General overview of geothermal energy in Bulgaria

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Všeobecný prehľad geotermálnej energie v Bulharsku

Low enthalpy geothermal reservoirs have been discovered on the territory of Bulgaria. Most of the geothermal resource has been revealed. About 160 geothermal fields of totally 4600 l/s flow rate were explored. Currently application, hermal water is mainly in balneology, space heating, bottling of potable water and in swimming pools. The total installed capacity amounts to 109.7 MWt and the annual energy use is 1671.43 TJ/year. Major characteristics of geothermal fields have been summarized. Different types of application are discussed and the most perspective geothermal reservoirs selected in terms of their thermal capacity are listed.

Key words: *thermal water temperature, flow rate, thermal capacity, thermal water use*

Introduction

The most intensive development of use of the thermal water and geothermal energy in Bulgaria took place in the period 1980 - 1990. Heating installations assisted by plate heat exchangers and heat pumps were constructed during this time.

Social and economical changes in the last 15 years impeded the geothermal resource development. State investments have been sharply reduced. A new legislation on the water exploration, protection and application has been completed and tested.

Only the bottling of mineral water and the soft drink preparation marked a rapid development in this period and the number of enterprises increased from 3 to 41. Several demonstration projects for space heating funded by international sources have been constructed. The renovation of spa resorts have started and many outdoor and indoor swimming pools were built.

The aim of the paper is to present the major geothermal resource characteristics and to point out the most perspective reservoirs for a future development.

Geological settings

The main hydrothermal deposits in Bulgaria are grouped in three major hydrothermal units: Moesian plate, Sredna gora zone (incl. Balkan) and Rila-Rhodope massif, Fig. 1.

Three types of aquifers are found out in the country - stratified, fractured and mixed (water from a fractured rock aquifer is secondary accumulated in younger sediment layers).

The stratified reservoirs are typical for the Moesian plate and are associated with the carbonate strata of Malm-Valanginian, Middle Triassic and Upper Devonian age. They consist of up to 1000 m thick artesian aquifers built up of limestone and dolomite, very fractured and with a high permeability.

The Sredna gora zone is rich in thermal waters accumulated in unstratifed (fractured), stratified and mixed hydrothermal systems. The water circulation takes place both in the fractured massif of granite and metamorphic rocks of various ages and in the Upper Cretaceous volcano - sedimentary deposits. Thermal reservoirs are formed also in many post-orogenic Neogene – Quaternary grebes filled up with terrigenious deposits.

The western Rila-Rhodopes massif contains mostly unstratified hydrothermal systems with thermal waters of highest temperature up to 100^{o}C. It is mainly built of Precambrian metamorphic and granite rocks, fractured by a dense system of seismically active faults. The metamorphic basin contains some large bodies of marble that act as hydrothermal reservoirs. Permeable terrigenous-clastic materials in the deep Neogene and Paleogene grabens also contain thermal waters. The eastern part of the massif is not rich in aquifers.

Resource characteristics

The basic characteristics of geothermal water on the territory of the country was reassessed and updated within the period 1994-1998 by an extensive study carried out the scientists from the Geological Institute of the Bulgarian Academy of Sciences (Petrov et al.,1998).

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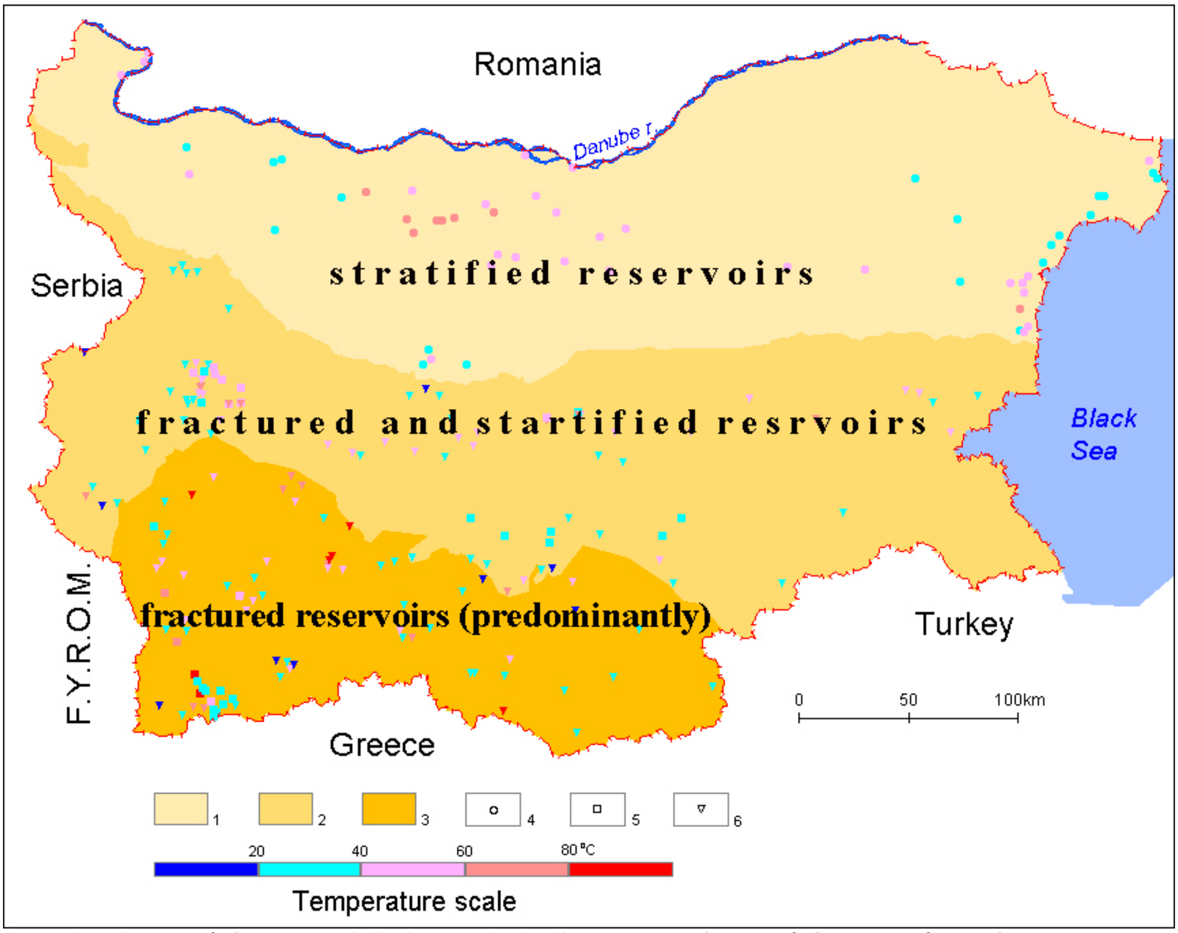


*1. **Moesian plate** (stratified reservoirs) 2. **Sredna gora, incl.Balkan zone** (secondary stratified reservoirs, fractured reservoirs) 3. **Rila-Rhodopes massif** (predominantly fractured reservoirs) 4. Major wells and groups of wells discovering stratified reservoirs in a plate region.5.Hydrothermal sources associated with waters from fractured reservoirs located in Southern Bulgaria. 6. Hydrothermal sources associated with waters from secondary stratified reservoirs located in Southern Bulgaria*

Fig. 1. Map of hydrothermal deposits of Bulgaria.

They are as follows:

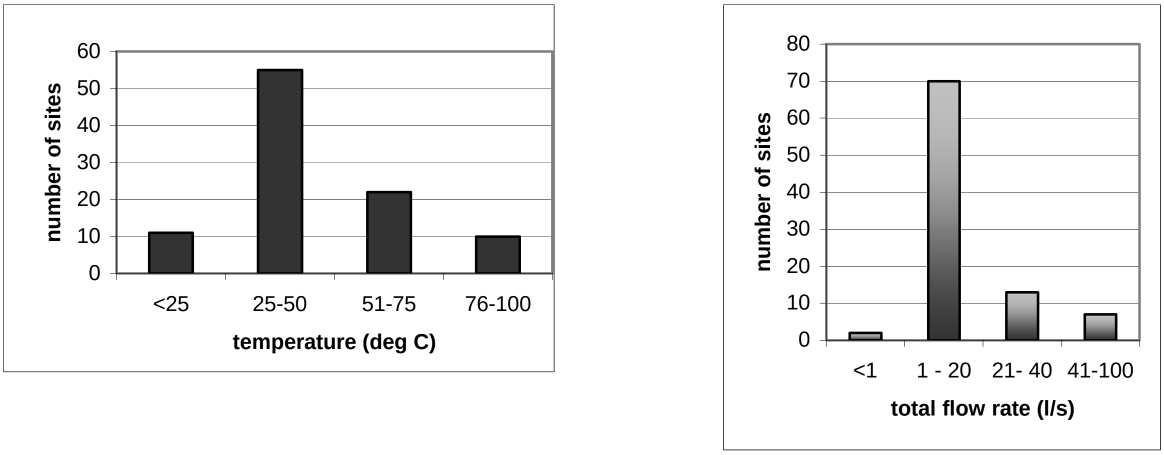
- Water temperature of the discovered reservoirs – (20-100)°C.
- Total dynamic flow rate - up to 4600 l s^{-1}.
- Established chemical water content (TDS), in:
  - Southern Bulgaria – (0.1 - 1.0) g.l^{-1} (only for a few sites it is between 1 g.l^{-1} to 15 g.l^{-1}),
  - Northern Bulgaria - 0.1 g.l^{-1} up to (100 – 150) g.l^{-1} .

About 70 % of the thermal waters in Bulgaria are slightly mineralized (<1 g.l^{-1}) with fluoride concentration ranging from 0.1 to 25 mg.l^{-1}, various metasilicic acid concentrations (up to 230 g.l^{-1}) and of mostly low alkalinity.

Both the State and Municipalities are owners of the thermal water sources according to the Water Law (1999). The numbers of discovered hydrothermal fields in the country amount to 160,102 of them are state owned. They play a leading role in the geothermal application. Update information on Municipality owned water sources is not currently available. State-owned water sources have a leading role in geothermal application of the country. They are predominantly located in Southern Bulgaria and along the Northern Black sea coast.

Two histograms presenting the number of state owned geothermal reservoirs in different temperature and flow rate intervals are shown on Fig.2a and 2b. The prevailing number of them (58 %) have a rather low temperature (25-50) °C. About 75 % are characterized by the flow rate varying within 1-20 l s^{-1}. Thermal waters of temperature in the range of (25-50) °C are used in 48 % of all applications and about 74 % of the installations are built on fields of total flow rate up to 20 l.s^{-1}. According to the last data published by the Ministry of Environment and Water, Sofia, only 31 % of the total discovered flow rate is currently in use (www.moew.government.bg).

Most of the state-owned reservoirs belong to the thermal capacity interval of less than 1600 kJ/s, (Fig. 3) and this is in accordance with the temperature and flow rate data distribution. (Thermal capacity is calculated for the outlet temperature – 15 ^{o}C).



a) **b)**

Fig. 2. Number of geothermal reservoirs for the defined temperature (a) and the flow rate intervals (b).

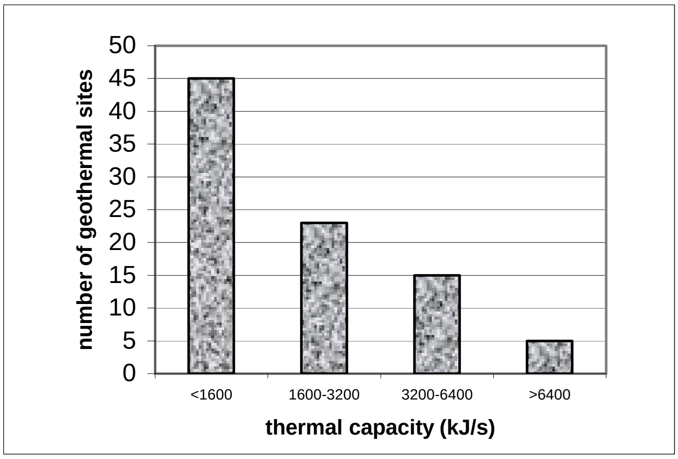


Fig. 3. Number of geothermal reservoirs for the defined thermal capacity intervals.

Thermal water application

Currently thermal water application is in balneology, public baths and tap water, domestic hot water supply, bottling of potable water and soft drinks, space heating (incl. greenhouses) and swimming pools. Micro algae open mass cultivation (Roupi filed, SW Bulgaria) was terminated for several years for financial and administrative reasons. Now it is in a process of restoration.

The most developed geothermal sites in the country are operating as spa centers and are mainly located in mountainous regions and on the Black sea coast. Public mineral baths, tabs and swimming pools are common in them. Wide ranges of diseases are treated using scientific methods and programs, confirmed by a long-term professional experience.

The total installed capacity in the country amounts to 109.7 MWt and the annual energy use is 1671.43 TJ/year (incl. balneology), (Bojadgieva et al.,2005). The fossil fuels saved due to the geothermal energy application are estimated at up to 39 921 TOE/year. According to the published energy balances of the country, the geothermal energy share is similar to the produced crude oil - 38 000 TOE/year (National Statistical Institute,2004).

Various types of utilization related to state owned reservoirs are presented on Fig. 4. These data come from the delivered concessions and permits for utilization issued by the Ministry of Environment and Water (www.government.moew.bg).

The highest share of geothermal energy utilization in Bulgaria belongs to space heating, bathing and swimming pools, Fig. 5. It is currently used for space heating of single buildings in 12 spas as in 4 of them air-conditioning is provided in addition.

Recently, the harnessing of low-grade geothermal energy for seasonal heating and cooling has marked a significant progress. About 34 new installations assisted by ground source heat pumps (GSHP) have been designed and constructed by private companies Geosolar V-63 Ltd and ESCO Engineering, Co, (Kolikovski, 2004; www.esco-engineering.biz). The installed capacity varies from 7 to 85 kW and COP (Coefficient of performance) is in the range of 3,5 - 4,5. The GSHP are fit in private houses and business offices. One of them provides a snow melting of outdoor stairs and a pavement around a private house.

Major hydrothermal reservoirs in Bulgaria

The summarized data on 18 state-owned reservoirs of highest thermal capacity (more than 3200 kJ s^{-1}) are included in Table 1. The most promising geothermal reservoir is the Northeast basin, which is a part of the largest J_3-K_1^v artesian aquifer located on the territory of Northern Bulgaria. Although the water temperatures of the basin are not high (35-55) ^oC the existing huge flow rate provides good perspectives for its further development all the more that the largest Black sea resorts are a part of it.

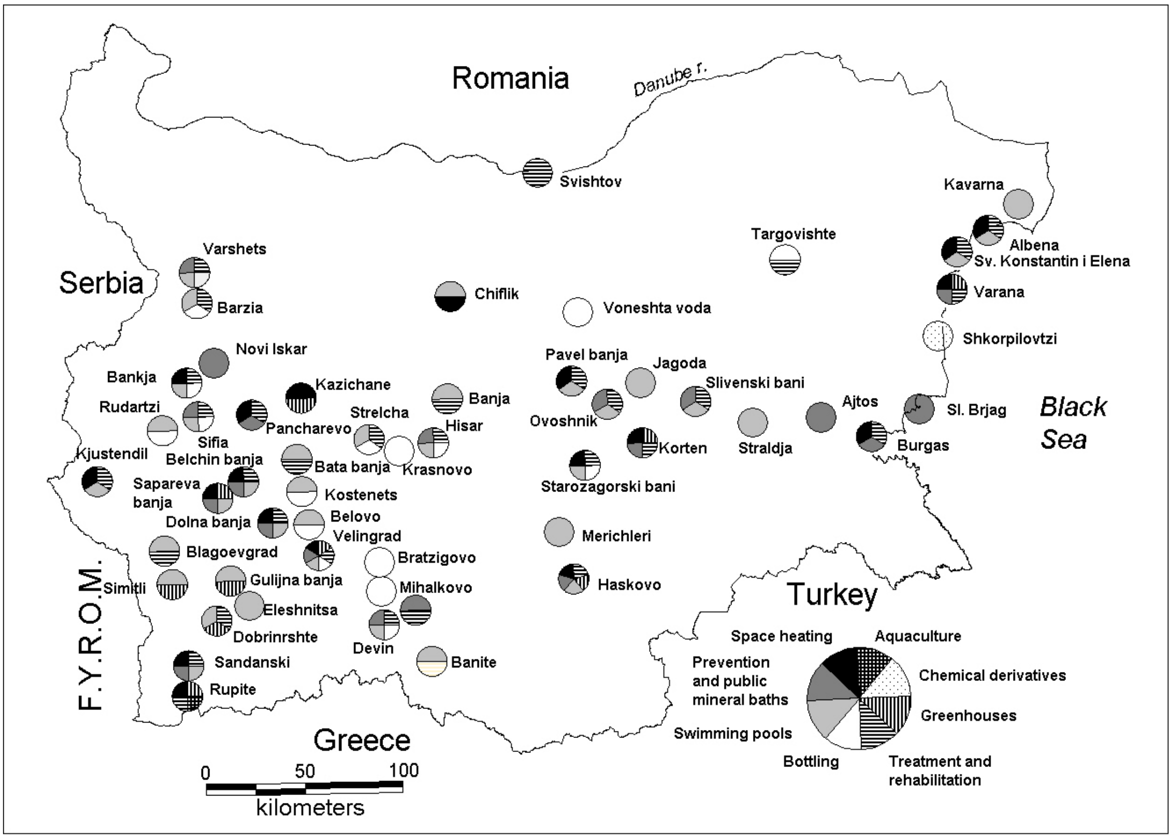


Fig. 4. Location of geothermal water application sites (state-owned).

All of the reservoirs included in Table 1 are not used to their fullest potential. The free (unused) flow rate for most sites is above 70 % and only in two of them it is comparatively low – Hisar (11 %) and Velingrad (Ladziane 1 and 2) (12 %), (www.moew.government.bg).

Thermal waters in Hisar town (S.Bulgaria), (Fig. 3), were utilized since the Thracian time. Many remains of Roman buildings and public baths are found there. Thermal waters are currently used for the treatment and rehabilitation in six spa centers, three sanatoriums and one policlinic, for the rehabilitation in many spa hotels (Fig. 6) and for public mineral baths. Two public outdoor swimming pools and several water pavilions (Fig. 7) are built in the town. Three enterprises for bottling of mineral water and soft drinks are operating there as well.

Five of the six geothermal fields located in the Chepinska valley (SW Bulgaria) are within the framework of Velingrad town. About 80 water sources of totally 150 l/s flow rate are available in the valley. This region also has an ancient tradition in the thermal water application. Currently, Velingrad town (Fig. 4) is one of the most developed spa and mountainous resort in the country. Thermal water is utilized for bathing, swimming pools, rehabilitation and treatment in about 50 spa hotels and rest houses and several sanatoriums, Fig. 8. Six public baths, ten indoor and outdoor public swimming pools and one enterprise for bottling of mineral water are built there (www.journey.bg). Many small private and public buildings are heated by simple schemes as well.

Tab. 1. List of most perspective geothermal reservoirs in Bulgaria.

N	Geothermal reservoir	Thermal capacity [kJ/s]	Temperature [deg C]	Total flow rate l/s	Current application
1	Northeastern basin (J_3-K_1^v) (NE Bulgaria)	69 868,7	23 - 50	668,6	balneology, space heating, public baths, swimming pools
2	Ovoshtnik (S.Bulgaria)	7774,8	45 – 78	40,0	balneology, public baths, swimming pools
3	Guliina banja (SW Bulgaria)	7636,9	42 – 57	43,5	public baths, swimming pools
4	Varvara (SW Bulgaria)	7210,5	90,0	23,0	balneology, public baths, swimming pools, space heating
5	Velingrad-Chepino (SW Bulgaria)	6513,0	37 – 47	62,8	balneology, public baths, swimming pools, greenhouses, space heating, bottling
6	Velingrad-Kamenita (SW Bulgaria)	6356,0	56 – 88	22,6	balneology, public baths, swimming pools, space heating
7	Svishtov (CN Bulgaria)	6019,2	47,0	45,0	balneology
8	Kiustendil (W Bulgaria)	5706,8	73 – 75	23,1	balneology, public baths, swimming pools, space heating
9	Sapareva banja (SW Bulgaria)	5551,0	98,0	16,0	balneology, public baths, swimming pools, space heating, greenhouses
10	Haskovski mineral baths (SE Bulgaria)	5467,0	53 – 57	32,7	balneology, space heating, greenhouses, public baths, swimming pools
11	Sandanski (SW Bulgaria)	5407,2	81,0	19,6	balneology, space heating, public baths, swimming pools
12	Velingrad (Ladzane1) Velingrad (Ladzane2) (SW Bulgaria)	5226,8	27 – 59	29,6	balneology, space heating, public baths, swimming pools
13	Velingrad (Draginovo) (SW Bulgaria)	4455,9	92 – 97	13,0	balneology, public baths, swimming pools, space heating
14	Hisar (S. Bulgaria)	4209,4	47,0	34,5	balneology, space heating, bottling, public baths, swimming pools
15	Levunovo (SW Bulgaria)	3752,0	81 – 83	16,0	greenhouses
16	Rupite (WS Bulgaria)	3856,0	74 – 79	15,0	baths, aquaculture
17	Eleshnitsa-r.Mesta (S Bulgaria)	3427,6	38 – 56	20,0	greenhouses, swimming pools
18	Obedinenie (CN Bulgaria)	3210,2	47,0	24,0	balneology, public baths

Fig. 6. Hisar town - Spa hotel "Augusta".

Fig. 7. Hisar town – water pavilion.

a) *b)*

Fig. 8. Velingrad - Ladzane geothermal site - spa hotels.

Conclusions

1. The prevailing number of Bulgarian state owned geothermal reservoirs have a rather low temperature (25-50) ^{o}C and flow rate varying within 1-20 l s^{-1}.
2. Selection of 18 most perspective geothermal reservoirs with the thermal capacity more than 3200 kJ.s^{-1} have been made. The unused flow rate in most of them is more than 70 % as only in two (Hisar and Velingrad-Ladzane) it is low – (11-12) %.
3. Update review of thermal water application in the country has been made with an emphasis on two sites – Hisar town and Velingrad town.

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