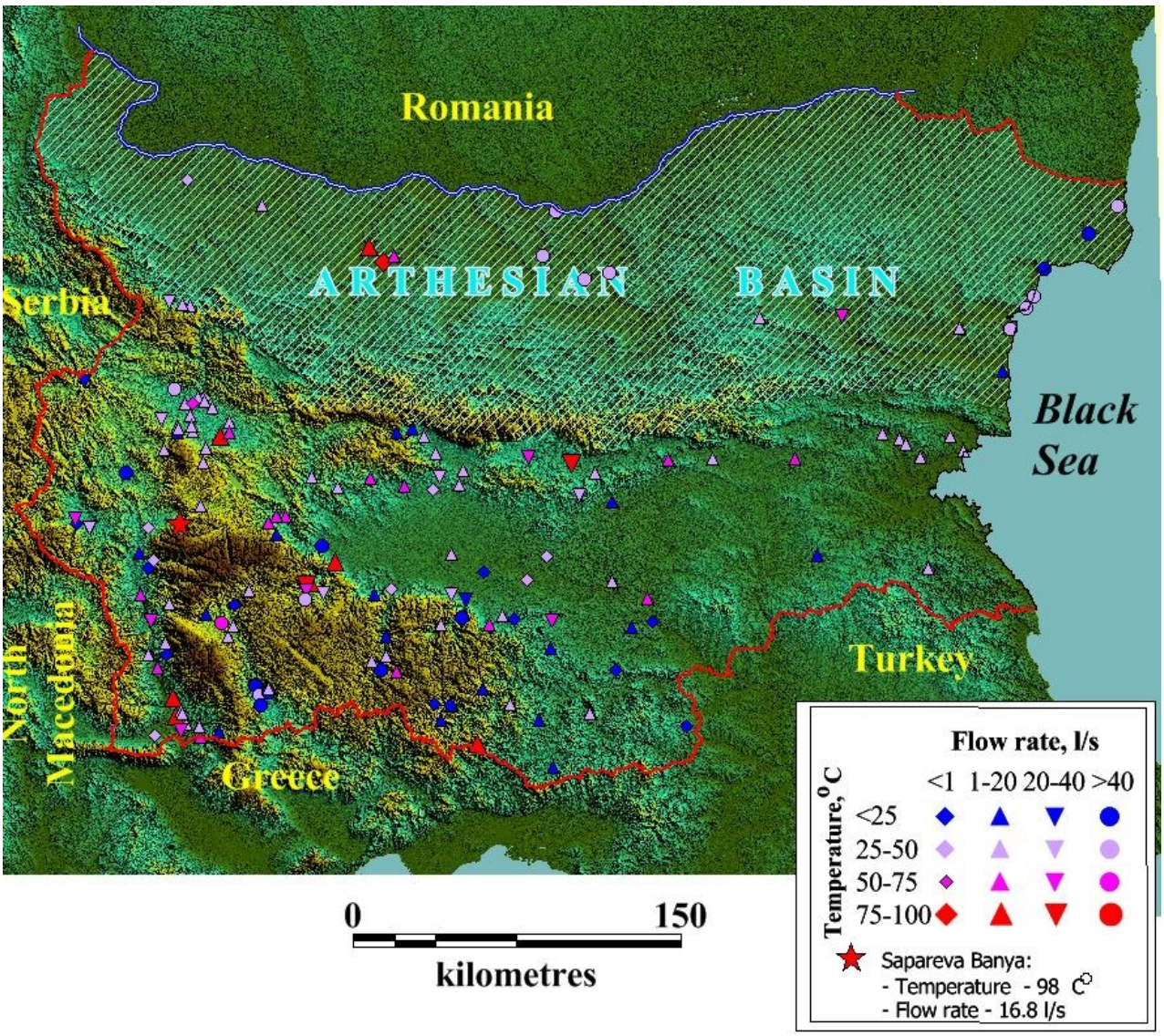


Figure 3: Schematic map with thermal sources

The geological and hydrogeological conditions forming hydrothermal fields (reservoirs) in Bulgaria are summarized in numerous publications (Shterev, 1964; Pentcheva, 1968, 1984; Petrov et al., 1970, 1998; Velinov and Bojadgieva, 1981 Galabov and Stoyanov, 2011, Benderev et al., 2016, etc.). The territory of Bulgaria is characterized by complex hydrogeological conditions.

The northern part of the country (among the Moesian plate) consists of widely distributed layered aquifers (limestones and dolomites) divided by aquicludes. Groundwater temperature there reaches more than 100°C at the bottom of some boreholes (Vidin, Slanotran, Pleven sites, etc.). The high salinity of the water impedes direct use due to the risk of scaling. The aquifers are penetrated by hundreds of deep boreholes (some of them deeper than 6,000 m). Most of these boreholes have been drilled for the purpose of oil and gas prospecting and exploitation. Following their exploitation, more than 2,000 of the exploration and production boreholes were decommissioned and sealed in order to prevent mixing of groundwater with very high TDS (Total Dissolved Solids) (up to 150 g/L) with fresh water from different upper aquifers. Currently, only some geothermal fields and occurrences along the Balkan and some others along the north-eastern part of Bulgarian Black Sea coast are used for different purposes (mainly for water-supply, balneology and spa-hotels). The second type of hydrothermal deposits – fractured confined systems, is found mainly in the southern part of the country. These deposits have a sporadic distribution and are attached to tectonic zones and regions characterized by higher heat flow. Most often the water there rises upward along faults and forms natural springs at the surface. More than 95% of all natural geothermal (mineral water) springs occur in Southern Bulgaria (Fig. 3). In some cases, thermal water is discharged in unconsolidated sediments (secondary reservoirs), which are deposited in graben type depressions. In Southern Bulgaria, the TDS of most geothermal natural springs and in boreholes is lower than 1.0 g/L.

According to the Water Act, 102 of all hydrothermal fields in Bulgaria are specified as exclusive state property. The rest are municipal property for 25 years.

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

3. GEOTHERMAL RESOURCES AND POTENTIAL

Bulgaria has a relatively good geothermal capacity of 9,957 TJ/year (2,765,855 MWh or approximately 315 MWt) (Petrov et al., 1998). Generally, the application of thermal waters is still about 30% of the total amount. The installed thermal capacity, excluding ground source heat pumps GSHP, increased to approximately 99.37 MWt in 2018 from 83.10 MWt in 2014 (Bojatgieva et al., 2015).

The natural thermal springs and thermal water, discovered in hundreds of boreholes in the country, have only direct application because of their relatively low temperature (less than 100°C). The total dynamic flow rate of sub thermal and thermal waters run up to 4,600 L/s (Petrov et al., 1998), of which about 3,000 L/s is the flow rate of the waters of temperature above 25°C. Only eleven geothermal fields have temperature higher than 75°C and the total flow rate of each of them varies between 6 L/s and 33 L/s (Hristov et al., 2018). The mineral (geothermal) water is used mainly for water-supply, balneological purposes (treatment, preventive care, relaxation, sanitary needs and pools) and only a small portion is used for heating of buildings, greenhouses etc. Most of the mineral waters are slightly mineralized and are suitable for bottling of potable water and soft drinks. Recently, thermal water from some geothermal sites is used for water supply to some relatively new spa-hotels centres.

Installation of GSHP is on the increase, along with the traditional installations for hydrothermal energy use. GSHP systems are assembled in family houses, blocks of flats, offices and industrial buildings. They provide heating, cooling and household hot water. Information about the exact number of units, their installed capacity and type (air to water, water to water) is not officially available, hence not discussed in this paper.

4. GEOTHERMAL UTILIZATION

The major factors that contribute to the geothermal development in Bulgaria are: long tradition, favourable climate, appropriate thermo-mineral water composition and developing new spa centres (Fig. 4) and bottling factories.

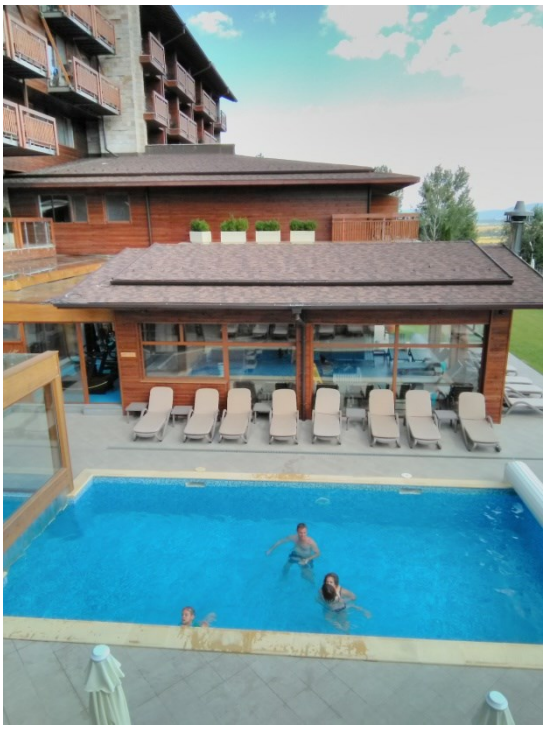


Figure 4: Katarino Spa-Hotel

Concerning renewable energy sources (RES), the national target of 16% share of the total internal energy consumption was achieved by 27 December 2013, according to the second National Report (http://www.nsi.bg) on the progress of Bulgaria - RES usage (Fig. 5). The geothermal share in RES is only 1.8% in 2013 as in 2017 (Fig. 6). Although the installed thermal capacity increased by 19,6% from 2014 to 2018, the geothermal utilization of RES has not changed due to the increase of other RES in the same period.

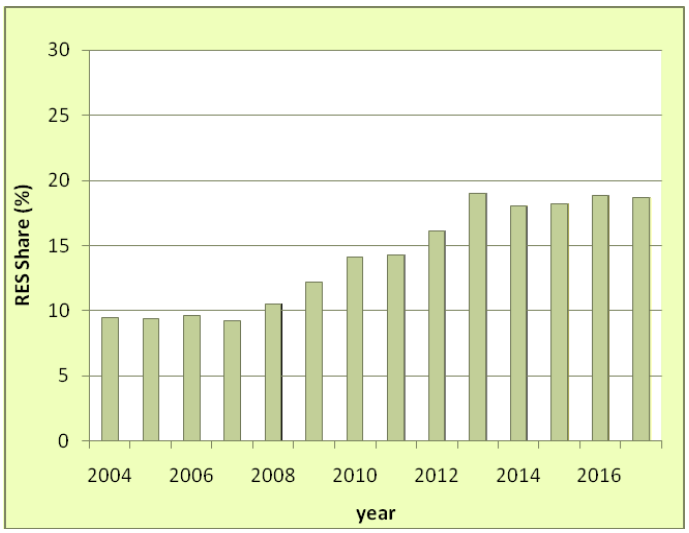


Figure 5: Share of renewable energy sources in the total energy use

Because of the relatively low temperatures (<100°C), thermal waters have only direct application. According to 2018 data from the River Basin Directorates (Fig. 7), the variety of uses includes: balneology, bathing and swimming (60%) others and water-supply (23%), space heating and air-conditioning (3%), greenhouses (2%) the rest is for bottling of potable water etc.

In the last five years the situation has changed significantly since mineral water of 32°C temperature is being supplied to several sea resorts along the northern Black Sea coast: Sv.Sv. Konstantin & Elena, Zlatni Pyasatsi, Albena, Rusalka and others. Direct supply is typical for many new spa resorts among mountain areas as Chiflika, Velingrad, Ognyanovo, Sapareva Banya and many others as well in some sea resorts.

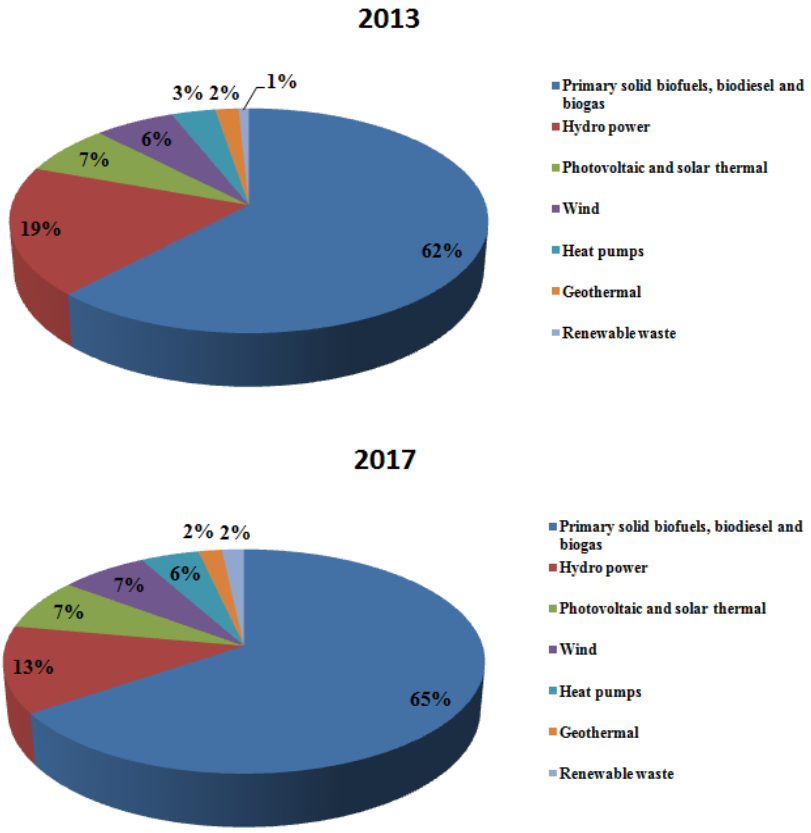


Figure 6: Comparison between 2013 and 2017 of share RES application in Bulgaria

Drinking mineral water on tap is free of charge all over the country.

Bottling of mineral potable water is regulated by the Concessions Act. The main reasons for the development of bottling include the generally low TDS (<1 g/L) and the wide variety of chemical compositions of the mineral waters in Southern Bulgaria. Bottling of mineral potable water is one of the very fast developing business affairs in the last 30 years. The number of bottling factories increased from 3 to more than 40 in the period of three decades only.

The share of water used for greenhouses is about 2% (2018) of the total use of thermal water. The geothermal water application in some relatively large greenhouses (the villages of Levunovo, Kazichene etc.) decreased.

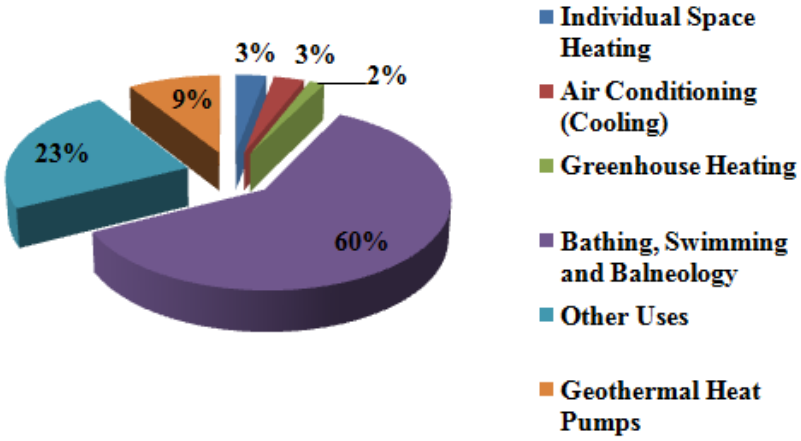


Figure 7: Thermal mineral water utilization in Bulgaria for 2018

The thermal water potential in the country is suitable mostly for low temperature floor heating or for systems assisted by convectors. Such installations need high initial investment and, at this stage of economic development, they are not competitive to the air-conditioning systems widely available on the market.

Heating is provided only to individual buildings (up to 3% of the total geothermal water used) and it is not connected in a district heating system. Heating installations are assisted by plate heat exchangers (Sapareva Banya, Varna etc.). In addition, they heat domestic water and are in operation for about 200 days/year.

5. DISCUSSION

The growth of RES energy production during the past 15 year's period is due to the rapid development of wind and solar energy. Thermal waters are not used for electricity generation due to the low temperature of less than 100ºC. Small RES - hydro plants (<10MW), photovoltaic, wind and biomass installations produce about 7% of the electricity generation in the country. 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: 3.3 Eurocents/kWh (NPP) and 4.5 Eurocents/kWh (TPS).

The utilization of geothermal water in Bulgaria for the periods (2009-2013) and (2014-2018) could be summarised as follows:

- The installed thermal capacity increased by 19.6% from 83.10 MWt in 2014 to 99.37 MWt at the end of 2018; GSHP excluded.
- Water supply of mineral water of approximately 32°C temperature to several sea resorts along the northern Black Sea coast has increased rapidly.
- Thermal water is being currently used for space heating and domestic hot water in only a few balneological sites. Many old heating installations in poor technical condition have been abandoned and only a small number of new installations have been constructed.
- The renewable geothermal resources in the country have the potential (only about 30% of them are utilized) for future development as direct application.
- The major factors promoting geothermal development in Bulgaria are the long existing tradition in thermal water use, favourable climate, appropriate thermal water composition for therapy as well as for bottling of potable water and soft drinks and a well developed spa system. The significant growth of hotel construction in the mountain and seaside resorts has been done. In most of them water is used for relaxation and small pools.
- Electricity generation from geothermal water is not currently available in the country but some binary cycle power plants could be built. Certainly, such systems will be only of local importance because of very limited geothermal potential for this kind of activity.

As a conclusion, due to the relatively low temperature of thermal water in Bulgaria (up to 100°C) direct-use of geothermal water in the country is used for balneology, swimming, bathing, space heating and air-conditioning, greenhouse heating, ground source heat pumps, direct thermal water supply, bottling of potable water and soft drinks and for some technological processes (oil, food and soft drinks production). The largest uses of the thermal water are for balneology (including, swimming and bathing) and water supply. Relaxation and sanitary needs are dominant at spa hotels located on mountain and seaside resorts.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

The main investor in Bulgaria for geothermal resources, installations and their use is the Ministry of Environment and Water. Unfortunately, there are no major projects in this area and, as far as it is known, in the near future no new significant projects are planned. The Ministry of Environment and Water is trying to restore exploitation in some areas where drilling has collapsed due to the expiration of their working period. Usually, these are small projects with relatively low funding therefore the work is done by small local drilling companies.

ACKNOWLEDGEMENTS

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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 2019	0	0	6,888	26,065	3,161	3,823	2,000	12,880	1,840	3,189	13,889	45,957
Under construction in December 2019												
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020												

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019 - it is not existed in BULGARIA

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019

(otherthanheatpumps)

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. Varna & Shumen districts	B, H, G, O	1079.60	33.98	27			31.53	658.78	606.51	0.61
2. V. Tarnovo & Lovech districts	B, O	51.54	42.41	29			2.90	23.76	42.03	0.46
3. Montana district	B	32.43	36.04	25			1.50	15.57	22.67	0.48
4. Bourgas district	B, G, O	17.05	36.54	30			0.47	6.65	5.74	0.39
5. Sliven & Haskovo districts	B, G	28.17	51.98	38			1.65	12.40	22.87	0.44
6. Stara Zagora district	B	64.70	52.17	25			7.36	29.77	106.69	0.46
7. Plovdiv district	B	94.22	46.14	26			7.94	41.47	110.16	0.44
8. Pazardzhik district	B, H, G, O	168.11	56.51	29			19.35	70.63	256.29	0.42
9. Smolyan district	B, O	20.74	51.62	38			1.18	8.09	14.53	0.39
10. Sofia district	B, H, G, O	121.90	45.27	35			5.24	54.87	74.33	0.45
11. Pernik & Kyustendil districts	B, H, O	28.64	77.85	38			4.78	10.89	57.24	0.38
12. Blagoevgrad district	B, H, G, O	159.08	61.28	38			15.49	55.70	171.03	0.35
TOTAL		1866.18					99.37	988.58	1490.09	0.45

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

rejectedtothegroundinthecoolingmodeasthisreducestheeffectofglobalwarming.

1) Reporttheaveragegroundtemperatureforground-coupledunitsoraveragewellwaterorlakewatertemperatureforwater-sourceheatpumps

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 - typically 3 to 4

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

6) Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures
Due to room limitation, locality can be by regions within the country.

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[5] (TJ/yr)	Cooling Energy[6] (TJ/yr)
Bulgaria	10.0-20.0	6-590*		V, H, W				
TOTAL								

* installed capacity range

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

[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)

Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

[4] Other than heat pumps

[5] Includes drying or dehydration of grains, fruits and vegetables

[6] Excludes agricultural drying and dehydration

[7] Includes balneology

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	
DistrictHeating[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: (a) Space heating and domestic hot water in some balneological sites - SPA hotels; (b)Domestic water for several sea resorts along NE Bulgarian Black Sea coast)	15.93 9.50	100.46 59.91	
Subtotal	99.37	1279.66	
Geothermal Heat Pumps	10.00	47.30	
TOTAL	109.37	1326.96	

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

There is not any well drilled for such purpose from JANUARY 1, 2015 to MAY 31, 2019

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

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

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	4	1	7	0	0	2
2016	3	1	6	0	0	2
2017	3	1	6	0	0	2
2018	3	1	6	0	0	2
2019	3	1	5	0	0	2
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl. Surface Explor. &Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.04		0.091	0		
2000-2004	0.77			0		
2005-2009	0.091		3.817	0		
2010-2014			3.599	0		
2015-2019			No available data.	0		