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Geothermal Update for Bulgaria (2000-2005)

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ABSTRACT

Geothermal development in Bulgaria has not marked a significant progress in last five years. It has been a time of testing and completing the new legislation concerning thermal waters and geothermal energy use. During this period the Government paid more attention to renewable energy development and some legal steps promoting it have been taken.

Bulgarian territory is rich in thermal water of temperature in the range of 20^{o}C-100^{o}C. About 72% of the total discovered flow rate has temperature up to 50^{o}C. Electricity generation from geothermal water is not currently available in the country.

The total installed capacity amounts to 109.7 MWt and the annual energy use is 1671.43 TJ/year (incl. balneology).

Major direct geothermal uses nowadays cover: balneology, space heating and air-conditioning, domestic hot water supply, greenhouses, swimming pools, bottling of potable water and microalgae cultivation. Several of them exhibit more stable development at the current stage and are discussed in more details. The update information on the state-owned hydrothermal fields' use is based on issued permits and concessions by the state. Revision of the application of hydrothermal fields controlled by the Municipalities has not been completed yet.

Lately most of the new administrative and one-family buildings have been designed for low temperature heating systems (50^{o}C/45^{o}C, 45^{o}C/40^{o}C) applying air-to-water heat pumps and fan coils for the internal installations. The application of ground source heat pumps has expanded during this period.

Main legal barriers for geothermal development in the country are also discussed.

1. INTRODUCTION

Thermal waters are integral part of the total water resources in Bulgaria but due to their particular qualities they are treated separately by the legislation.

According to the Water Law (1999) thermal waters are owned by the State or by the Municipalities. Ministry of Environment and Waters (MOEW) approves the exploitable thermal water resources and hydrothermal energy and sets up the wellhead protection zones of all reservoirs (state-owned and municipal). Ministry of Health controls mineral composition and general state of all water sources.

State-owned thermal waters are administered by the Council of Ministers according to the Concession Law (1995) through concession regime and by the MOEW – according to the Water Law (1995) through permission regime.

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

There is no specialized company in Bulgaria operating only in the field of geothermal energy. The organizations dealing with thermal waters and geothermal energy are predominantly private and are involved in two basic fields. The first one is associated with the exploration, investigation and assessment of hydrothermal resources and the second – with design and construction of geothermal systems. Specialists from Bulgarian Academy of Sciences, Sofia University and other High Schools also take part in geothermal energy development in Bulgaria.

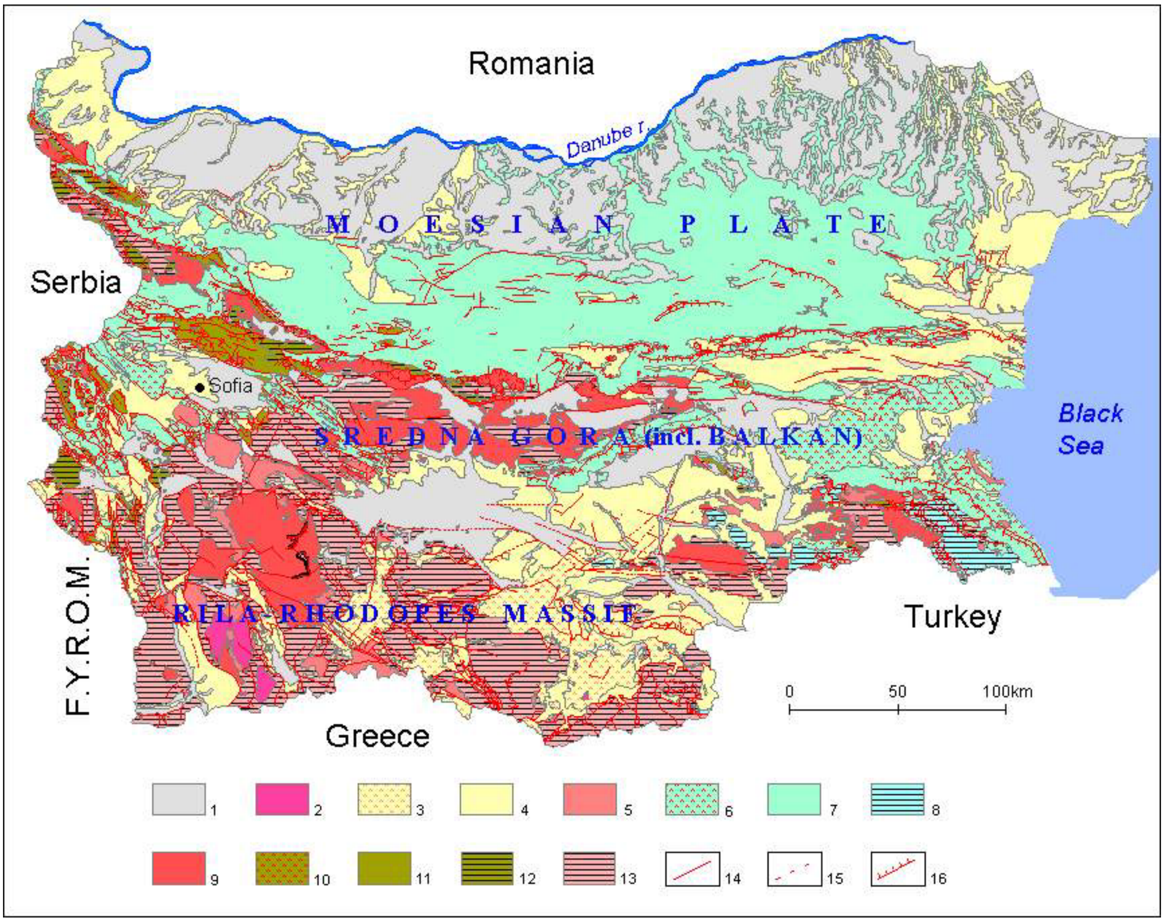
2. GEOLOGICAL BACKGROUND

Bulgarian territory is characterized by a complex and diverse geological structure, Fig1. It is built of rocks of different origin, various lithologic and petrologic compositions and of Quaternary to Archean and Proterozoic age.

Bulgaria is divided into three major hydrogeological units: Moesian plate, Sredna gora zone (incl. Balkan zone) and Rila-Rhodopes massif, Fig.1 and 2. 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 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.

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°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.



1. Quaternary unconsolidated deposits	**9. Paleozoic intrusive rocks**
2. Neozoic intrusive rocks	**10. Paleozoic volcanic and volcano-sediment rocks**
3. Neozoic volcanic and volcano-sediment rocks	**11. Paleozoic sediment rocks**
4. Neozoic sediment rocks	**12. Paleozoic metamorphic rocks**
5. Mesozoic intrusive rocks	**13. Prepaleozoic metamorphic rocks**
6. Mesozoic volcanic and volcano-sediment rocks	**14. Faults**
7. Mesozoic sediment rocks	**15. Assumed faults**
8. Mesozoic metamorphic rocks	**16. Line of overthrust**

Figure 1: Geological map of Bulgaria

3. GEOTHERMAL RESOURCE AND POTENTIAL

Hydrothermal data come from prospecting carried out in hundreds of exploratory and production wells and from springs. Most temperature measurements are taken in wells drilled for oil, gas, coal and minerals. The depth of wells ranges from 100 m to 5000 m in Northern Bulgaria and from 100 m to 1500 m in Southern Bulgaria.

3.1. Resource Characteristics

The basic characteristics of geothermal water on the territory of the country have been reassessed and updated within the period 1994-1998 by extensive study carried out by the scientists from the Geological Institute under Bulgarian Academy of Sciences. 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 the discovered reservoirs ranges between 20°C-100°C.

The total dynamic flow rate of sub thermal and thermal waters run up to 4600 l/s (Petrov et.al., 1998), of which 3000 l/s is the flow rate of the revealed thermal waters of T>25°C.

About 43% of the total flow rate are waters of temperature between 40°C-60°C.

According to Petrov et al.(1998) a new drilling could discover about 2300 l/s of recoverable resource in addition.

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 to 15g/l)

- 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).

3.2. Hydrothermal Deposits

The main hydrothermal deposits in Bulgaria are plotted on Fig.2. They are grouped in three major hydrothermal units: Moesian plate, Sredna gora zone (incl.Balkan) and Rila-Rhodope massif.

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

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 Rila-Rhodopes massif, Table1. Nowadays, thermal sources, situated on the northern Black Sea coast, are mainly utilized. Still partially used are the reservoirs of high thermal potential located in the western part of the Rila-Rhodopes massif (Southern Bulgaria). 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°C.

4. GEOTHERMAL UTILIZATION

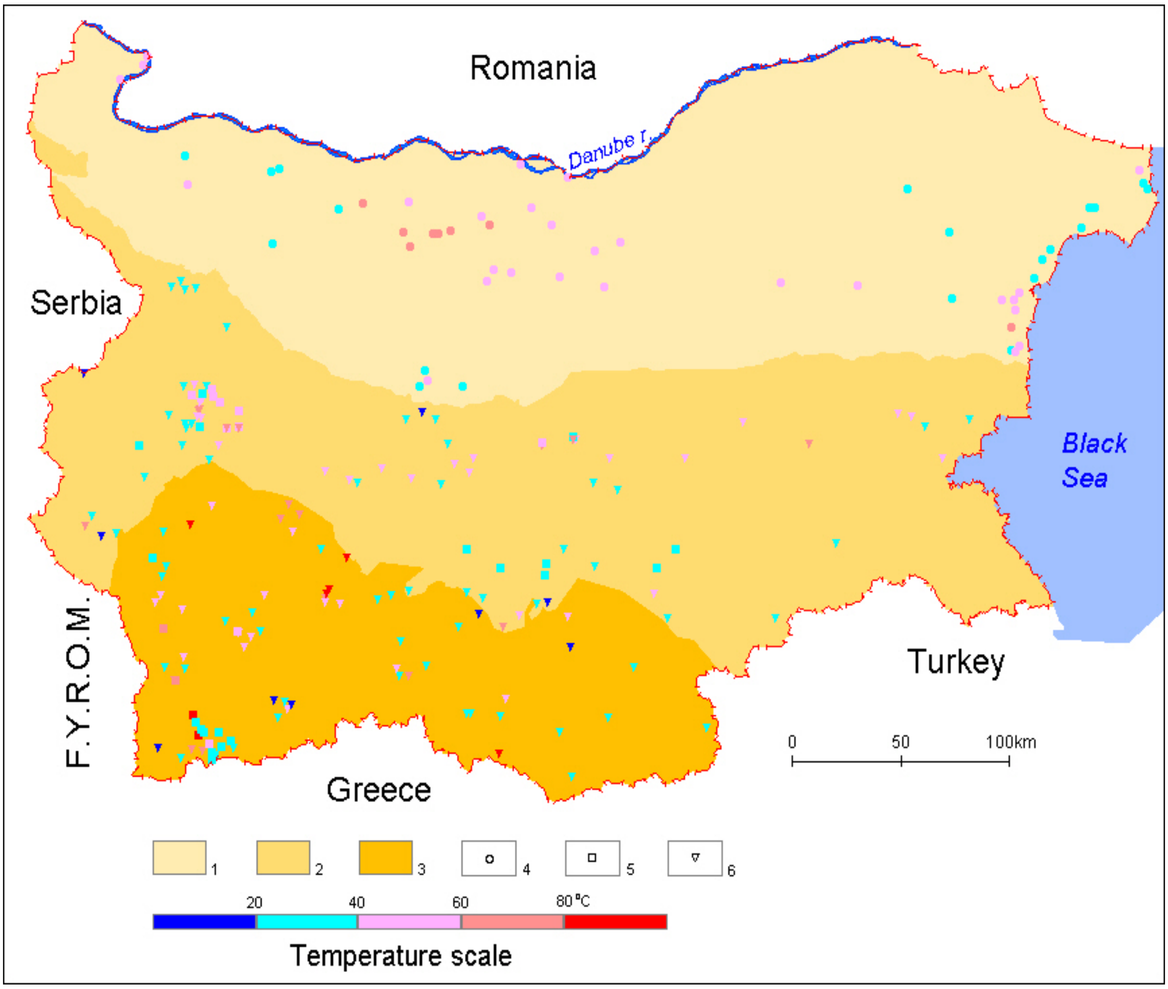
Geothermal energy in Bulgaria has various direct applications and no electricity generation so far. During ancient times thermal waters had been utilized mainly for healing, disease prevention, washing and bathing. As early as Roman times waters were used on a large scale for under floor heating in Public baths (hypocausts).

Currently thermal water application is mainly in balneology, space heating and domestic hot water supply, greenhouses, swimming pools, bottling of potable water, aquaculture (microalgae) and extraction of chemical derivatives. The total installed capacity amounts to 109.70 MWt (incl.balneology). The annual energy use is 1671.43 TJ/year (at average load factor 0.48).

A small enterprise for production of iodine paste and methane extraction is in operation near Varna city (Northern Black Sea coast).

State-owned water sources have a leading role in geothermal application of the country. The different types of their utilization are presented on Figure 3.

These data are based on the delivered concessions and permits by the Ministry of Environment and Water.



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**

Figure 2: Map of hydrothermal deposits of Bulgaria

Thermal waters of temperature in the range of (30-50)^{o}C are used in 48% of all applications. About 74% of the installations are built on fields of flow rate up to 20 l/s.

Currently are utilized only 37% of the state-owned thermal waters.

Most of thse reservoirs are not used to their full potential. The prevailing number of sites (43) are with one or two applications in them.

4.1 Balneology

A number of large spa resorts had developed in places of old Thracian or Roman residential areas on the territory of the country. Bulgarian spa resorts nowadays offer accommodation in 3 to 5 stars hotels and a built up structure of health centers controlled by the Ministry of Health. Highly experienced specialists working in spas offer treatment of a wide range of diseases (Bojadgieva et al.,2002). Currently operating health centers using thermal water sources (state-owned and municipal) amount to about 60. Mineral baths and swimming pools are common in them. Thermal waters in most of the spas also flow out of taps. This allows a free-of-charge and massive water use for drinking and disease prevention. Geothermal energy is currently used for space heating of buildings only in 12 spas as in 4 of them air- conditioning is providing in addition.

Table 1: Hydrothermal resource (Petrov et al., 1998)

N	Major hydrothermal units	Water temperature,degC	Total flow rate, l/s	Thermal potential, kJ/s
1	**Moesian plate (total)**	**21.5 - 71**	**1 241.6**	**101 482**
	Lom basin*	29.8 - 35.9	3.04	193
	Central Northern Bulgaria and Balkan Foreland zone*	21.5 -71	191.1	5 819
	J_3 -K_1 horizon	22 - 50	1012.9	92 891
	West Balkan	24.9 - 38	34.6	2 579
2	**Sredna gora, incl.Balkan (total)**	**20.5 - 78**	**669.4**	**85 960.5**
	West Sredna gora	23.5 - 67.5	241.7	27 058.6
	Dolna banja basin	42 - 72	47	8 846
	Central Sredna gora	20.6 - 78	211	27 402.8
	East Sredna gora	22 - 77	81	10 128.5
	Upper Thracian basin and Sakar-Strandja zone	20.5 - 51	26.5	2 763.6
	Kraishte zone	22.4 - 75	62.2	9 761
3	**Rila-Rhodope massif (total)**	**20 - 98**	**1015.8**	**128 291.6**
	Struma region	20 - 98	254.6	49 156
	Mesta region	25.5 - 55	265.93	24 331.7
	West and East Rhodopes	20.6 - 95	495.3	54 803.9

*Resource potential is assessed only for wells in exploitation

4.2 Space heating

Geothermal space heating marked insignificant progress in the last decade although it is of a high environmental importance especially in the spas mostly situated in mountainous and sea resorts. Several small new buildings using simple schemes have been heated in the last five years.

Lack of investments, some legal and organizational problems are the major obstacles for the geothermal development in the country.

Currently going process of managing water resources through concession regime has set the geothermal development on a new basis. About 26 concessions have been delivered for geothermal energy use of the state-owned sources within last 5 years. The new managers declared their intention to provide more complex thermal water application but for the time being mostly renovation of the existing systems are carried out.

4.3 Greenhouses

Geothermal greenhouses practically have no current development for the lack of investments, lost foreign markets and some land ownership problems. At the same time gas supply development is getting a strong competitor and in most cases gas heating provides cheaper greenhouse production compared to the geothermal one. The approximate total area covered by geothermal greenhouses (about 20.7ha) is close to that reported in Bojadgieva et al. (2000). Greenhouses in 11 sites are currently in operation.

4.4 Swimming pools

Reconstruction of swimming pools has marked a progress in the last years and the number of newly built outdoor pools has increased as well. Swimming pools have been built in 44 localities using state-owned water sources. This application is usually a part of complex thermal water utilization for domestic purposes, treatment and rehabilitation.

Figure 3.Types of geothermal water application (for state-owned hydrothermal sources)

4.5 Bottling

The number of bottling companies has increased during the last ten years from 3 state-owned (before 1990) to 41 private enterprises nowadays. 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.

This activity is very profitable also because the water cost is low and amounts to 2.5 USD/m^3.

4.6 Ground source heat pumps

Recently the use of low-grade geothermal energy for seasonal heating and cooling has marked a significant progress.

The first installation of that kind was built in Sofia city in 1999, Hristov and Bojadgieva (2003). About 18 new installations assisted by ground source heat pumps have been recently designed and constructed by private company Geosolar V-63 Ltd., member of the European Heat Pump Association (Kolikovski, 2004), Fig.4 and Fig.5. The heat pumps are made in Bulgaria including efficiency Compliant & Scroll Copeland compressors. The installed capacity varies from 7 to 45 kW. The COP is in the range of 3,5 - 4,5. Ground water temperature varies from 11 to 14 ^{o}C. Another two installations of 60 kW heating capacity are under construction.

The existing systems are located mainly in Sofia city and provide space heating and domestic hot water supply for single apartments and family houses. About half of the installations are operating in a cooling mode.

Figure 4.Family house heated with ground source heat pump (Sofia district)

Figure 5. Internal installation

4.7 Aquaculture

The installation for open maicroalgal mass cultivation located in Roupi region (SW Bulgaria) is a successful example for geothermal application in the county for more than 35 years, Fig.6.

The use of geothermal water in algal technology provides a high optimization of the cultivation process and considerable reduction in production costs, Fournadzieva et al.,(2003).

New products have been released on the local market in the last several years - pills enriched in Ca and Mg and various shampoos, face and hand creams.

Figure 6. Open mass cultivation of Spirulina (Roupi area, SW Bulgaria)

5. DISCUSSION

The primary energy production from domestic sources hasn't changed during last five years. The highest shares get nuclear and hydropower (52.5%) and coal (41.2%), National Statistical Institute, (2004). The contribution of renewable sources has not been considered in the recently published issue of the country energy balances (except for some wood residuals) and it is less than 1% of the primary energy production.

The installed capacity for geothermal energy use in Bulgaria is in the first place compared to other renewables, excluding hydro-electrical stations of capacity (>10 MW). The fossil fuels saved due to the utilization of geothermal energy are estimated at up to 39 921 TOE/year (Phare Project, 1997). According to the published energy balance of the country it is similar to the share of crude oil - 38 000 TOE/year (for 2002).

Among different types of application only bottling of mineral water and ground source heat pumps have shown a growth.

Nowadays the use of heat pumps air-to-water type has proved to be 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 water application. The cost of geothermal energy produced by the existing systems varies from 1.3 to 3.1 US cents/kWh, Phare Project, (1997). The payback period for these systems varies from 2.5 – 8 years. The cost for well drilling is not included. These data concern the installations constructed before 1990. Recently estimated geothermal energy prime cost is competitive to the thermal energy produced by heat power plants on fossil fuels.

For example, the cost of subsidized thermal energy for district heating in Sofia city is 2.6 US cents/kWh, while the cost of unsubsidized thermal energy including WAT amounts to 4.2 US cents/kWh.

5.1. Regulatory framework and state policy

Until 1990 the geothermal systems were entirely financed by the state. Bulgaria has no specific legislation for geothermal energy. Regulations exist however for obtaining permits and concessions, and there are guidelines in place for geothermal exploration. Thermal waters as a product of the bowels of the Earth are under the jurisdiction of the Constitution and the Water Law. The following laws govern the use of geothermal waters for energy purposes: Law on Waters, Law on Concession, Energy and Energy Efficiency Law, Law on Territorial Structure and Municipality Property Law.

The Law on Waters states that the sole right for the use of waters is owned fully by the State and may be delivered via concession only for mineral waters when the use is for bottling, energy generation and extraction of chemical elements and derivatives.

Permits issued by the Minister of Environment and Water are required for state-owned thermal waters used for treatment, rehabilitation and prevention, swimming pools, thermal water supply for domestic, technical and industrial aims.

The Law on Concessions regulates the conditions and order for delivery of concessions. They are awarded on the basis of a tender and are issued for up to 35 years. The Consul of Ministers issues geothermal licensing.

Energy and Energy Efficiency Law states that electricity produced by renewable energy sources or combined-heat power plants (CHP) may be purchased at a preferential price, which is defined by regulations accepted by Energy Regulation Commission under the Council of Ministers.

A fund called "Energy Efficiency and Renewables" has been set up under the supervision by the Minister of Energy and Energy Resources in order to promote these energies.

Major current barriers for geothermal development in the country are:

Lack of administrative and practical expertise in geothermal development under the new social and economic conditions in Eastern Europe after 1990.

The procedure for obtaining a concession for water use is very complicated and time consuming. In some cases, the investors have to finance complex preliminary geological and hydrogeological study without having guarantee for gaining the concession after completing the procedure.

The investor who intends to utilize geothermal energy is expected to develop simultaneously other geothermal applications. The Government policy is encouraging customers for a cascade use but these requirements increase additionally investor's expanses often change their business plans.

Local taxes and fees are important but very insufficient source of funds for the Municipalities budgets. The Municipalities are also not allowed to influence on the size of these taxes.

6. FUTURE DEVELOPMENT

A new project funded by the World Bank ("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 just started.

The project achievements would form a base for promotion of systematic use of geothermal energy and to mitigate technical, legal and implementation risks.

The application of ground source heat pumps and air-to-water 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 develop towards achieving higher standards in treatment, services and tourism.

ACKNOWLEDGMENTS

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	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 2004	0	0	6628	21,971	2720	2376.14	2,880	17,278	154 wind and small hydro (<10 MW)	920.786	12,382	42,546
Under construction in December 2004												
Funds committed, but not yet under construction in December 2004												
Total projected use by 2010			770		80						850	

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

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

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

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] 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. (^oC) - outlet temp. (^oC)] 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 (kg/s)	Temperature (^oC) Inlet	Temperature (^oC) Outlet	Enthalpy[2] (kJ/kg) Inlet	Enthalpy[2] (kJ/kg) Outlet	(MWt)	Ave. Flow (kg/s)	Energy[4] (TJ/yr)	Capacity Factor[5]
Montana district	B,H	16.73	42	32			0.70	8.03	10.59	0.48
Lovech district	B,H	260.90	48	36			13.1	120.05	190.03	0.46
Varna district	B,H,C	607.10	45	30			38.1	364.37	720.90	0.60
Burgas district	B,H	83.65	40	30			3.5	36.82	48.56	0.44
Haskovo district	B,H,G	103.57	55	40			6.5	39.37	77.89	0.38
Plovdiv district	B,H,G	266.49	60	40			22.3	111.96	295.36	0.42
Sofia district	B,H,G	286.80	67	50			20.4	114.76	257.33	0.40
Sofia city	B,H	93.76	43	30			5.1	41.27	70.77	0.44
TOTAL	1719						109.7	836.63	1671.49	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

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.

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

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)

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

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

Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^{o}C) - outlet temp. (^{o}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. (^{o}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)
Sofia city	12.5	7.2	6	V-DX	3.6	2500	105	0
Sofia city	12.5	16.5	4	W	4.5	2500	165	72
Sofia city	12.5	17.5	1	V	4.1	2800	49	19
Sofia city	12.5	45.4	1	V	4.1	2500	112	35
B.Slatina town	12.0	28.3	1	W	4.5	2500	71	20
Sofia city	12.5	42	1	W	4.5	2500	105	30
Sofia city	12.5	12	2	W	4.5	2500	90	0
Sofia city	12.5	12	1	V-DX	3.6	2500	31	0
Sofia city	12.5	10	1	V-DX	3.6	2500	25	0
Sofia city	14.0	140	1	W	4.2	4297	460	426
Note: DX - direct expansion								
TOTAL						27097	1213	601.6

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

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 = 1
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 = 1
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)]	49.74	721.55	0.46
District Heating [4)]			
Air Conditioning (Cooling)	9.80	95.80	0.31
Greenhouse Heating	16.90	261.15	0.49
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]			
Snow Melting			
Bathing and Swimming[7)]	25.60	557.05	0.69
Other Uses (specify)	7.33 aquaculture, extraction of derivatives,etc.	31.51	0.14
Subtotal	109.37	1667.06	0.48
Geothermal Heat Pumps	0.33	4.37	0.42
TOTAL	109.7	1671.43	0.48

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 (2004) 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$	%	%
1990-1994	0.85 (state funded drilling)					
1995-1999	0.04 (state funded)		0.091(Phare programme)			
2000-2004			0.770 (World Bank)			