GEOTEERMAL ENERGY UTILIZATION IN BULGARIA WITHIN THE PERIOD 1990 -- 1994

Klara Bojadgieva, Hristo Hristov * and Vladimir Hristov **

Geology & Geophysics, Co, Sitnyakovo 23 bld.1505 Sofia, Bulgaria

*Ecothermengineering, Ltd., 51 Varban Genchev str. 1100 Sofia, Bulgaria
**Geological Institute, Bulgarian Academy of Sciences, G. Bonchev str.bl.24 1113 Sofia, Bulgaria

Key words: district heating. thermal waters, Bulgaria

ABSTRACT

Bulgaria is a country with an area of 111 000 sq.km and population of 8 500 000. There are more than 1000 geothermal springs and wells with total flow rate of approximately 5100 l\s.

The thermal water utilization in Bulgaria is related mainly to balneological needs, space heating and greenhouses, bottling of potable water and soft drinks, swimming pools and some industrial uses.

The share of solar and geothermal energy resources in the energy balance structure of the country amounts to 0.1--0.2 %.

The installed power capacity for geothermal energy is 97 MWt, being 20% of the heat potential of the waters discovered all over the country.

The technological schemes available use mainly heat carriers of 50°C/40°C and 60°C/40°C parameters.

The main problems in geothermal energy application in Bulgaria are discussed.

1. INTRODUCTION

The social and economical changes which have occurred in Bulgaria after 1989 are reflected in all the spheres of industrial activities. The problems related to the country's energy balance and economic efficiency have been re-evaluated based on the new economic wnditions and orientation to the marketing policy.

Based on data from Energy Charter'93 for Bulgaria (in press) geothermal and solar energy are included in the energy balance ofthe country amounts of 0.1--0.2% that are expected to increase within the next 10--15 years lo 1,5--2%.

2. ENERGY BALANCE OF THE COUNTRY

The *primary* energy production for 1991, in the energy balance, (before the energy treatment processes) is shown on Fig.1

Local energy resources provide only 25% of the total energy balance. They comprise mainly low quality coal and limited hydro resources.

The resources of fossil fuels were estimated to be about 200 toe/capita (considerably below the mean value all over the world -- 2000 toe/capita). Almost all liquid fuels required are imported.

At the beginning of the period 1990--1994 energy consumption in Bulgaria dropped reaching its lowest value for the last ten years in 1991,Fig.2. A gradual increase was expected afler 1993, reaching the level of 1988 in year 2000

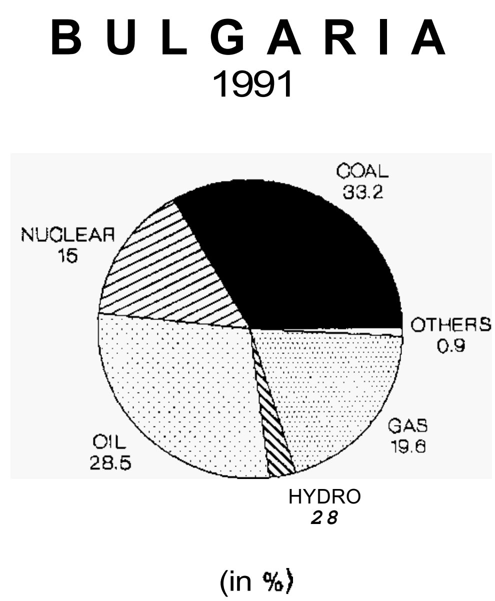


Figure 1: Primary energy production by source (others: geothermal, solar and imported energy).

The decrease in energy consumption encountered afler 1988 is due to: reduction of industrial production; import of fuels and energy resources; increase of the prices of energy carriers,..etc.

The basic consumer of fuels and energy resources in Bulgaria is in industrial sphere (60% relative share of the end consumer in 1991), while a constant tendency lo decrease (reaching 43--46%) was observed in the period 1993--1994. Thus wincided with the decreasing share of the electrical energy consumed by the population.

2.1. Electroenergetics

The basic energy sources for the future development of the energetics in Bulgaria are local coal, nuclear and hydro resources.

The total installed power at the moment amounts to 12065 MW, 5335 MW of which are based on fossil fuels, 3720 MW nuclear, 1970 MW hydro energy and 1040 MW factory power stations (Energy Charter'93, in press).

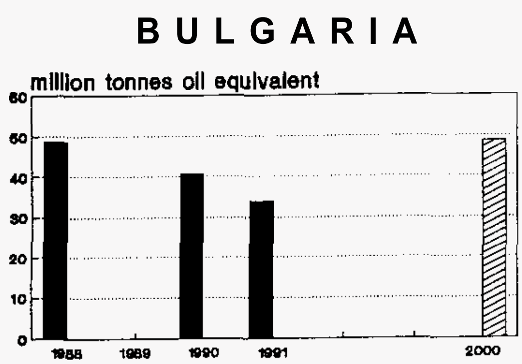


Figure 2: Energy consumption.

These sources cover the maximum demand of 7200 MW, but they do not ensure the operational resources required. Up to the year 2000 new 1465 MW are scheduled to be generated at power stations based on fossil fuels, and 910 MW for the hydro power stations. The total capacity will reach thus 48 TWh, Fig. 3.

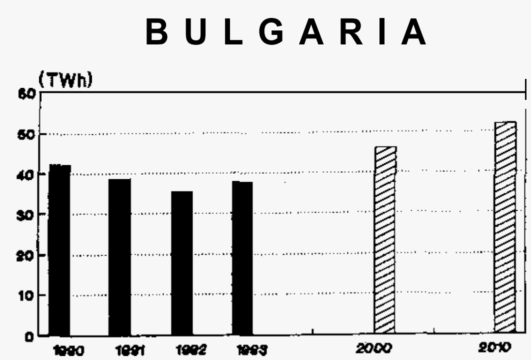


Figure 3: Electricity production.

Geothermal energy is not included in the electricity production in Bulgaria, mainly due to the low temperatures (up to 100°C) of the thermal waters.

2.2. Heating

The total electrical capacity of thermo-electrical power stations of the country is 573 MW, while the added public and industrial loads amount to 10286 MWh. In 2000 year the above value is expected to reach 1163 mill.MWh (incl.74 mill.MWh within the industrial spheres)

2.3. Renewable energy sources

As a result of the joint explorations carried out in Bulgaria within the period 1991–1992 by the French Agency for Environment Protection and the European Bank for Develop ment and Research, the Committee of the European Community and the World Bank, a monograph was published "The Danube.. .For Whom and For What?" (Equipe Cousteau, 1993). Chapter 5.2. discusses data for the renewable energy resources in Bulgaria based on small hydro power stations (<10MW), solar water heating energy, energy from wood and energy from rural and urban waste, According to the estimation made they will account for 12% of the primary energy consumption.

3. GEOTHERMAL ENERGY

3.1 Basic characteristics of geothermal fluids

The country is rich in low enthalpy geothermal energy.

About 1000 thermal aquifers and thermal springs have been discovered. The total dynamic resources of thermal and subthermal waters reach about 5100 l/s (Petrov et al., 1993).

The temperature of artesian thermal waters varies between 20°C–100°C, 2/3 of which are within 42°C–50°C range.

Water mineralization in Bulgaria varies from 0.1 to 100 g/l while in Southern Bulgaria region they are nitrogen type of less than 1 g/l TDS, Fig.4.

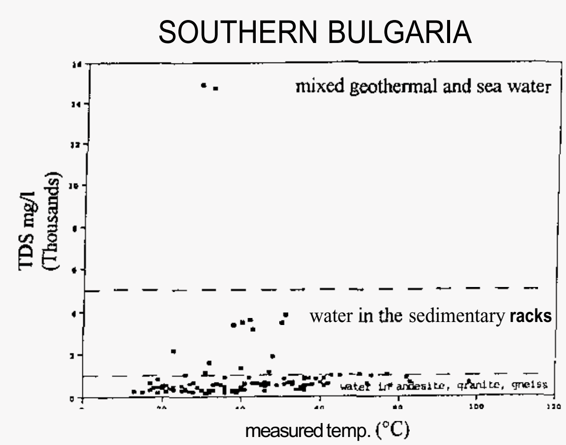


Figure 4: Southern Bulgaria: total dissolved solids vs measured temperatures (Hristov, V., 1993).

3.3. Geothermal water and energy utilization in Bulgaria

– Historical review and analysis

Based on existing traditions in Bulgaria, thermal waters were used mainly for heating and medical treatment since Roman limes.

The heat potential estimated for the thermal waters discovered in Bulgaria amounts to 488 MWt, 1/3 of which could be obtained by heat exchangers, while the remaining 2/3 by heat pumps. Thus a b u t 70 toe multiplied by the annual working hours of all the facilities will be highly efficient for our national economy (Hristov and Nikolova,1993). Waters of temperatures 32°C to 42°C are not included as according to the Bulgarian legislation these waters are used only for balneological purposes.

- Until 1980 thermal waters were used only for medical treatment needs in the big resort centres, swimming **pools,** for flax and hemp processing, derivative production, bottling, baths,..etc.

  Their complex utilization both for heating and medical treatment was limited to only a few sites. The thermal waters were input directly for the heating of buildings and greenhouses.

  During the 1960s the Bulgarian Academy of Sciences set up lhe only farm in the region (1 ha) for open mass cultivation of microalgal biomass, (Furnadzieva et. al.,1993). It is located in the region of Petrich (SW Bulgaria, 41° Northern latitude) where thermal waters of 76°C, containing a high content of freely released CO_2 are available. The farm is in operation between April and October. The biomass is utilized for extraction of proteins and other products used in medicine, cosmetics and animal breeding.
- After 1980 the number of spas increased to 70, and thermal complex utilization was extended. Up--to--date technological systems were under construction and the total installed capacity reached 35 MWt, (Table I), Fig.5. In addition to the systems listed in Table I, several others totaling 5 MWt were constructed by other organizations. The total capacity of the systems for direct geothermal energy utilization in Bulgaria which are of simple design added up to 62 MWt, half used for space heating and lhe other half for greenhouses, Fig.5.

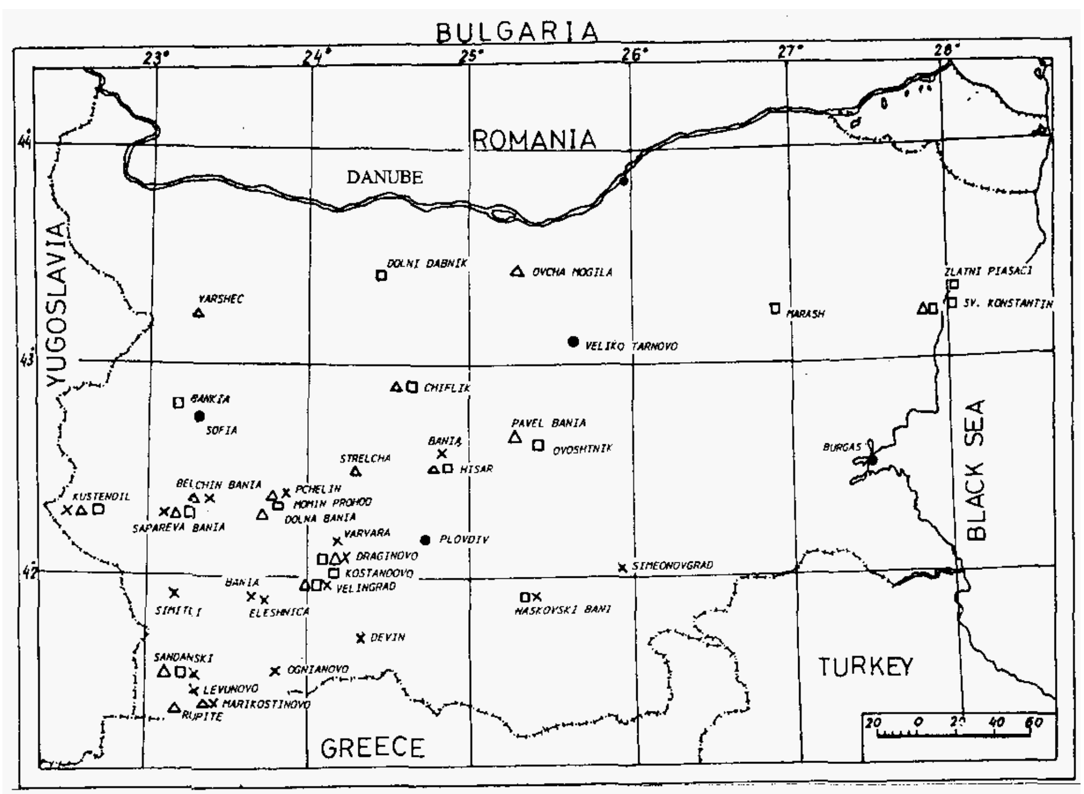


Figure 5: Map of the locations in Bulgaria using thermal water energy

A -space heating by simple schemes

□ - **space** heating by sophisticated schemes (heat exchangers and heat pumps)

X -greenhouses.

The technical conditions of the greenhouses are poor as a result of scaling, corrosion and lack of funds for capital repairs.

At present about 17.6 ha of greenhouses for vegetables and flowers are heated by the thermal waters from 15 reservoirs. Heating is realized by simple direct schemes. For one reservoir alone in Northern Bulgaria, the geothermal system constructed has a 1.2 MWt capacity, heating 0.65 ha, Table 1.

Table 1: Geothermal installations, designed and assembled by Ecothermengineering, Ltd., Sofia.

No. Location	Installed capacity, (MWt)	Utilization
1. Balneological complex . Momin prohod	1.45	Heating, Sanitary water
2. Balneosanatorium - Hisar town	0.26	Heating, Sanitary water
3. Balneosanatorium - Bankja town	0.26	Heating
4. Balneosanatorium - Sandanski town	2.1	Heating, Ventilation, Air-conditioning, Sanitary water
5. Balneosanatorium - Kjustendil town	1.0	Heating, Sanitary water
6. Rest house. Vama town	2.5	Heating, Ventilation, Air-conditioning, Sanitary water
7. Rest housing complex St.Konstantin resort, (Black sea)	4.0	Heating, Ventilation, Air-conditioning, Sanitary water
8. Rest house - Chiflik village	0.25	Heating, Sanitary water
9. Rest house - Chaika resort (Black sea)	2.0	Heating, Ventilation, Air-conditioning, Sanitary water
10. Kindergarten - Haskovo baths	0.15	Heating, Sanitary water
11. Kindergarten - Kostadinovo village	0.35	Heating, sanitary water
12. Youth club - Velingrad town	0.15	Heating
13. Sport palace - Varna town	3.5	Heating, Ventilation, Air-conditioning. Sanitary water
14. Hotel - Golden sands (Black sea)	0.35	Heating, Ventilation, Sanitary water
15. Greenhouse (0.65 ha) Marash village	1.7	Heating

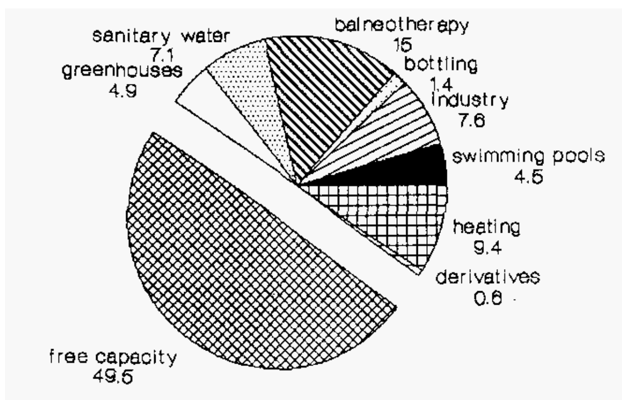
- After 1990 several simple systems for direct application in two sites (Dolna Bania and Maritza) were constructed. These are very small greenhouse areas of 600-1000 sq.m. and of insignificant total power capacity (below 0.5 MWt).

At present, for space heating only 20% of the country's 488 MWt heat capacity is used (Bojadgieva and Hristov,1994).

Within the same period no progress was observed in the geothermal water utilization for balneological purposes, swimming pools and baths. Only the bottling of potable mineral water and soft drinks production increased, Fig.6. Until 1990, 7 reservoirs were used – Gorna Bania, Hissar, Mihalkovo, Brazigovo, Merichleri, Narechen and Targoviste. Four more were added after 1990 – Nevesiio, Sadievo, Devin and Aytoss.

The mineral water consumption per capita increased two times, compared to 1985. A part of natural mineral water production is exported abroad. The basic investors in it are private bodies and companies that like small initial investments.

BULGARIA
1993



(in % of the total flow rate)

Figure 6: Direct uses of thermal waters.

There are very favorable conditions in Bulgaria for the utilization of geothermal resources in the development and construction of new mountain and sea resorts also at the existing old hotels and spa centers. At the moment, most of them are healed by coal and fossil fuels causing ecological problems in the more densely populated regions.

- Principle schemes

The rather low temperatures of the majority of water reservoirs determine the utilization of the technological schemes built up for heat carrier of 50°C/40°C and 60°C/40°C parameters (Hristov and Nikolova,1993a). The latter are suitable for low temperature floor heating. Only from a few of the reservoirs is possible to use a heat carrier of 90°C/70°C parameters.

Up-tu-date technological installations use mainly plate heat exchangers of stainless steel (Bulgarian made and foreign production) and heat pumps. Some systems have fossil fuel boilers to provide for the periods of peak loading.

The basic types of technological schemes used in the construction process of geothermal plants are discussed by Hristov and Nikolova (1993a).

The average duration of the heating season in Bulgaria is 180 days. Geothermal systems built provide further to heating ventilation and air-conditioning. Table 1

-Economic efficiency

The results of feasibility studies and estimations based on all the projects which have been conducted in Bulgaria show that the price of 1 GJ of produced energy is about 2-4 times lower than the price of the fossil fuel plants energy. The pay back period for the capital investments, based on the lower price of the geothermal energy compared to the fossil fuel plants, amounts to 2.5 to 8 years. Drilling costs are not included in the above analysis. All sites studied used wells already drilled for other purposes.

4. BASIC PROBLEMS IN THERMAL WATERS AND THERMAL ENERGY APPLICATION IN BULGARIA

-- Old equipment

Most of the existing production wells drilled in the sixties are completely depreciated. The organizations responsible for their maintenance, namely the Ministry of Health and the Municipalities have not the funds required for their improvement. There are also cases of complete geothermal water loss due to technical reasons.

- Laws and regulations in the country

In accordance with the existing laws and regulations, the regimes of geothermal reservoir utilization are determined by the Ministry of Health if the reservoirs are of national importance and otherwise the Municipalities have the responsibilities. It is determined by means of resolutions issued by the Council of Ministers, and not by special laws. They lead often to certain changes which create problems in the implementation of projects of higher investments.

- State energy policy

There is still not a state policy of preferential prices for products and materials, needed for the development of non-traditional systems providing economically efficient energy. High interest rates on credits for construction of renewable energy systems exist.

- Land ownership

The recent economic and social changes in Bulgaria are related also lo the restoration of private lands. Because they still pending and there are unsolved problems related to the above, the process of construction of greenhouses has practically stopped.

ACKNOWLEDGMENTS

We are grateful to Dr.A.Panajotov, the President of the Committee of Geology and Mineral Resources for his kind assistance in paper preparation.

Many thanks to our colleagues Atanas Toshev, Dobrinka Dobreva, Georgy Mihailov and Jordan Jordanov for the geu thermal data collection.

REFERENCES

Bojadgieva, K. and Hristov, H. (1994). ***Hydrothermal resources in Bulgaria - type, distribution and application.*** Communications. International Symposium. Geothermics 94 in Europe, Orleans-France, 8-9 Feb. 1994, 8 pp.

Energy Charter, 93 (in press, in Bulgarian)

Equipe Cousteau. (1993). ***Evaluation of the economically operable potential of renewable energies.*** In: The Danube. . . for Whom and for What, Chapter 5. 2. (Final report), Ed. Equipe Cousteau, 233 me du Faubourg Saint-Honore, 75405, Paris Cedex 08, France, Savana, BG, pp . 91-92%

Furnadzieva, S. , Georgiev, D and Bozkova, M. (1993). ***Geothermal fluids technology of microalgal cultivation in Bulgaria.*** Geothermal energy. Technology. Ecology. 1993 Course Text Book and Guideline, International Summer School on direct application of geothermal energy, 9pp.

Hristov, H. , and Nikolova, N. (1993). ***Geothermal waters in Bulgaria - a real energy source.*** Proceedings of the International Workshop, Bansko, Bulgaria, May 28-30th. K. Dimitrov(Ed.), EC Lets go East, Project 922813-Geothermal energy for greenhouses and aquaculture in Central and East European countries, 6pp.

Hristov, H. , and Nikolova, N. (1993a). ***Designing and assembly ofgeothermal systems in Bulgaria.*** Proceedings of the International Workshop, Bansko, Bulgaria, May 28-30th, K. Dimitrov(Ed.)EC Lets go Fast, Project 922813- Geothermal energy for greenhouses and aquaculture in Central European countries, 7pp.

Ilnstov, V. (1993). ***Application of chemical geothermometers to low temperature fields in Southern Bulgaria.*** Report 7 for the UNU Geothermal Training Programme, Orkustofnun-National Energy Authority, Rejkyavik, Iceland, 40pp.

Petrov, P. and Bojadgieva, K. (1993). ***Hydrothermal*** resources ***and their utilization in Bulgaria.*** Proceedings of the International Seminar on Environmental protection by use of geothermal energy, 13-18th Sept. 1993, Zakopane-Koscielisko, 7pp.

Petrov, P. , Hristov, V. and Bojadgieva, K. (1993). The ***geothermal resources in Bulgaria.*** Proceedings of an International Workshop, Bansko, Bulgaria, May 28-30th, K. Dimitrov(ed.), EC Lets go East, Project 922913-Geothermal energy for greenhouses and aquaculture in Central and East European countries, 11pp.

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geoth.		Fossil Fuels		Hydro		Nuclear		Total	
	Capacity MW	Cross Prod. GWh/yr	Capacity MW	Cross Prod. GWh/yr	Capacity MW	Cross Prod. GWh/yr	Capacity MW	Cross Prod. GWh/yr	Capacity MW	Cross Prod. GWh/yr
*In operation in January 1995			5 335		1 970		3 720		11 025	
Under construction in January 1995										
Funds committed, but not yet under construction in January 1995										
Total projected use by 2000			865				880			

*Note: Factory power station production (1040 MW) is not included.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT IN DECEMBER 1994

1) I = Industrial process heat
C = Air conditioning
A = Agricultural drying
F = Fish and other animal farming
S = Snow melting
D = Space heating
B = Bathing and swimming
G = Greenhouses
O = Other (please specify by footnote)

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

3) Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.1319

Locality	Type[1]	Maximum Utilization					Annual Utilization		
		Flow Rate kg/s	Temperat. (°C) Inlet	Temperat. (°C) Outlet	Entalpy[2] (kJ/kg) Inlet	Entalpy[2] (kJ/kg) Outlet	Average Flow Rate kg/s	Energy Use[3]	Load Factor
1. Momin prohod	D,B	15.0	64	41	-	-	5.7	17 29	0.38
2. Hisar town	D,B	8.0	46	40	-	-	2.56	2.02	0.32
3. Bankja town	D,B	6.0	36	28	-	-	2.1	2.21	0.35
4. Sandanski town	C,D,B	8.0	64	17	-	-	4.08	25.29	0.51
5. Kjustendil town	D,B	8.0	70	40	-	-	3.04	12 03	0.38
6. St. Konstantin	C,D,B	75.0	42	27	-	-	39.0	77.16	0.52
7. Varna town 1	C,D,B	20.0	49	27	-	-	9.6	27.85	0.48
8. Chiflik village	D,B	5.0	51	39	-	-	1.75	2.77	0.35
9. Chajka resort	C,D,B	21.0	45	25	-	-	10.5	27.69	0.5
10. Haskovo bath	D,B	2.5	55	40	-	-	0.82	1.62	0.33
11. Kostadovo	D,B	*6.0*	50	35	-	-	2.1	4 15	0.35
12. Velingrad	D	2.5	56	41	-	-	0.57	1.13	0.23
13. Varna town 2	C,D,B	55 0	55	35	-	-	21.45	56 58	0.39
14. Golden sands	C,D,B	6.5	31	21	-	-	2.37	3.6	0.42
15. Marash	G	20.0	65	40	-	-	5.0	16.48	0.25
Total		258.5	-	-	-	-	111.0	277.87	-

Note: Only the available information about installations (constructed after 1980 by Ecothermengineering, Sofia) is included in the table.

TABLE 4. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES

1) Inst. thermal power (MW) = Max. water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.004184

2) Energy use (TJ/yr) = Annual average water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.13119

	Installed Thermal Power 1) MW	Energy Use 2) TJ/yr
Space heating	51.0	221.37
Bathing and swimming	15.0	98.45
Agricultural drying	-	-
Greenhouses	31.0	165.45
Fish and other animal farming	-	-
Industrial process heat	16.0	74.6
snow melting	-	-
Air conditioning	6 8	56 5
Other uses (specify)	-	-
Subtotal	119.8	616.37
Heat Pumps	13.28	161.98
Total	133.08	778.35

TABLE 5. GEOTIIERMALHEAT PUMPS

1) Thermal energy used (TJ/yr)
= Annual average geothermal water flow rate (kg/s) x [Inlet temp. (°C) - Outlet temp. (°C)] x 0.1319

Locality	Heat source °C	COP - Factor	Heat Pump Rating MW (Output)	Thermal Energy Used in Heating 1) TJ/yr
Hisar town	46	4.5	0.26	0.765
Bankja town	36	4.7	0.26	2.22
Sandanski town	40	4.6	1.2	12.91
St. Konstantin resort	42	4.3	5.85	77.16
Varna town 1	37	5.8	1.5	18.8
Chaika resort	30	5.4	1.0	13.19
Varna town 2	55	6.3	2.86	33.34
Golden sands resort	31	4.9	0.35	3.6
Total			13.28	161.985

TABLE 6. INFORMATION ABOUT GEOTHERMAL LOCALITIES

1) Main type of reservoir rock

2) Total dissolved solids (TDS) in water before flashing. Put v for vapor dominated

3) N = Identified geothermal locality, but no assessment information available
R = Regional assessment
P = Pre-feasability studies
F = Feasability studies (Reservoir evaluation and Engineering studies)
U = Commercial utilization

Locality	Latitude	Longitude	Rock	TDS mg/kg	Status3) in 1995	Estimated Reservoir Temp * (°C)	Measured Reservoir Temp (°C)
1. Varshets	43-12	23-19	diorites	200	U	49	38
2. Spantchevtsi	43-10	23-15	diorites	200	P	50	30
3. Elenov dol	4343	21-28	diorites	950	N		26
4. Shipkovo	42-52	24-32	imestones	2500	U		36
5 Bankja	4243	2349	andesites	280	U	42	38
6. Ivaniane	4241	23-19	andesites	250	F	37	27
7 Gorna bania	4241	23-15	andesites	130	U		42
8. Kniajevo	42-40	23-14	andesites	140	U	40	31
9. Sofia	4242	23-19	andstones	280	U		47
10 Pantcharevo	42-36	23-24	imestones	530	U		48
11. Ovtcha cupel	42-41	23-16	imestones	1200	U		32
12 Dole Rakovets	42-28	2341	imestones	460	R		31
13. Rudartsi	42-36	23-10	monzonites	300	U		29
14. Jeleznitza	42-33	23-24	diorites	350	F		12
15. Iskar	42-28	23-33	diorites	280	N		25
16. Beltchinski bani	42-22	23-28	diorites	290	U		41
17. Ptchelinski bani	42-22	2346	diorites	950	U	99	72
18 Momin prochod	42-20	25-53	granites	960	U	88	65
19. Banja (Panagur.	42-28	2448	granites	600	U		43
20. Streltcha	42-31	24-19	granites	310	U	62	56
21. Krasnovo	42-28	24-29	granites	240	F		55
22 Staro Jelezare	42-27	24-39	granites	290	F		29
23. Hisaria	42-31	24-43	granites	270	U	69	52
24 Pesnopoi	42-28	2448	granites	320	F	76	43
25. Banja Karlovo	42-33	24-50	granites	270	U		54
26. Stoletovo	4242	24-34	granites	250	P	47	33
27. Klisura	42-42	24-27	granites	270	P		21
28 Pavel banja	42-38	25-19	granites	500	U	90	61
29. Ovoschtnik	42-37	25-24	granites	530	F	78	78
30. Jagoda	42-32	25-35	granites	590	U	61	46
31. Starozagorski b.	42-27	25-30	imestones	580	U		46
32 Banja - Korten	42-36	2640	granites	990	U	86	57
33. Slivenski bani	42-36	26-14	imestones	1970	U		50
34. Burgaski bani	42-37	27-24	andesites	580	U	41	41
35. Medovo	42-42	27-31	andesites	540	P	64	29
36. Kableshkovo	42-39	27-35	andesites	530	P		22
37. St. Karadjovo	42-13	26-50	imestones	1970	U		21
38. Meritchleri	42-09	25-30	andesites	4810	U	60	45
39. Kiustendil	42-18	2242	gneisses	720	U		76
40. Nevestino	42-16	2249	diorites	790	U		32
41 Sapareva banja	42-17	23-15	gneisses	670	U		101
42. Blagoevgrad	4242	23-06	gneisses	820	U	100	55
43. Struma (Blag.)	4240	23-04	gneisses	840	P		57
44. Osenovo	41-57	23-14	gneisses	570	P	72	50
45 Simitli	41-54	23-05	gneisses	600	F	78	63
46. Oshtava	41-48	23-13	granites	470	P		56
47. Gradeshka banja	41-42	23-14	granites	580	P		68
48. Sandanski	41-35	23-17	sands	690	U	108	83
49. Levunovo	41-29	23-18	gneisses	1000	U	97	87
50. Rupite	41-28	23-15	gneisses	2350	U	93	76
51. Marikostinovo	41-26	23-19	gneisses	1000	F	87	62
52. Musomishta	41-35	23-46	marbles	430	P		22
53. Ognanovski bani	41-37	23-48	gneisses	280	U	4s	40
54. Gotzedelchev b	41-37	23-49	gneisses	320	P		43
55. Dobrinishte	4149	23-34	gneisses	340	U	79	43
56 Guljina banja	41-53	23-32	granites	390	U	61	58
57. Eleshnitza	41-52	23-36	diorites	360	F		56
58. Zlataritza	41-54	23-39	gneisses	220	F	41	36
59. Bachevo	41-56	23-26	granites	210	F	46	26
60. Chepino	41-59	23-58	granites	240	U		48
61. Ladjane	4242	23-59	granites	600	U		63
62. Kamenitza	4243	23-59	granites	820	U		91
63 Draginovo	4243	2440	gneisses	770	U		97
64. Banite-Varvara	4248	2447	gneisses	810	U		91
65. Belovo	42-12	2443	marbles	580	F		25
66. Kostenetz	42-16	23-50	granites	270	U	88	47

TABLE 6. (cont.d)

67. Dolna Banja	42-18	23-46	gneisses	620	F	65	64
68. Bratzigovo	4242	24-22	rhyolites	420	U	-	26
69. Krichim	41-59	24-28	marbles	920	P	-	30
70. Mihalkovo	41-51	24-26	marbles	43w	F	98	27
71. Posestra	41-46	21-26	marbles	1050	F	-	36
72. Bedenski bani	4142	24-30	gneisses	1830	U	-	76
73. Narechenski h.	41-54	2444	gneisses	1670	U	109	31
74. Vlahovo	41-34	24-50	marbles	290	P	-	23
75. Davidkovo	41-38	24-59		920	P		44
76. Kirkovo	41-19	25-20	marbles	290	P		22
77. D Botevo	41-45	2543	sandstones	500	P		21
78. Haskovo	41-56	25-21	rhyolites	1640	F		58
79. Harmanli	41-56	25-54		4280	P		23
80. Simeonovgrad	4242	25-53	gneisses	1600	F		21
81. Targovishte	43-18	26-31	limestones	587	U		27
82. Varna	43-15	27.51	limestones	611	U		55
83. Drujba	43-17	2842	limestones	549	U		47
84. Barzia	43-17	2347	granites	286	U	66	31
85 Slatina	43-19	23-11	diorites	348	P	49	18
86 Mramor	42-46	23-23	sands	1513	F	91	42
87. Ilientzi	42-44	23-26	limestones	4526	F	58	52
88. Birimirtzi	4243	23-25	sands	3069	F	65	30
89. Al Voikov	42-47	23-28	sands	1648	F	56	43
90. Gniliane	42-46	23-28	sands	3437	F	50	42
91. Svetovrachene	4246	23-29	sands	1194	F		48
92. Chepintzi	4245	23-32	sands	3287	F	60	51
93. Ravno pole	42-39	23-36	limestones	719	U	68	53
94. Kliment	42-34	24-44	granites	276	F	62	3u
95. Karnobat	42-36	26-54	andesites	560	F		24
96. Aitos	4240	27-13	andesites	417	F	52	19
97. Slanchev briag	42-38	27-38	andesites	11710	U	37	34
98. Rila	42-07	23-10	diorites	952	F		32
99. Hotovo	41-28	23-21	sandstones	442	F		36
inn. Spatovo	41-29	23-21	sands	550	F		40
101. Kromidovo	41-25	23-25	sandstones	642	F	39	23
102. Iakoruda	41-58	2341	granites	642	U	77	43
103. Rakitovo	41-56	2448	gneisses	326	F		51
104. Erma reka	41-22	24-58	marbles	981	F		87
Total							

*Note: Estimated le ratures ;omputed ing various chemical g ıermometers (chalc ıy,
Na-K, Na-Li, Na-K- and K-

TABLE 8. WELLS DRILLED FOR DIRECT BEAT UTILIZATION OF GEOTERMAL RESOURCES FROM JANUARY 1, 1990 TO DECEMBER 31, 1994

(Do not include thermal gradient wells less than 100 m deep)

[1] Type or purpose of well and manner of production
Use one symbol from column (a) and one from column (b)

(a)	.... (b)
T = Thermal gradient or other scientific purpose	A = Artesian
E = Exploration	P = Pumped
P = Production	F = Flashing
I = Injection	

[2] Total flowrate at given wellhead pressure (WHP)

Locality	Year Drilled	Well Number	Tipe of Well[1]	Total Depth	Max. Temp.	Fluid Enthalpy	Well Output[2]	
				m	°C	kJ/kg	Flow Rate kg/s	WHP bar
Northern Bulgaria								
1. Devnja	1991	148	P,A	503	21.0	-	60	2.15
2. Devnja	1991	154	P,A	767	21.0	-	60	1.18
3. Devnja	1991	150	P,A	800	19.0	-	100	1.35
4. Varna	1992	161	P,A	2 000	51.0	-	48	3.02
5. Devnja	1992	160	P,A	524	21.0	-	20	2.54
6. Albena	1992	149	P,A	1 409	28.0	-	20	1.75
Southern Bulgaria								
7. Pavel banja	1991	19	E,A	483	55.0	-	9.6	-
8. Poljanovo	1991	135	E,A	433	47.0	-	18	-
9. Poljanovo	1991	136a	E,A	500	39.8	-	0.7	0.4
10. Bresovo	1994	154	E,A	300	20.7	-	-	0.03
11. Topolitsa	1994	159	E,P	300	19.1	-	13.2	0.00
12. Sofia	1992	36	P,P	550	44.8	-	3.0	1.29
13. D. Bogrov	1992	25	P,P	250	27.5	-	15.0	0.00
14. Spatovo	1991	1	E,A	700	54.0	-	4.0	0.44
15. Levunovo	1990	5	E,P	300	67.8	-	10.0	0.2

TABLE 9. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES
(Restricted to personnel with a University degree)

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

Year	Professional Man Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
1990	13	15	2	-	-	-
1991	12	12	2	-	-	-
1992	12	10	2	-	-	-
1993	12	10	2	-	-	-
1994	12	10	2	-	-	-

TABLE 10. TOTAL INVESTMENTS IN GEOTHERMAL IN (1994) US$

Period	Research & Development Include. Surf. Exp. & Exp. Drilling	Field Development Include. Prod. Drilling & Surf. Equipment	Utilization		Funding Type	
	Million US$	Million US$	Direct Million US$	Electrical Million US$	Private %	Public %
1975 - 1984	-	-	-	-	-	-
1990 -1994	0.82*	-	-	-	<10	>90

*Note: Private investments in bottling are not included