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Bulgaria – Geothermal Update Report

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ABSTRACT

Bulgarian territory is rich in thermal water of temperature in the range of 20°C-100°C. Direct thermal water use nowadays is for balneology (prevention, treatment and rehabilitation, bathing and swimming pools), space heating and air-conditioning, greenhouses, geothermal ground source heat pumps (GSHP), direct thermal water supply, bottling of potable water and soft drinks and for some other processes. The cultivation of microalgae and production of iodine paste and methane extraction have been terminated. Several applications - balneology and geothermal ground source heat pumps show more stable development at the present stage 2005-2010. Electricity generation from geothermal water is not currently available in the country.

The update information concerns mainly state-owned and only partially municipality-owned hydrothermal fields and is based on the existing permit and concession regime.

The installed capacity amounts to about 77,67 MW (excl.GSHP) and produced energy is 1083.89 TJ/yr. During this period geothermal energy used for heating of buildings and greenhouses considerably decrease, while ground source heat pumps marked a rapid development.

A great progress has been made in the state policy promoting electricity generation from renewable. Support mechanisms and feed-in conditions have been created. A new Law on Renewable, Alternative Sources and Biofuels was passed in 2007. According to the last amendments of Water Law taxes for thermal water application are conformable both to flow rate and water temperature of the source.

1. INTRODUCTION

The government setting and leading agencies involved in geothermal development discussed in Bojadgieva et.al (2005) haven't changed during the reported period 2005-2010.

A great progress however has been made in the policy related to promotion of renewables development in Bulgaria. The major steps that concern both electricity generation and direct use are as follows:

- Priority connection to the transmission and distribution national electric grid for every producer of electricity from renewables.
- Between 15 and 25 years guarantee for compulsory purchasing prices of electricity produced by new energy stations based on renewables.
- Preferential purchasing prices for trading electricity produced from renewables. They are calculated taking into account the electricity market, characteristics of different energy sources and available production technology. The compulsory purchase of produced electricity at preferential prices will be in power until the system of trading green certificates starts operating.
- Replacement of conventional fuels for heat production with renewables.
- Complex utilization of renewable energy sources.
- Issuing of certificates corroborative the origin of produced electric and thermal energy.
- Financial schemes for funding projects on construction of renewables energy stations have been created. These are Bulgarian Energy Efficiency and Renewable Energy Credit Lines, Energy Efficiency Fund, Public-Private Partnership grants, concluding an agreement called "Contracts with guaranteed result" with energy companies ESCO type, etc. The utilization of renewables is also included in the National strategic plan for development of rural regions for the period 2007 – 2013.

The most significant act concerning the electricity generation from renewables is the Directive 2001/77/EC. Bulgaria is obligated to reach 11% of gross electricity generated from renewables by 2010. Until 2009 the installed capacity of wind energy has reached about 112,6 MW and 0,1 MW – for solar energy (photovoltaic), (Ministry of Economy and Energy). The present share of renewables is about 6,5 % of the total produced electricity in the country. Fig.1. Regarding the structure of energy generation from renewables towards 2008 the share of hydropower plants (above 10 MW) was 81%, small hydro power plants (up to 10 MW) – 15% and wind and solar (photovoltaic) stations - 4 % (Ministry of Economy and Energy), Fig.2.

Electricity generation from geothermal water is not currently available in the country due to comparatively low temperatures of the discovered reservoirs - up to 100°C.

Direct thermal water use nowadays is for balneology (prevention, treatment and rehabilitation, bathing and swimming pools), space heating and air-conditioning, greenhouses, geothermal ground source heat pumps, direct

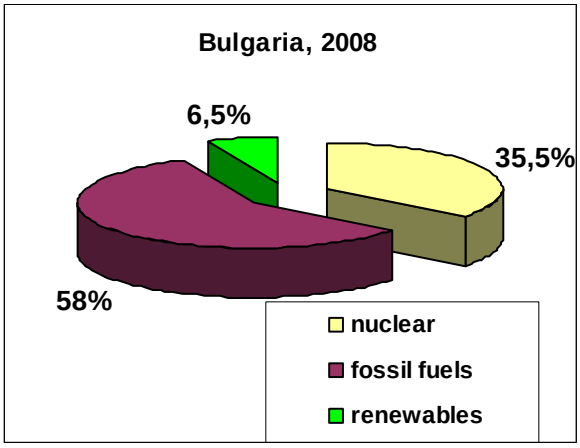
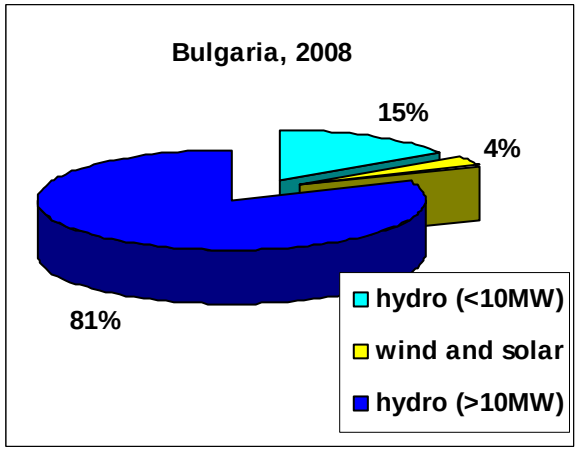


Figure 1: Electricity production in Bulgaria



…Figure 2: Electricity generation by renewables

thermal water supply, bottling of potable water and soft drinks and for some technological processes.

Thermal water application has been promoted during the last 5 years due to the alleviating permit regime and normative requirement for a complex use of thermal waters and geothermal energy reflected in the tariff system.

The official registers of issued permits for state-owned thermal waters and issued concessions for state-owned and municipality-owned thermal waters have been uploaded in the Internet. They are also currently updated which creates a base for a reliable information.

Polices and incentives concerning geothermal include utilization of existing wells, reduction of VAT by 2 percent and reduction in income tax by 3 percent. (http://ebrdrenewables.com/sites/renew/countries/Bulgaria/profile.aspx).

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 et al., 1971).

Bulgaria is divided into three major hydrogeological units: Moesian plate, Sredna gora zone (incl. Balkan zone) and Rila-Rhodopes massif, Fig.3. The Moesian plate has a Caledonian-Hercynian basement and a cover of Upper Paleozoic and Mesozoic sediments.

Their thickness decreases from about 6-7 km in the west down to several hundred meters in the east. The main geothermal reservoirs in the platform area are situated in 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 high permeability. The Sredna gora zone is a rich and heterogeneous hydrothermal region where unstratified (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.

The western Rila-Rhodopes massif is mainly built of Precambrian metamorphic and granite rocks, fractured by a dense system of seismically active faults. Unstratified hydrothermal systems with thermal waters of low salinity, meteoric origin and of highest measured 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 materials in the deep Neogene and Paleogene grabens also contain thermal waters. The eastern part of the massif is not rich in thermal waters.

Three types of reservoirs are found out in the country - stratified, fractured and mixed (water from a fractured reservoir is secondarily accumulated in a younger sediment reservoir). The total hydrothermal potential is defined as the thermal energy contained in the discovered thermal waters and amounts to 9 957 TJ/year (Petrov et al, 1998). It has been calculated for output temperature of 15^{o}C.

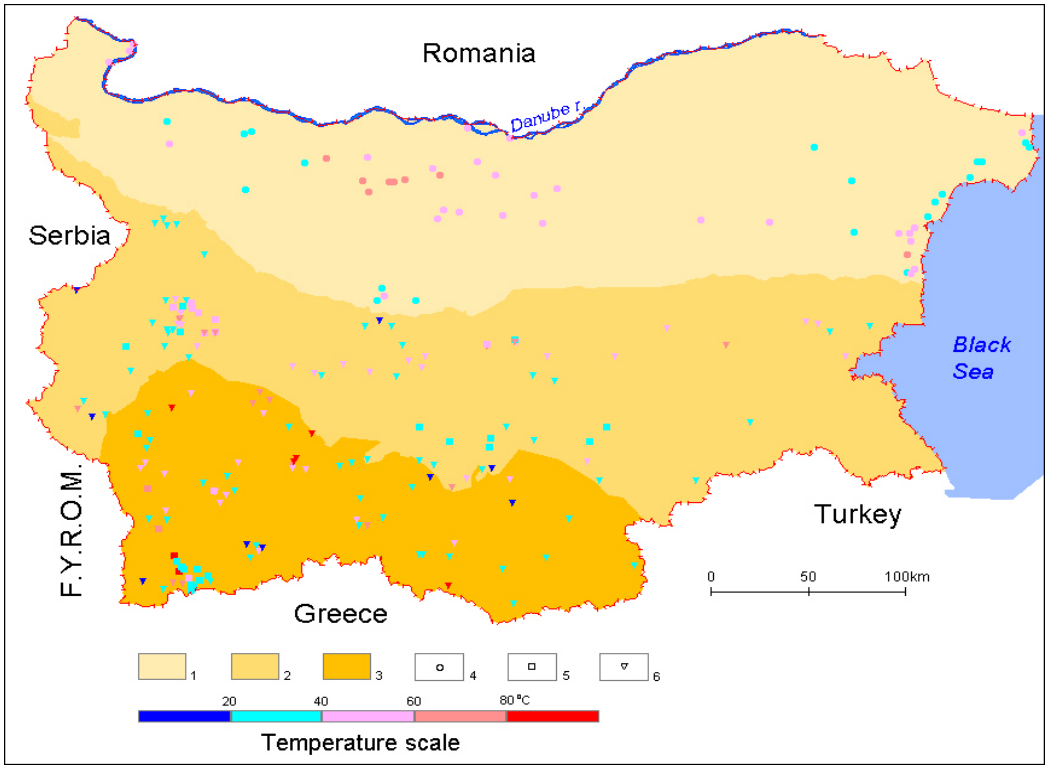
The most perspective regions for geothermal application are located in the central and eastern part of Moesian plate (J_3-K_1^V horizon) and in the Rila-Rhodopes massif, (Bojadgieva et al., 2005).

Nowadays, the mostly utilized thermal waters are in five hydrothermal basins, (defined by Petrov et.al. 1998): North-east Bulgaria basin and those in South Bulgaria - Chepino, Sandanski, South Sredna Gora and Razlog. They account for 47% of the total thermal water flow rate in use in Bulgaria.

3. RESOURCE CHARACTERISTICS

The basis for resource reassessment was data taken from about 160 hydrothermal fields located all over the countries, of which 102 are state-owned.

The water temperature of all discovered reservoirs in Bulgaria ranges between 20°C and 100°C. About 43% of the total flow rates are waters of temperature between 40^{o}C-60^{o}C. The total dynamic flow rate of sub-thermal and thermal waters runs up to 4600 l/s, (Petrov et.al., 1998).



1. Moesian plate (stratified reservoirs)

2. Sredna goraSredna 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

Figure 3: Map of hydrothermal deposits of Bulgaria

Ministry of Environment and Waters is managing only state-owned thermal waters and their total discovered resource estimated in March, 2009 was 1914,3 l/s. During the last five years the exploitable part of it hasn't significantly changed varying between 25 and 28%, Fig. 4. Systematic information on municipality-owned thermal waters is still not officially available.

Established chemical water content (TDS) varies respectively, in: - Southern Bulgaria it is from 0.1g/l up to 1.0 g/l (only for a few sites it is between 1 g/l to 15g/l) and in Northern Bulgaria - from 0.1g/l up to (100g/l - 150g/l). About 70% of the thermal waters are slightly mineralized (<1g/l) with fluoride concentration ranging from 0.1 to 25mg/l, various metasilicic acid concentrations (up to 230mg/l) and of mostly low alkalinity. In comparison to most of the European mineral waters, the Bulgarian ones have a lot of advantages: low TDS close to the optimal one typical for potable water, high purity level especially in terms of anthropological pollution, microbiological purity and a variety of water types (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.

4. GEOTHERMAL UTILIZATION

The share of flow rate used for different types of applications is presented on Fig.5. The utilized water quantities are calculated based on the issued permits and concessions for the state-owned thermal waters. At present, about 80% of the used thermal water quantities are regulated by permits.

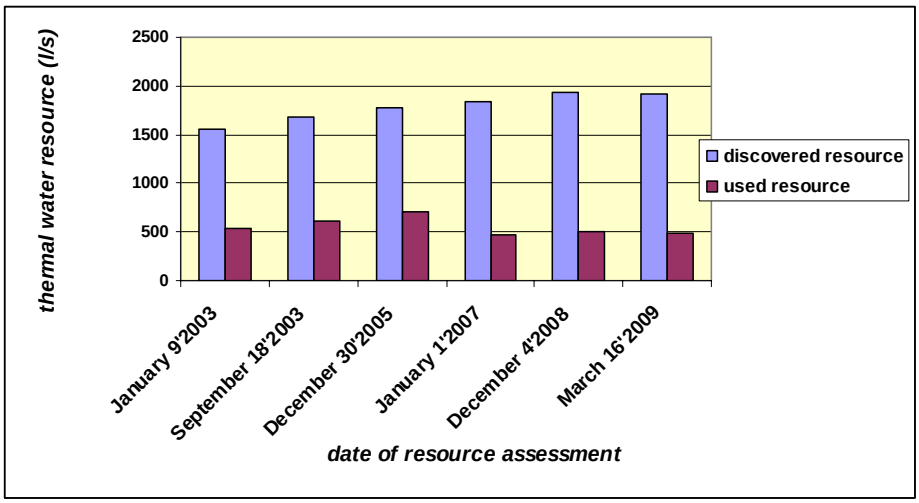


Figure 4: Discovered and used resource for state-owned thermal waters during the period 2003-2009

The highest flow rate currently belongs to balneology (56%), followed by direct water supply (19%) and space and greenhouse heating – totally 17%. In our analysis we integrate all applications like prevention, treatment, rehabilitation, swimming pools, sanitary needs, relaxation, drinking water out of taps only in one category – balneology. Drinking water out of taps allows massive use for disease prevention. Utilized water for relaxation and sanitary needs has the highest share in balneology due to the existing intensive hotels construction currently going on in the mountain and sea resorts. The sites that are not registered according to the Law on Medical Institutions and utilize thermal water for swimming pools, sanitary needs and prevention get permits for relaxation. Permits issued for treatment and rehabilitation are of lower fee paid for water use – (0, 08 – 0, 26) EURcents/m^3, compared to permits for relaxation – (0.13 – 0.51) EURcents/m^3.

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 – Golden sands, Albena, Kavarna and Balchik.

A number of large spa resorts had developed in places of old Thracian and Roman residential areas on the territory of the country. They offer accommodation in 3 to 5 stars hotels and a built up structure of health centers controlled by the Ministry of Health. Geothermal energy is currently used for space heating of public buildings only in 8 spas as in 4 of them air- conditioning is provided in addition.

Geothermal activity is mainly concentrated in the southern part of the country due to the higher water temperature there and low water salinity (TDS), mostly below 1g/l. The cultivation of microalgae and production of iodine paste and methane extraction have been terminated.

The total installed capacity for direct heat use (excl.GSHP) runs up to 77, 67 MWt, which is about 30% less compared to the previous 5-years period.

According to the available information, geothermal energy for individual space heating and air-conditioning is presently used in 11 state-owned reservoirs. It has decreased drastically during the period 2005-2010 and the total installed capacity was reduced to about 16 MWt. Heating installations are assisted by plate heat exchangers. In addition they prepare domestic hot water and are in operation for about 200 days/year. Direct scheme systems still exist in several sites, but they are of small capacity, in bad technical conditions and are excluded from the estimation of total installed capacity.

The number of greenhouses has been also reduced during the reported period. The approximate total area covered by geothermal greenhouses is now about 6,5 ha and the total installed capacity reaches 6 MWt. Greenhouses are in operation in 7 sites and produce mainly vegetables and flowers. This application has no current development for the lack of investments, lost foreign markets and some land ownership problems. Only one new greenhouse cultivating flowers was built during the last five years in Poljanovo (SE Bulgaria) (Fig.6).

The intensive building of new hotels in Bulgarian resorts resulted in construction of indoor and outdoor swimming pools. At the same time many old ones have been closed. Swimming pools using state-owned thermal water currently exist in 34 sites according to the issued permits. Municipality-owned thermal water is used in 4 sites.

Bottling of mineral water has preserved its level compared to the previous 5 years period. This activity is regulated by the Law on Concessions. About 24 bottling plants using state-owned waters and 11, using municipality-owned waters, are currently in operation, (Fig7). Their production meets mainly the demand of the local market. Several major reasons for high development rate of bottling exist due to the: - predominant thermal waters of low TDS (<1 g/l); - big variety of water chemical content that provides opportunity for bottling of potable water as well as of mineral water for drinking in prescribed doses; - short-term payback period. Bottling activity is very profitable also because the water purchasing price is low and amounts to 2.5 USD/m^3.

Information on investments for space heating during the last five years was published by the Ministry of Economy and Energy. They amount to about 2,729 mills. EUR and of them 20% are covered by the Bulgarian Energy Efficiency and Renewable Energy Credit Lines through EBRD (www.mee.government.bg).

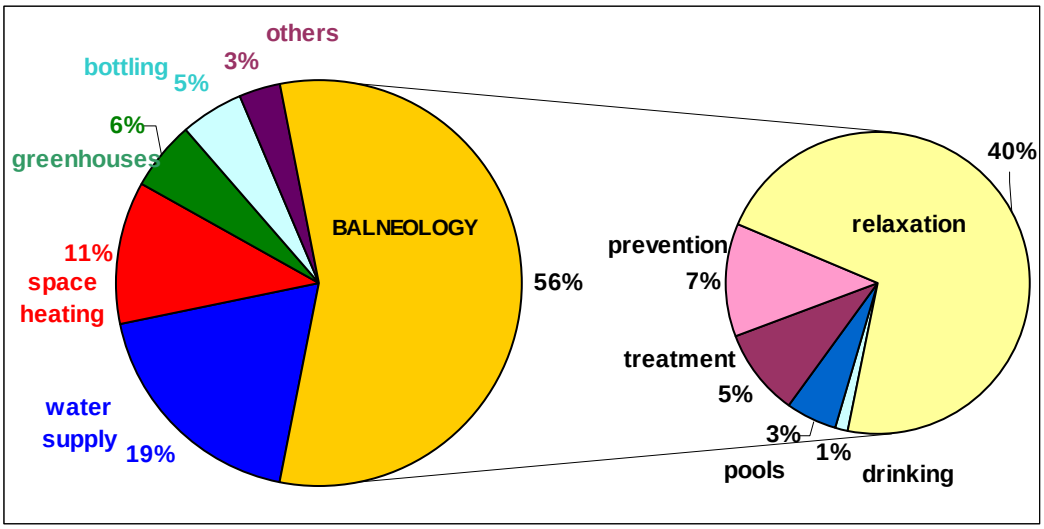


Figure 5: Used flow rates by application (towards 2009)

Figure 6: Newly built greenhouse for flowers (Polyanovo, SE Bulgaria)

Figure 7: Newly built plant for bottling of potable water (G. Delchev town, SW Bulgaria)

The use of low-grade geothermal energy for seasonal heating and cooling has been intensively developing during the reported period. The application of geothermal ground source heat pumps is carried out by private companies and very often is only one sector of their activity. The data on existing installations are collected from the published information in Bulgarian Internet sites and doesn't give an overall picture of their number but confirm the progress of this application.

Several companies have been published general data on their systems. Most actively presented on the market are Geosolarv 63 Ltd, Mix2000 Ltd, Esco-Engineering Ltd and Nelbo-Engineering Ltd. Some of the installations are combined with solar panels for domestic hot water preparation. Open and closed loop systems with vertical or horizontal collectors have been implemented. The inside installations include under floor radiant heating or fan coils. The installed capacity of the GSHP systems presented in the Internet sites varies from 6-7 to 590 kW. The total installed heating capacity of the reported systems amounts to 20, 63 MW.

Ground source heat pumps are assembled in family houses, blocks of flats, hotels and restaurants, office buildings (Fig.8), sport complex, auto-service and industrial buildings in different regions of Bulgaria. A system for snow melting has been also constructed.

5. REGULATORY FRAMEWORK

The general structure of regulatory framework has been presented in Bojadgieva et al., 2005 and no changes have been made during the last five years period. For this reason only new legislative and regulating steps concerning RES are discussed in the paper.

Some amendments have been made in the Law of Energy and Law on Territory Planning during the period 2007-2008 aiming at securing stable electricity production from renewables.

During the same period a new Law on Renewable, Alternative Energy Sources and Biofuels has been adopted.

Figure 8: GHP heating and cooling of an office building (Sandanski town, SW Bulgaria) (heating capacity - 22,5 kW, cooling capacity- 25,0 kW)

Two acts for its application have been issued as well. The promotion of electricity generation from RES is regulated by this law through introducing compulsory joining of renewable electricity producers to the national distribution grid and by fixing preferential energy purchasing prices.

Some measures have been taken towards facilitation of administrative regulation of RES energy production and construction of needed grid connections. The companies dealing with electricity transmission and distribution include in their yearly investment resources for repair and grid development.

According to the Law on Energy no license is required for electricity producers from renewables in case the installed capacity of the energy station is up to 5 MW. License for higher installed capacity is issued for a period of 35 years.

6. DISCUSSION

The primary energy production from domestic sources hasn't changed considerably during last five years. The highest shares get coal (49%) and nuclear - 38,3 %, (National Statistical Institute,2009), Fig.9. The contribution of renewable sources is jointly presented with hydropower – totally 2,9%. Only biomass (wood combustion) is given separately from other RES (7,1%).

According to the published report by the Ministry of Economy and Energy a target of 16% share of RES in 2010 could be achieved mainly by increasing the contribution of hydro power plants (>10 MW).

A National Program promoting development of renewable energy sources for the period 2007-2015 has been approved. It is focused on the reduction of electricity and liquid fuels as sources for heating and their replacement with renewables.

The role of the Bulgarian Energy Efficiency Fund has been growing during the reported period**.** It has the combined capacity of a lending institution**,** a credit guarantee facility and a consulting company**.** No geothermal project has been funded by the fund till now.

A State Commission for Energy and Water Regulation issues licences and sets compulsory preferential purchasing prices for electricity generation from renewables. The prices are formed based on the analysis of investment expenditures by technology, expenses for energy generation by technology and the rate of capital repayment. No purchasing prices are available for electricity generation from thermal waters because such activity is still missing in the country.

A substantial problem in RES development in the country is the lack of coordination of this process. Still, no official register for renewables application (except for geothermal) is available.

Among different types of geothermal application only balneology (prevention, treatment, rehabilitation, swimming pools and relaxation) and ground source heat pumps have shown a growth. High quantities of thermal water have been used to meet the demand of potable and domestic water for the resorts on the Northern Black sea coast. The total installed capacity for direct heat use (excl.GSHP) runs up to 77,67 MWt, which is about 30% less compared to the previous 5-years period.

The cost of 1 kW installed capacity implied from several newly built installations amounts to about 600 EUR. According to the data from existing systems heating with geothermal energy is compatible with conventional energy sources (Bojadgieva, 2005, Phare project, 1997). The cost of produced thermal energy by using geothermal ground source heat pumps is about 2 EURcents/kWh.

The use of heat pumps air-to-water type has still remained a quicker solution for the construction of new buildings than water-to-water heat pumps. Consumers do not need to apply for well drilling permits and to start a procedure for issuing water permits.

According to the amendments in the Law on Water from 2006 the fee payable for thermal water use is formed depending not only on the quantity used (as it has been till now) but also on the water temperature. Thus, the complex resource utilization is promoted. Besides, the concession regime is applied only for thermal installed capacity above 5 MWt, while for smaller systems a permit regime is in force.

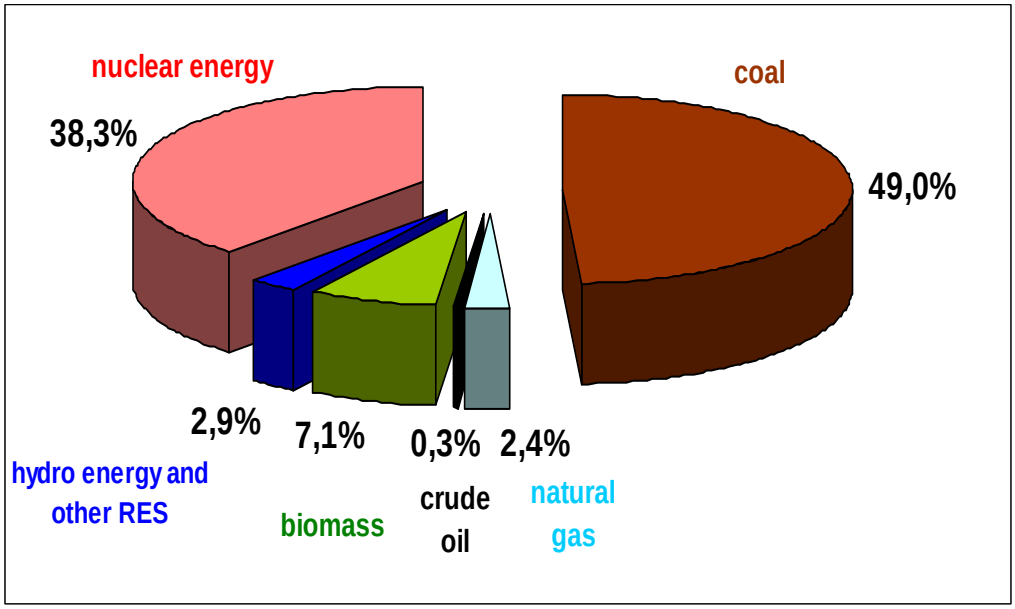


Figure 9: Primary energy source in the energy balance of the country

A project "Identification of key barriers for the utilization of the national geothermal resources in Bulgaria and site case studies for Velingrad, Sapareva Bania and other geothermal heating systems" has been completed in consortium with COWI, Denmark. It was financed by a grant received under the Japan Climate Change Initiative Programme – Japanese Trust Fund. Site case studies have been developed for 11 geothermal reservoirs. Total installed capacity of 14,89 MWt with annual heat utilization of 37855 MWh/year have been calculated for several perspective sites in selected geothermal areas. Their total investment cost was estimated to reach 3520 718 EUR. The pay back period for 7 of them would vary in a range of 2,4 to 8,5 years.

A new innovated project "Redevelopment of European Mining Areas into Sustainable Communities by Integrating Supply and Demand Side based on Low Energy Principals" Under the 6 Framework Program of EC – Concerto II started in 2007. Four local communities – Heerlen (Netherlands), Zagorje (Slovenia), Czeladz (Poland) and Bourgas - Cherno more (Bulgaria) will demonstrate the use of available low valued renewable energy sources from water in abandoned coalmines for heating and cooling of buildings.

Major current barriers stated for the previous 5 years period for the geothermal development in the country remain the same:

- Lack of preferential status to the use of geothermal energy for heat production.
- Lack of expertise in preparation of exploration and business plan.
- Insufficient commercial financing.
- Local taxes and fees are important but very insufficient source of funds for the Municipalities budgets.
- Lack of investments and organizational problems are still the major obstacles for the geothermal development in the country

6. FUTURE DEVELOPMENT

The application of ground source heat pumps would continue to grow particularly concerning private and business buildings. Spa centers located in the mountains and on the Black sea coast would also increase the share of thermal water in their activity and the type of applications as well. A process of reassessment of the existing geothermal resource regarding possibilities for electricity generation by using modern technologies is in progress.

ACKNOWLEDGMENTS

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REFERENCES

Bojadgieva,K., Hristov,H.,Hristov,V., Benderev,A. and V.Toshev: Geothermal update for Bulgaria (2000-2005). *Proceedings* World Geothermal Congress 2005, Antalya, Turkey, 24-29 April2005 (2005).

List of geothermal resources - public state property – Appendix No.II to the Law on Water.

Yovchev.Y. (ed): Tectonic structure of Bulgaria. PH.Technika,S. pp.558 (1971).

National Statistical Institute: Energy balances'2007, (2009)

Petrov,P. et al.: Reassessment of hydrogeothermal resources in Bulgaria, Report for the Ministry of Environment and Waters, National Geofund, Sofia, Bulgaria (1998). (in Bulgarian).

Phare Project BG 9307-03-01-L00: Report Writing: Technical and Economic Assessment of Bulgarian Renewable Energy Resources. Ministry of Energy and Mineral Resources, Sofia, Bulgaria, (1997).

Vladeva,L. and Kostadinov, D.: Bulgarian Potable Mineral Waters,I part, M-8-M, S.pp.175, (1996) (in Bulgarian)

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2009			6205	25 772,90	2729,4 (incl. PSHPP*)	2799,9	2000	15 765,10	317,7**	649,7	11252,1	44987,6
Under construction in December 2009					80 (HPP>10 MW)	158						
Funds committed, but not yet under construction in December 2009												
Total projected use by 2015									25 (SHPP <10 MW)	142		46890

* PSHPP - pumped storage hydro power plant
** wind -112,6 MWe, solar - 0,1 MWe, small hydro power plants (SHPP) (<10 MW) - 205 MWe
(Source: Ministry of Economy and Energy)

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT
AS OF 31 DECEMBER 2009 (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. (^{o}C) - outlet temp. (^{o}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. (^{o}C) - outlet temp. (^{o}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 (^{o}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	24,26	36,24	25			1,14	11,64	17,26	0,48
2. Lovech and Tarnovo districts	B, H	50,69	44,64	30			3,11	23,82	46,01	0,47
3. Varna and Shumen districts	B, H,G,O	498,92	37,76	29			18,26	299,35	345,78	0,60
4. Kjustendil and Pernik districts	B, H, O	78,06	80,31	40			13,17	28,72	152,69	0,37
5. Sofia city and Sofia district	B, H	78,78	53,13	40			4,33	35,45	61,40	0,45
6. Blagoevgrad district	B, H,G,O	168,6	62,5	40			15,87	57,34	170,17	0,34
7. Smoljan district	B, H	20,88	57,74	40			1,55	8,35	19,54	0,40
8. Pazardjik district	B, H, O	151,27	50,96	34			10,74	63,53	142,13	0,42
9. Plovdiv district	B	74,37	43,66	32			3,63	31,23	48,04	0,42
10. Stara Zagora district	B	52,31	49,41	34			3,37	23,02	46,78	0,44
11. Sliven and Haskovo districts	B,G	17,05	59,82	40			1,41	7,5	19,60	0,44
12. Bourgas district	B,G,O	30,13	38,48	30			1,07	12,95	14,49	0,43
TOTAL		1245,32					77,67	602,9	1083,89	0,44

* The districts represent a new territorial division of the country

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

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.

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	from 6 to 590 *	543	V,H,W	3,2	3854	286,23	201,36

* Installed capacity range
** Data on GSHP are taken from Internet sites and are tentative.

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

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 0.1315 (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

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)]	9,28	128,56	0,44
District Heating [4)]			
Air Conditioning (Cooling)	6,7	65,5	0,31
Greenhouse Heating	5,99	88,68	0,47
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]			
Snow Melting			
Bathing and Swimming[7)]	48,78	768,32	0,51
Other Uses (specify)	6,92	32,83	0,15
Subtotal	77,67	1083,89	0,44
Geothermal Heat Pumps	20,63	286,23	0,44
TOTAL	98,30	1370,12	0,44

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 (2009) 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 (state funded)		0,091 (PHARE Program)			
2000-2004	0,77 (Japanese Trust Fund)					
2005-2009	0, 091 (EC)		3,817 (EBRD)			