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GEOTHERMAL ENERGY DEVELOPMENT IN BULGARIA

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ABSTRACT

The use of geothermal energy in Bulgaria originates back to ancient times. The geothermal resources are of low-enthalpy type with temperatures in the range 20-101°C, found both in the northern part of Bulgaria in deep sedimentary formations and in the southern part, both in stratified grabens and unstratified mountainous systems with abundance of springs. Major utilisation has been associated with balneology, bottling, swimming pools, space heating and greenhouses.

Until 1990, all geothermal research and development was financed by the state. Economical changes after 1990 led to a sharp decrease in energy use, and consequently fossil fuel import. A new legislation with regard to water and energy has been passed in order to deal with ownership and granting of concessions, so the requirements of the free market can be met. However, geothermal development in these years has been rather modest. With the rich potential and the environmental benefits, the geothermal resources should be able to provide a real contribution to the energy sector in the future.

1. INTRODUCTION

Bulgaria is located in the Balkan Peninsula region with an area of 111,000 km^2. It has a population of about 8,350,000. The country has a considerable low-enthalpy geothermal potential, which is suitable for direct heat utilization. The use of natural hot springs for health bathing in Southern Bulgaria has been known since the time of the Roman Empire. Many famous health spas of that time are still in use. The present capital of Bulgaria, Sofia, was founded by Thracian tribes in the 3rd century BC. The city was based around mineral springs with water temperature in the range 20-50°C.

Up until 1980, thermal water was only partially used for health and recreational bathing, swimming pools, bottling of portable water and soft drinks, derivatives, etc. After the eighties, up-to-date systems for space heating were utilized. At that point, the total installed capacity in Bulgaria reached about 94.5 MWt. The use of geothermal energy resulted in saving fuels amounting to 46,778 toe/year. The utilization of geothermal resources was though delayed due to the low price of fossil fuels obtained from the Soviet Union (up to 1989) and high investment costs of the geothermal stations. After 1989, the social and economic changes in Bulgaria forced the formation of a new geothermal policy with a new legislation framework being developed. The orientation of geothermal practice towards the requirements of the free market economy imposed a new technological assessment of the existing geothermal projects. This included relationships with experienced foreign partners with investing potential, co-ordination between users, developers, financiers and government regulations and concessions that control projects (Bojadgieva et al., 1995).

The latest estimates have shown that the rich geothermal energy resource base can be tapped extensively and sustainably to achieve a real contribution to the energy sector. It could provide important environmental benefits through the reduction of carbon dioxide emissions.

2. TRENDS OF ENERGY BASE SUPPLY IN BULGARIA

The trend of energy flows for the last 10 year period is shown in Figure 1 (National Statistical Institute, 1998). After 1989 the economic crisis in the country caused a sharp decrease in domestic use of primary energy and consequently in fossil fuel imports. In the period 1989-1992 there was also a decrease in local production (mainly low quality coal and hydropower), as well as in the export of electricity generated from the nuclear power station. In Bulgaria the primary energy (Figure 2) is mainly based on nuclear and hydro power (49.7%) and on coal (45.7%). Renewable energy sources other than hydro are estimated to contribute 0.8%. According to the new Draft Law of Energy Efficiency an increase in the use of natural gas is envisaged, while the renewable energy resource share is anticipated to reach 2% by the year 2010.

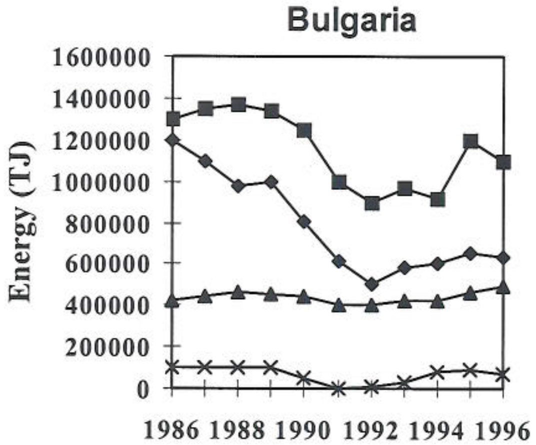

Figure 1: Trend of energy flows

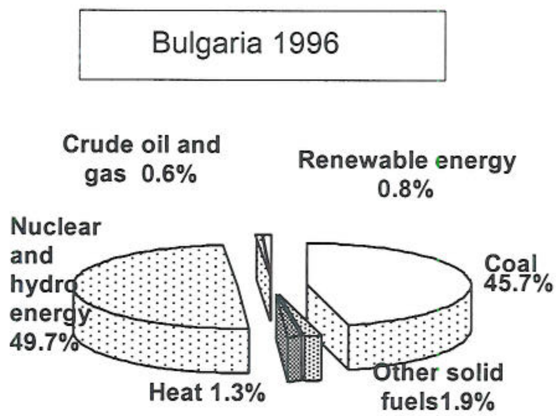

Figure 2: Production of primary energy (Domestic sources)

Good management and exploitation of the geothermal reservoirs using cascade systems will considerably decrease the use of imported fossil fuels and the environmental pollution associated with them. This is of vital significance for the numerous spas in Bulgaria. The fossil fuels saved due to the utilization of geothermal energy are estimated at up to 46,778 toe/year (PHARE Energy Programme, 1997)

3. GEOLOGICAL BACKGROUND

3.1 Basic characteristics of geothermal water

The country is rich in low-enthalpy geothermal energy. The hydrothermal data comes from prospecting carried out in hundreds of exploratory and production wells, springs, ore pits and tunnels.

- The thermal water temperature (natural flow) is in the range 20-101°C, 2/3 of which are within the 42-50°C range.
- The total flow rate of subthermal and thermal waters runs up to 5100 l/s (Petrov and Bojadgieva, 1993), of which 1000 l/s come from a karst spring (Musomishte, S.Bulgaria) with 20°C water temperature. In latter years the total flow has decreased due to the deterioration of the boreholes. The assessment of the flow rate now gives about 3200 l/s (PHARE Energy Programme, 1997).
- Established water mineralization varies from 0.1g/l to 50-100 g/l. The prevailing thermal waters in the Southern Bulgaria region are of nitrogen gas composition and are less than 1 g/l TDS. The highest percentage of low alkaline waters pH (7.2 - 8.5) is about 55% of the total flow rate.

The above data refers to the last 40 years and will be updated by the end of 1998. This geothermal resource reassessment has been carried out over several years by the Geological Institute under Bulgarian Academy of Sciences (Bojadgieva and Hristov, 1994; Shterev et al., in press).

An estimation of the total (theoretical) and technical potential of the discovered geothermal reservoirs in the country has been made (PHARE Energy Programme, 1997). The theoretical resource is defined as the thermal energy contained in the thermal waters and amounts to 14,122 TJ/year (440 MWt). This is a simplification as estimates of theoretical geothermal energy can be highly technical and include all energy beneath the earth's surface. Restraints related to technical policy and economic constraints (current energy prices and capital requirements for projects) have been applied in order to get an assessment of the technical potential. It amounts to 11,195 TJ/year (PHARE Energy Programme, 1997). The basis for the resource assessment was data from more than 120 different sites all over the country.

3.2 Hydrothermal reservoirs

The geological structure of Northern and Southern Bulgaria is varied and contrasting. The thermal regime and hydrothermal systems have been formed mainly during the Alpine tectonic activity in the Balkan region.1

In the ex-socialist countries, geological exploration has been given extensive budgets enabling the identification of geothermal reservoirs, proven by wells. The basic types of hydrothermal geological systems are:

- Stratified systems within the sedimentary formations (platform and folded areas), widely spread in Northern Bulgaria (Figure 3). Natural thermal springs are not found in the region of Northern Bulgaria. Thermal pressurized water was discovered only in deep wells.
- Stratified systems and Tertiary intermountain grabens located within S. Bulgaria (Figure 4).
- Unstratified mountainous

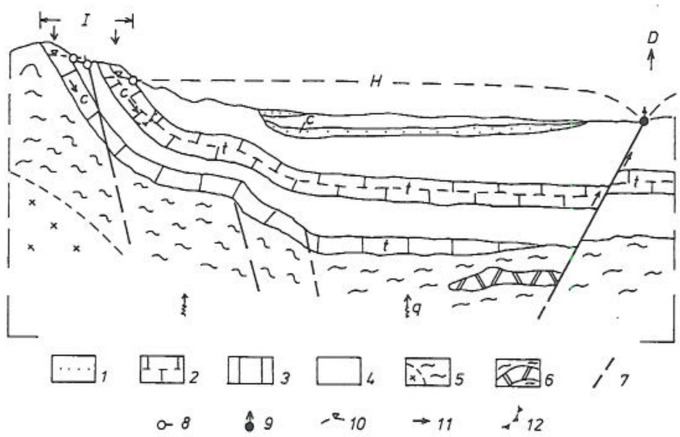

Figure 3: A scheme of sedimentary, layered, hydrothermal systems (basins) (Petrov and Bojadgieva 1993); (1) Subsurface waterbearing horizon, (2-3) Thermal reservoir, (4) Impervious rock complexes, (5) Impervious and low-permeability basement rocks, (6) Thermal reservoir of the basement, (7) Faults, (8) Cold springs, (9) Thermal springs, (10) Level of cold infiltrated water, (11) Direction of the underground water flows, (12) Cold and thermal water contact, (H) Piezometric surface, (I) Infiltration zone, (D) Drainage zone, (c) Cold water, (t) Thermal water, (q) Conductive heat flow

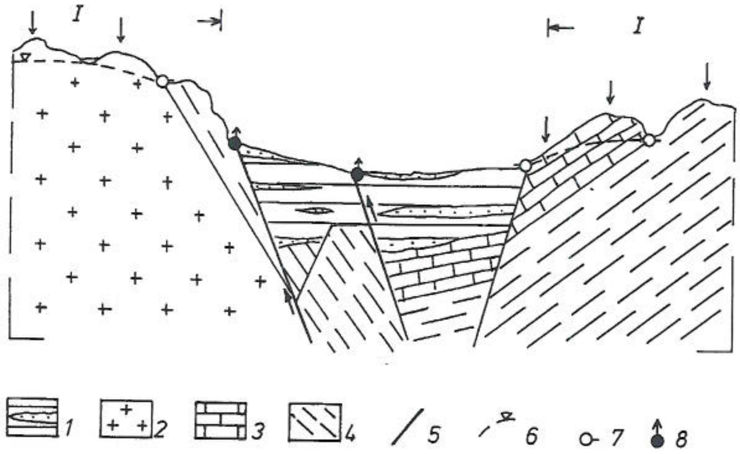

Figure 4: A scheme of layered, intermountain (graben) basin (Petrov and Bojadgieva, 1993); (1) Sediments and superimposed Tertiary graben basins with waterbearing layers and lenses, (2) Fractured, permeable intrusive (granitoids), (3) Permeable rocks (limestones, marbles) with subthermal and thermal water from the basement , (4) Impervious or low permeable rocks, (5) Faults, (6) Level of cold infiltrated water, (7) Cold springs, (8) Thermal springs, (I) Infiltration zone

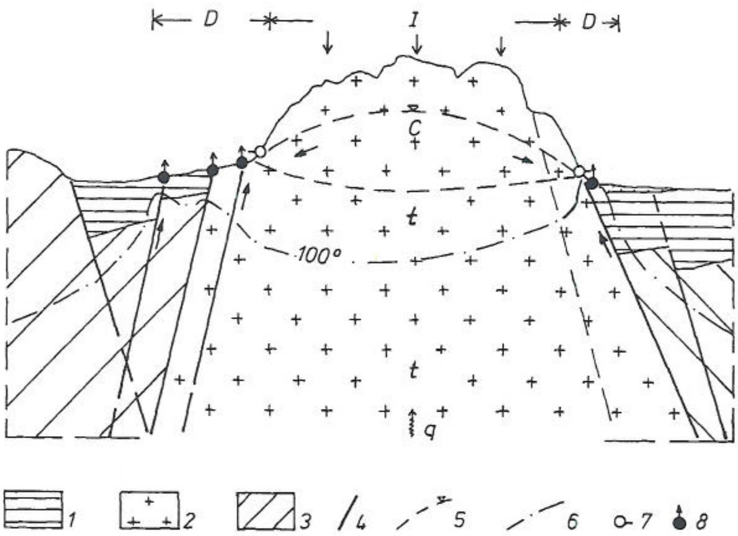

Figure 5: A scheme of unstratified, faulted mountainous, hydrothermal systems (Petrov and Bojadgieva,1993); (1) Tertiary sediments, (2) Southern Bulgarian granites and granitoids, comprising nitrogenous thermal water, (3) Metamorphic complexes,(4) Faults, (5) Level of cold infiltrated water, (6) Assumed temperature isoline 100°C, (7) Cold springs, (8) Thermal springs, (I) Infiltration zone, (D) Drainage zone, (c) Cold and subthermal water, (t) Thermal water, (q) Cond. heat flow

systems into fracture crystalline massifs (Figure 5). These occur mostly in S. Bulgaria. The main reservoirs of nitrogen thermal water are represented by southern Bulgarian granite and granitoid intrusive.

The southern part of the country is abundant in springs, serving as a drainage of unstratified mountain systems. These are developed mainly in granite and granitoid intrusions and ancient siliceous and metamorphic complexes. The Rhodopes marbles, the carbonate Mesozoic rocks as well as the Upper Cretaceous and Tertiary volcanites are sources of thermal water.

3.3 Typical temperature profiles from deep exploration wells in major geothermal areas in Bulgaria

The region of Northern Bulgaria is represented by the most water-saturated and thickest horizon (up to 1000m) - Upper Jurassic-Lower Cretaceous (Figure 6). This is located within the Moesian plate both on Bulgarian and Romanian territory, and is built up mainly by fractured, karst limestones and dolomites. It is encountered to the west at a depth of 3000 m and there it is built of predominantly clayey-marly facies.

The TDS varies from 0.5 g/l (in the East) to 60 g/l (in the West).The flow rate of a single artesian well along the Black sea coast reaches 60-70 l/s, whilst the highest temperature is 55°C. Thermal water from

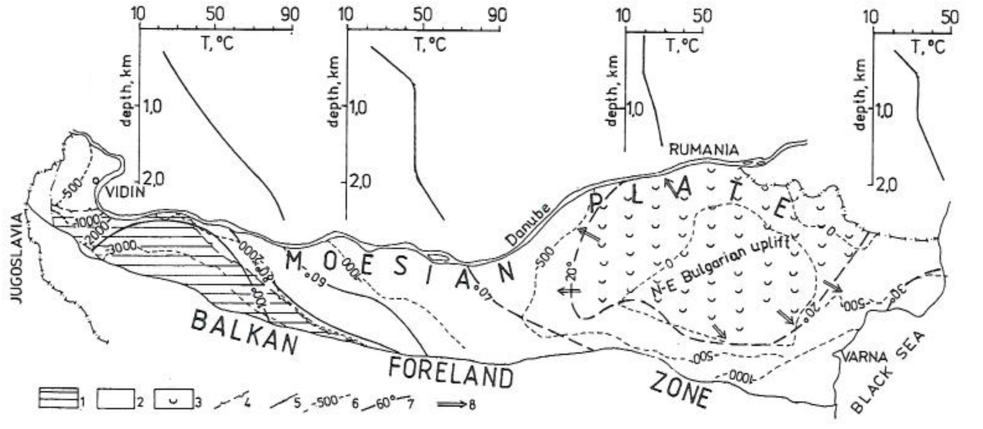

Figure 6: A scheme of the J_3 - K_1^v reservoir (Northern Bulgaria); (1) Predominantly clayey and marly complexes, (2) Carbonate facies, (3) Fresh cold water in the J_3-K^v recharge zone, (4) Assumed boundaries between carbonate and clayey-marly complexes, (5) Boundary between Moesian plate and Balkan Foreland zone, (6) Isolines of the top of J_3-K^v in m (below sea level), (7) Temperature isoline,C°, (8) Underground water movement directions

the central part (43-45°C) and from the eastern part along the Black Sea coast (30-52°C) is used. In Southern Bulgaria, the diversity of geothermal reservoirs is greatest regarding both the structure and the temperature, reaching 100°C (Figure 7).

About 160 geothermal fields have been discovered in the country. Their distribution in the different regions is presented in Figure 8.

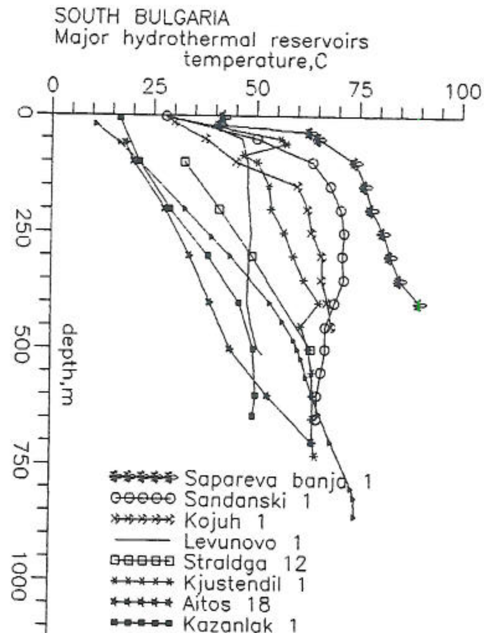

Figure 7: Typical temperature profiles from the region of Southern Bulgaria

4. GEOTHERMAL ENERGY APPLICATIONS IN BULGARIA

4.1 Types of application

Along the Northern Black Sea coast and in one site in SW-Bulgaria (Sandanski town) geothermal energy is being used in public buildings all year round for heating, air-conditioning and ventilation. The thermal water in these sites is utilized for recreation and swimming pools as well as for extraction of iodine, bromine, boron, strontium etc. (Northern Black Sea coast). The major application of thermal water in the country is in balneology (healing and recreation), for bottling, swimming pools, space heating, greenhouses and open cultivation of microalgy. There is some processing of flax and hemp fibres.

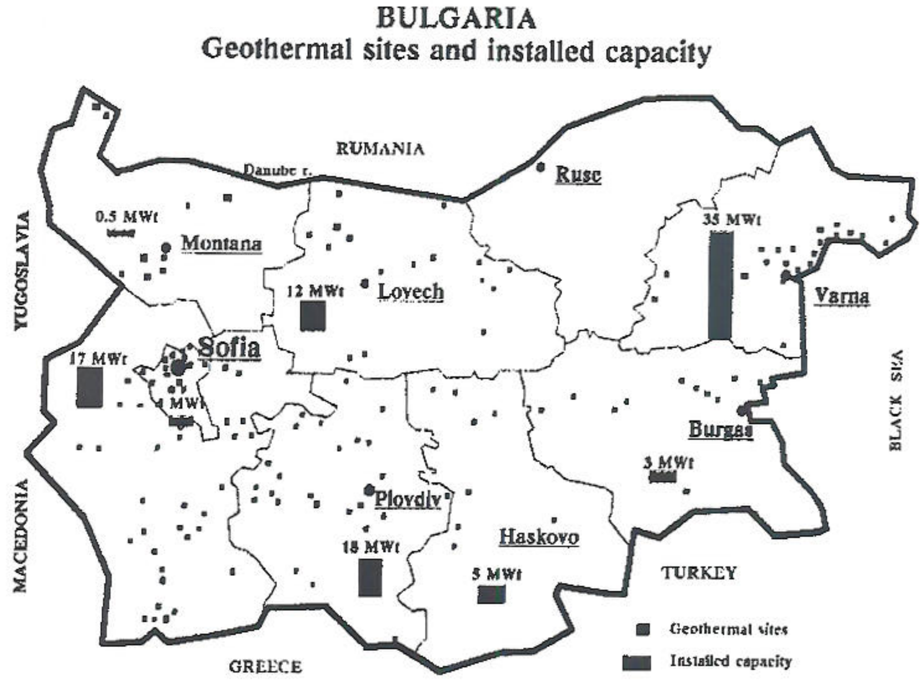

Figure 8: Geothermal site distribution and installed capacity by administrative region

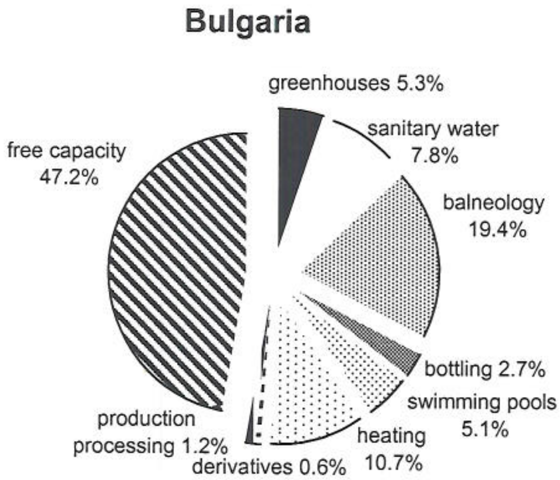

Figure 9: Direct uses of thermal water (in % of the total flow rate)

The basic types of thermal water and geothermal energy application in Bulgaria are shown in Figure 9. The share of bottling of portable water and soft drinks increased during the last 5 years. About 30 enterprises have obtained licenses for performing this activity. The greatest part of this production meets local market demand (Figure 9).

4.2 Technology and techniques

The total installed capacity is 94.5 MWt (Figure 8), which includes all types of installations. The energy produced is 1371 TJ/year (at 0.46 load factor). The duration of the heating season in Bulgaria is 180 days. The rather low temperatures of the majority of reservoirs determine the utilization of the technical schemes used for heat carriers of 50/40°C and 60/40°C parameters (Hristov, and Nikolova, 1993). The latter are suitable for low-temperature underfloor heating. Only a few of the reservoirs are suitable for use as heat carriers of 90/70°C parameters. Modern installations use mainly plate heat exchangers of stainless steel and heat pumps. Some systems have fossil fuel boilers to provide for periods of peak loading. In addition, indirect systems provide ventilation and air conditioning. Much of the equipment is manufactured under license or directly by a foreign company with a Bulgarian facility.

The majority of direct geothermal systems currently operating have a low performance being technically and morally worn out. Present production is below the potential allowed by the resource assessment. There is no injection of the waste water into the source reservoir and no pressure maintenance. The concept of a doublet has no application in the country.

When high-temperature reservoirs were used for medical purposes, the thermal waters were often left in open tanks to cool down to the desired temperature or mixed with expensive cold mains water. At the same time, buildings were heated using conventional fossil fuels boilers, usually coal or oil. This gives a situation of reduced efficiency of medical applications, wasted energy and locally polluted environment. This is the situation of most the sites in SW-Bulgaria. The building up of cascade geothermal systems will considerably improve the efficiency.

5. GEOTHERMAL ENERGY DEVELOPMENT POLICY IN BULGARIA

5.1 Demonstration projects

The geothermal sites built in Bulgaria during the last years are rather modest. At this point in time there are two small demonstration projects, entirely financed by the PHARE Programme. These projects were intended to demonstrate the legal and financial policies and other issues that impede or support renewables in Bulgaria.

From 1994 to1996, CSM Associates Ltd. (Penryn,UK), ESD (Bath, UK) and Ecothermengineering (Sofia, Bulgaria) conducted a study into the renewable energy potential in Bulgaria. Five energy sources were considered - biomass, wind, solar, hydro and geothermal. A demonstration project was conducted for each of the technologies and detailed costing produced regarding the effectiveness of each project. The geothermal project was implemented in a large balneological centre in SW-Bulgaria (Sapareva banja town). The cost of the project was ECU 25,000. Equipment for heating and providing sanitary water for a building of the balneological complex was installed. The system has a capacity of 0.25 MWt. Permanent monitoring of its parameters is performed.

Another large project for the same site was put forward by CSMA,UK for financing by other European programmes. It provides for the heating of 13 public buildings with a potential heat load of about 9.5 MWt. The approximate cost was estimated at US$ 8,130,000.

The other demonstration project was executed by COWI (Denmark) and Energyproject (Bulgaria) by a programme concerned with energy efficiency in a large region of Southern Bulgaria (Haskovo region). An installation amounting to ECU 20,000 for heating of the Municipality of the town of Haskovo and a kindergarten was constructed. The installed capacity is 100 kWt. The next step for the development of geothermal energy should be the modernization and extension of the existing systems to achieve higher technical and economic parameters.

5.2 Financing and legislation

Geothermal water and geothermal energy are still delivered to the consumers free of charge. The basic consumers are the balneological complexes. According to one of the Bulgarian health laws, they are entitled to all of the required mineral water completely free. Until 1990, the geothermal systems were entirely financed by the state. At the moment, foreign investments are used only for small demonstration projects. Private investments are directed mainly to the bottling industry. A state fund for energy efficiency which will help projects for renewables is under formation.

New methods for assessing the price of the mineral water and geothermal energy are to be introduced in the near future. Installed costs for geothermal heating systems are site specific and a range of ECU 150-1200 per kW is possible (PHARE Energy Programme, 1997)

Until recently, mineral water application was controlled by the Ministry of Health. Later on some of the mineral water sources passed on to local municipality control. The first law of cold and thermal water in Bulgaria was published in 1891. At the moment, there are several laws treating issues related to waters. The Water Law and Concession Law are the important ones while others play only a co-ordination role:

- The Water Law (Draft) regulates the ownership, the research, the utilization and the protection of the mineral water as well as its management.
- The Concession Law regulates the rules for granting concessions. The offer for concession for thermal water (which is state owned) are made by the Minister of Environment and Waters, who co-ordinates them with the Ministry of Health. The final decisions are taken by the Government. The concession is not considered an exclusive right but as a particular right of property. For the present a permit or license regime for using mineral water is not dealt with by legislation.
- The Health Law regulates water sources intended for balneology, their control, and the requirements for bottling mineral water.
- The Municipality Property Law regulates the use and management of mineral water including granting concessions for those sources which are communal property and are intended for public needs.
- The Energy Efficiency Law (Draft) determines the state policy on the development of renewable energy resources. This law deals particularly with thermal water and geothermal energy in connection with the utilization and control of water reservoirs as well as with the conditions of geothermal energy development.

The fact that these new laws are untested means that a great deal of uncertainty still exists with regard to policy support for the industry and development of regulations.

6. ORGANIZATIONS AND SPECIALISTS

Different organizations are involved in geothermal activities in Bulgaria - ministries, scientific institutes, state-owned and private companies. There is a university base for the training of specialists in all spheres of geothermal development. Five Bulgarian specialists have completed the UNU Geothermal Training Programme in Iceland, 2 in 1990, 1 in 1993 and 2 in 1995, respectively, in Borehole geophysics, Chemistry of thermal fluids and Reservoir engineering. In this way, a team able to settle the complex issues in exploration and evaluation of geothermal reservoirs was created. These specialists take part in the process of re-assessment of the geothermal resources in the country as well as in international projects in Bulgaria. Their qualifications enable them to meet the challenges of recent economic changes and, together with engineers and specialists in balneology, to fully participate in the process of development of geothermal energy in the country.

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On behalf of the Bulgarian specialists who completed the UNU Geothermal Training Programme in Iceland, I would like to thank its exceptional training staff for their dedication and willingness to teach and help us. I would also like to express my happiness in being invited to attend the 20th anniversary of the UNU Geothermal Training Programme and to introduce the problems and the hopes of Bulgarian geothermal society.

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