GEOTHERMAL OPPORTUNITIES in EASTERN EUROPE: *A Survey*

January 1996

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INTRODUCTION

Since the times of earliest man, the multitude of geothermal springs in Eastern Europe have been known and utilized for basic human needs. The use of many of these springs for bathing goes back as far as recorded history. More recent uses, such as greenhouses, building heat, and geothermal electric generation are just now being considered and employed.

The Springs, themselves, often became focal points for habitation, and small villages and cities grew up around the more popular and accessible resources. As will be shown in the following pages, many of these villages took on the name of "bath" (whatever the local language word was) as a result of the geothermal springs.

Beginning with the Roman Empire, a number of the springs were developed (on the surface) into formal bath houses and structures. In some cases, these structures still exist and are used today. Many are resort areas, and the Springs are thought to have certain healing powers for such ailments as arthritis and other joint and muscle ailments.

Eastern Europe is almost entirely dominated by low enthalpy resources, although some of these are very abundant in such countries as Hungary and Yugoslavia (the former Yugoslavia). As a result, very few instances occur of surface or wellhead temperatures exceeding 100 degrees C. Therefore, the most common uses of these resources are district heating, (apartments or other dwellings), agricultural heating (greenhouses, soil, fish ponds), and therapeutic bathing. In many cases, efficiency has been optimized through "cascading", where the first use of a hot geothermal water stream is district heat, followed by agricultural, and finally bathing.

American technologies presently winning international contracts are almost entirely electrical generation technologies. These will rarely be applicable in Eastern Europe; however, such integral parts as chemical treatments, pumps, materials, and other components common in both electric generation and direct use applications may well find attractive markets as Eastern Europe expands its use of geothermal resources. Additionally, there appears to be a high and growing level of interest in geothermal heat pumping, since many of the reservoirs and aquifers are at promising depths for this technology.

It is clear that use of these resources in Eastern Europe <u>will</u> expand. There is generally a lack of sufficient electricity and inexpensive primary energy resources, and a great need and desire for such creature comforts as a warm place to live and reliable hot water for residences. There also seems to be a common recognition that use of the low enthalpy resources may well present solutions to these needs. Therefore, the capability to work with and utilize geothermal resources will be sought after, and American technologies can play a role.

The following sections of this report attempt to lay out, on a country by country basis, the known resources, their present use, and the country's inclination for further use. Resource definitions are presented as well as they have been found in the literature. For those interested in pursuing opportunities further in any given country, extensive references are listed. The authors will be happy to help with any questions which the reader may have.

Acknowledgment

Bob Lawrence & Associates wishes to acknowledge and thank the many embassy personnel and members of foreign institutes and organizations who provided timely information for this project. We also would like to thank the Library of Congress personnel who dedicated time and energy to help us find all available current literature on this subject. Finally, we especially wish to thank the National Renewable Energy Laboratory (NREL) and the Department of Energy for the opportunity to carry out this study. Our special thanks to Allan Jelacic, Marshall Reed, Gladys Hooper, John Anderson, Ellen Morris, and Raleigh Makarechian for their support and assistance with this effort.

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ALBANIA

Albania is a small, poor, mountainous country, and it has always been one of the poorest of the Eastern European countries. As a result, very little real exploration of geothermal resources has been accomplished. Like most Eastern European countries, the geothermal waters occurring at the surface have been used mostly for bathing and vacation spas, and little actual development has occurred.

According to the Geothermal Atlas (Ref. 1), the available data from which the geothermal field has been estimated was taken from boreholes and mines. No reports have been found where resources have been thoroughly explored or developed commercially. Much of the reason for this underdevelopment is due to the austere government history (Albania was the most "Stalinist" of all the Eastern European countries) and small regard for standard of living increases in the country. Therefore, the resource amount, or potential flow rate of any given resource area, is difficult to predict.

The locations and surface temperatures of the best known resources are as follows:

Table 1: Albanian Geothermal Resources (Ref. 1)

Location	Temperature Degrees C	Minerals (Chemistry)
Krane-Sarande	34	Cl, Na
Langarice-Permet	26 - 31	Cl, Na, Ca
Sarandaporo-Leskovik	26.7	Cl, HCO_2, Ca, Na
Tervoll-Gramsh	24	Cl, Na
Lixha-Elbasan	58	Cl, Na(H_2S)
Kozan-Elbasan	57	(not documented)
Shupal-Tirane	29.5	SO_4, Na, Cl, Ca, H_2S
Mamurras-Tirane	21	Cl, Na(H_2S)
Peshkopi	35-43	SO_4, Ca, H_2S

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In addition to the minerals and chemicals listed, the geothermal outflows also characteristically contain methane, bromine, iodine, organic material, and other absorbed gases in varying amounts. Mineral concentrations in the outflows vary widely.

In general, then, Albania may be described as a country with some promising outflows, such as Lixha-Elbasan and Kozan-Elbasan, but a country in which the resources have never really been examined, developed, or exploited. The outflows generally have small population centers nearby, and central heating is the most generally assumed possibility.

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BULGARIA

Geothermal outflows are extensive in Bulgaria, and their temperatures range from lower ambient temperatures (13-14 deg C) up to steam. As with other countries of the region, Bulgaria has a history going back before Roman times of rudimentary utilization of these resources. It ha been thought as far back as recorded history exists that these springs had beneficial effect on human health. In Southern Bulgaria, near Sofia, a Roman bath house is in use today, for bathing and steam baths.

More recently, some of these resources have been tapped for home heating. In fact, very recently, Some have been used as the water sources for geothermal heat pumping.

Bulgaria is a country which appears to offer more utilization potential than many others in the region due to several factors: a) The history of use, b) The available temperatures, c) Available investment funds, such as the Black Sea Investment fund. Known surface occurrences, their locations and temperatures, follow:

Table 1: Geothermal Occurrences (Ref. 1):

Location	Temperature (deg C)	Flow Rate (l/s)	Minerals/ Chemicals
Varshets	20 - 38	15.0	C,S
Spantchevsi	14 - 30	9.0	C,S
Elenov dol	19 - 26	0.5	S
Shipkovo	19 - 36	40.0	C
Bankja	34 - 38	35.0	C,S
Ivaniane	20 - 27	6.0	C,S
Gorna Bania	16 - 42	7.5	C,S
Kniajevo	23 - 37	4.4	C,S
Sofia	46.7	17.0	C,S
Pantcharevo	43 - 48	12.5	C,S
Ovtcha Cupel	30 - 32	10.0	C,S
Dolni Rakovets	21 - 31	20.0	C
Rudartsi	16 - 29	26.0	C,S
Jeleznitza	21 - 32	6.0	C,S
Iskar	25	0.5	C,S
Beltchinski Bani	41	16.0	C,S
Ptchelinski Bani	72	12.0	S
Momin Prochod	65	15.0	S
Banja, Panagiursko	25 - 43	22.0	S
Streltcha	23 - 56	20.0	C,S

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Serbia and Montenegro have asserted the formation of a joint independent state, but this entity has not been formally recognized as a state by the United States.
Bulgaria
International boundary
Province (oblast) boundary
National capital
Province (oblast) capital
Railroad
Expressway
Road
Sofiya Oblast is administered from Sofia.
0 20 40 60 Kilometers
0 20 40 60 Miles
ROMANIA
Serbia
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
GREECE
TURKEY
Black Sea
Thrakikón Pélagos
Bucharest
Sofia
MONTANA
LOVECH
RUSE
VARNA
GRAD SOFIYA
SOFIYA
PLOVDIV
KHASKOVO
BURGAS
Danube
Vidin
Lom
Montana
Vratsa
Pleven
Lovech
Ruse
Razgrad
Shumen
Varna
Dobrich
Veliko Tŭrnovo
Gabrovo
Sliven
Burgas
Yambol
Stara Zagora
Kazanlŭk
Plovdiv
Pazardzhik
Pernik
Kyustendil
Blagoevgrad
Smolyan
Kŭrdzhali
Khaskovo
Silistra
Thessaloníki
Kavála
Alexandroúpolis
Edirne
Constanța

Table 1: Geothermal Occurrences (1) - continued:

Location	Temperature (deg C)	Flow Rate (l/s)	Minerals/ Chemicals
Krasnovo	21 - 55	14.0	C,S
Staro Jelezare	20 - 29	3.6	C
Hisaria	23 - 52	42.6	C,S
Pesnopoi	30 - 43	10.0	C,S
Banja Karlovo	35 - 54	28.0	C,S
Stoletovo	26 - 33	1.9	C,S
Klisura	17 - 21	11.0	C,S
Pavel Banja	19 - 61	18.0	C
Ovoschtnik	41 - 78	38.0	C,S
Jagoda	28 - 46	12.0	C,S
Starozagorski Bani	36 - 46	20.0	C
Banja-Korten	42 - 57	7.0	C,S
Slivenski Bani	42 - 50	17.0	C,S
Burgaski Bani	41	48.0	C,Cl
Medovo	23 - 29	12.0	C
Kablesckovo	22	0.3	C
St. Karadjovo	15 - 21	4.9	C
Meritchleri	21 - 45	6.0	C,S,Cl
Kiustendil	26 - 76	35.0	C,S
Nevestino	23 - 32	39.0	C,S
Sapareva Bania	33 - 101	16.0	C,S
Blagoevgrad	55	16.0	C,S
Blagoevgrad Region	57	10.0	C,S
Osenovo	36 - 50	11.0	C,S
Simitli	20 - 63	16.0	S
Oschtava	40 - 56	5.0	C,S
Gradeschka Bania	45 - 68	4.8	C,S
Sandanski	41 - 83	21.0	C,S
Levunovo	40 - 87	10.0	C,S
Rupite	73 - 76	34.0	S
Marikostenovo	42 - 62	15.0	C,S
Musomischta	21 - 22	15.0	C
Ognianovski Bani	35 - 40	40.0	C,S
Gotzedeltchevski Bani	25 - 43	70.0	C,S
Dobrinischte	31 - 43	50.0	C,S
Banja	28 - 58	70.0	C,S
Elechnitza	39 - 56	25.0	C,S

Table 1: Geothermal Occurrences (1) - continued:

Location	Temperature (deg C)	Flow Rate (l/s)	Minerals/ Chemicals
Elechnitza Region	21 - 36	8.0	C,S
Batchevo	21 - 26	10.0	C,S
Velingrad-Tchepino	32 - 48	70.0	C,S
Ladjane	22 - 63	22.0	C,S
Kamenitza	53 - 91	25.0	C,S
Draginovo	59 - 97	15.0	C,S
Banite-Varvara	36 - 91	24.0	C,S
Belovo	20 - 25	85.0	C
Kostenetz-Banite	36 - 47	30.0	C,S
Dolna Banja	55 - 64	25.0	C,S (estimated)
Bratzigovo	18 - 26	3.0	C
Kritchim	28 - 30	10.0	C
Michalkovo	13 - 27	30.0	C
Posestria	36	1.0	C,S
Bedenski Bani	76	10.0	C,S
Naretchenski Bani	21 - 31	5.0	C,S
Vlachovo	20 - 23	5.0	C,S
Davidkovo	35 - 44	3.0	C,S
Kirkovo	22	2.0	C
D. Botevo	21	1.0	C,S
Haskovo Bani	50 - 58	35.0	S
Harmanli	13 - 23	3.0	S,Cl
Simeonovgrad	21	1.0	C,S

When it is considered that Bulgaria is a country with a population equal only to that of New York City, one can readily see that in geothermal occurrences per unit of population, the country is well blessed. It should also be noted that the temperatures in the foregoing table are surface temperatures only, as little geothermal development has been accomplished using deep wells.

Two of the most promising areas for future development, from a resource standpoint, are the Lom depression, in the western part of the Moesian platform, and the Rila-Rhodope region. Heat flow values exceed 80 mw/m^2 in the Lom depression region (1), and down hole measurements have resulted in temperature values of 115-120 Deg. C at depths of 3km. In the Varna area, a resort region of significant population, measurements at the same 3km depth have shown heat flows to be in the range of 50mw/m^2 and temperatures of 70-80 deg. C.

The Geothermal Atlas (1) describes the Rila-Rhodope region as follows:

> Characteristic for the whole Rila-Rhodope region are the hydrothermal basins with numerous hot springs. Several heat flow density anomalies exceeding 100mw/m^2 are present in the Struma and Chepino valleys and in the central Rhodopes, the largest being "Erma Reka" at the southern margin of the central Rhodopes. The heat flow density within the central gneiss complex is higher than 200mw/m^2 and at a depth of 1300 meters a temperature of 130 Deg. C was measured.

Due to the geographical location of the country and topographical structure, the climate is relatively temperate; not unlike New York City. However, electricity is at a premium, and energy resources such as fuel oil and natural gas are very expensive and with an unreliable supply. Therefore, reliable heating is desirable. In southwest - central Bulgaria, numerous rudimentary installations are present, using nearby geothermal springs for heating. In D. Dabnik and Tchiflika, geothermal water is used directly for home heating.

Since ancient times, the hot springs at Kjustendil, Hisarya, Velingrad, and Sapareva Banya have been used for healthy bathing. Today, they are national bathing resorts.

There are no electricity generating geothermal installations presently in Bulgaria. However, significant use has been made of these resources for bathing, direct space heating, and greenhouses. The following geothermal installations are presently in place (1):

Table 2: Bulgarian Geothermal Installations: (B = Bathing; D = District Heating; G = Greenhousing)

Location	Wellhead Temp Deg. C	MWth Installed	MWth Planned	Type
Zlatni Pyasatzi Resort	30	3.1		D,B
Druzhba Resort	46	20.8	6.0	D,B
Marash	66	1.7		B,G
Varna	50	8.6	35.0	D,B
Tchiflik	51	1.9		B,G
Dolni Dabnik	65	8.0		G
Sofia Kazitchene	64-80	8.5		G
Banya, Karlovo	40	0.4	2.5	B,D,G
Ptchelinski Bani	72	0.7		G,B
Momin Prohod	65	1.9		B,D
Kjustendil	76	1.5	6.0	B,D,G
Sapareva Banya	98	4.2	5.0	B,D,G
Varvara-Banita	65-90	2.0		B,G

Velingrad-Kamenitza	90	1.0		B,G
Draginovo	95	2.5		G
Velingrad-Ladzhane	62	1.0		B,D
Blageovgrad-Struma River	57		2.0	G
Velingrad-Tchepino	48	2.0		B,D,G
Mineralni Bani	55	1.2	5.0	B,G
Somitlii	62	1.8		G,B
Banya-Gulina	41-53	4.0	6.0	G,B
Eleshnitza	55	1.9		G,B
Sandanski	82	2.4		B,D,G
Levunovo	87	2.0		G
Marikostenovo	62	0.3		B,G

The following is a summary table of Geothermal Direct Heat Uses, provided by Bojadgieva el al (Ref. 3).

Use	Installed MW thermal
Space Heating	51.0
Bathing and Swimming	15.0
Greenhouses	31.0
Industrial Process Heat	16.0
Air Conditioning (Absorption)	6.8
Heat Pumping	13.3
TOTAL:	133.1

Very recently, some areas of Bulgaria have begun the installation of geothermal heat pumps. Although this technology is still very sparse, some house heating unit are in place. New construction projects which will use geothermal heat pumping are planned for Velingrad, Kjustendil, Sapareva Banya and Erma Reka. As of 1994 (Ref. 3), the following units were in place:

Location	Heat Source Temperature (Deg. C)	Heat Pump COP	Output (Mwth)
Hisar Town	46	4.5	0.26
Bankja Town	36	4.7	0.26
Sandanski Town	40	4.6	1.2
St. Konstantin Resort	42	4.3	5.85

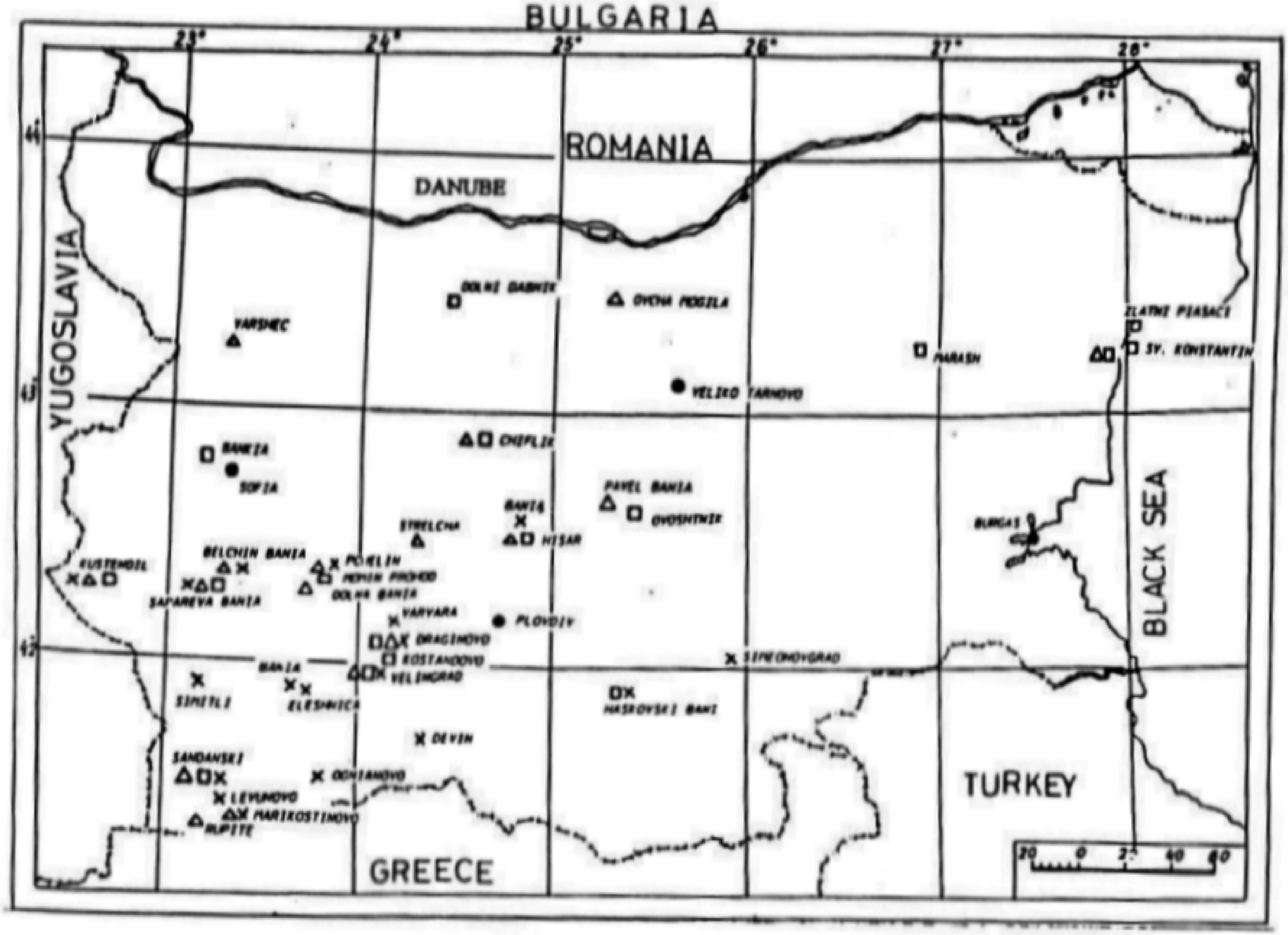

Figure 1 Map of the locations in Bulgaria using thermal water energy

△ - space heating by simple schemes

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

Varna Town 1	37	5.8	1.5
Chaika Resort	30	5.4	1.0
Varna Town 2	55	6.3	2.86
Golden Sands Resort	31	4.9	0.35

In summary, then, Bulgaria is a country with extensive geothermal resources, but few of which are above 100 Deg. C in surface temperature. The population has thousands of years of experience using these resources, but mostly for bathing. Some direct heating of houses, district heating, and greenhouse applications have occurred, and the concept of geothermal heat pumping is just now taking hold. Bulgaria is a country of entrepreneurs and represents an opportunity for American companies with advanced district heating and heat pumping technologies.

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THE CZECH REPUBLIC AND SLOVAKIA

For obvious reasons, the literature addressing this region almost entirely addresses the former country of Czechoslovakia. Therefore, it is logical for the purposes of this study, to treat these two countries, geothermally, as one. In the breakup into the Czech Republic and Slovakia, it is apparent that Slovakia got the better geothermal resources.

In the Czech Republic, the most promising areas are in and around a mountainous region called the Bohemian Massif. In Slovakia, the Carpathian region shows considerable promise as does an extension of the Pannonian Basin, where it continues into Southern Slovakia from Hungary.

As with most of Eastern Europe, the history of use of surface geothermal water flows is limited to mostly therapeutic bathing, extending back to ancient times. More recently, some use has been made of the outflows for rudimentary space heating purposes.

The locations of known geothermal outflows are as follows (1):

Location	Temperature (deg. C)	Known Chemical Content
Usti n/L	27	U*
Teplice	42	U
Usti n/L	30	U
J. Lazne	23	U
Teplice	38	U
Usti n/L	31	U
Jachymov	28	U
K. Vary	72	U
Teplice n/B	22	U
V. Ruzbachy	23	CO_2, H_2S
Same Region	17	CO_2, H_2S
Same Region	33	CO_2
R. Teplice	40	U
Ruzomberok	22	CO_2
Same Region	22	CO_2
Same Region	22	H_2S
Lipt. Jan	29	H_2S
Same Region	23	CO_2
S. Nova Ves	20	U
Tr. Teplice	40	H_2S
Tur. Teplice	22	U
Same Region	45	U

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Location of Geothermal Outflows (continued):

Location	Temperature (deg. C)	Known Chemical Content
Herlany	24	CO_2
Same Region	19	U
Bojnice	48	U
Handlova	33	U
Same Region	22	U
Same Region	39	U
Partizanske	40	U
Zvolen	46	U
Sliac	33	CO_2
P. Mikulas	80	U
Skl. Teplice	53	U
Same Region	37	U
Hlohovec	24	U
B. Stiavnica	48	H_2S
Safarikovo	17	U
D. Strehova	30	CO_2
Same Region	22	U
Same Region	36	U
Same Region	35	U
Levice	26	U
Same Region	26	CO_2, H_2S
Dudince	29	CO_2, H_2S
Sturovo	41	U
Same Region	23	U
Same Region	27	U

* - U means unknown or unpublished.

As may be readily seen in the above table, the preponderance of Czechoslovakian outflows are low enthalpy in value, suitable for bathing or greenhousing, and in rare cases, for space heating. However, in some areas of the Bohemian Massif and Carpathians, substantially higher temperature hydrothermal resources appear to exist at reachable levels below the Earth's surface. Estimates (Yoder and Tilley, 1962) indicate that regions of the Carpathians may have temperatures as high as 400 Deg. C between 4 and 10km. Similarly, regions of the Bohemian massif may reach 200 deg. C at 7km. Mean heat flow values for these regions have been calculated from between 56 and 90 data points at each location. The results are: Bohemian

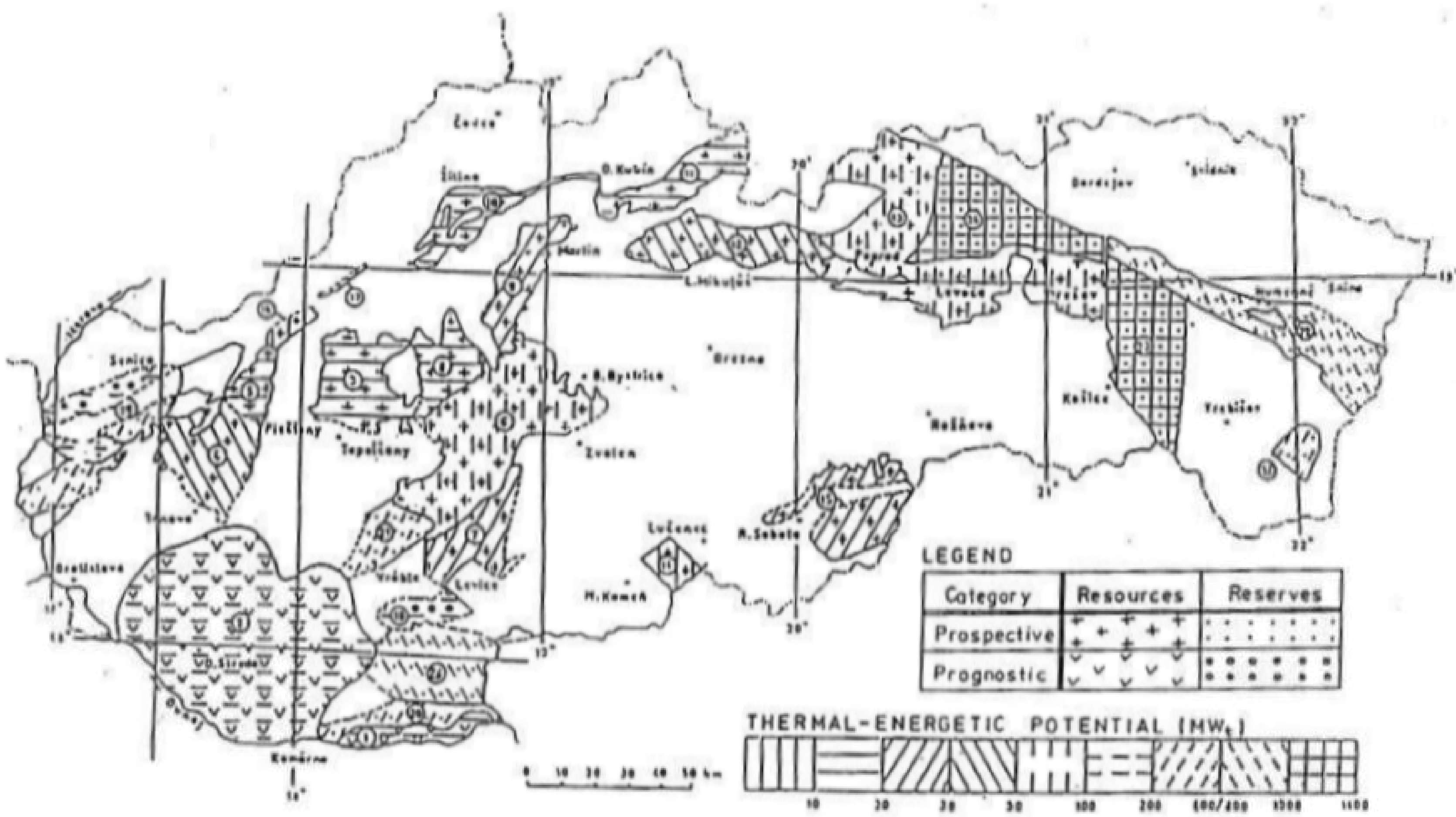

Fig. 1 Map of prospective geothermal water areas or structures in Slovakia and their thermal-energetic potential (Remšík and Fendek, 1994).

1 - Komárno high block, 2 - Central depression of the Danube Basin , 3 - Bánovce basin, 4 - Trnava bay, 5 - Piešťany bay, 6 - Central Slovakian neovolcanics (NW part), 7 - Central Slovakian neovolcanics (SE part), 8 - Upper Nitra basin, 9 - Turiec basin, 10 - Žilina basin, 11 - Skorušina Mts., 12 - Liptov basin, 13 - Levoča basin (Wand S part), 14 - Horné Strháre-Trenč graben, 15 - Rimava basin, 16 - Trenčín basin, 17 - Ilava basin, 18 - Levice block, 19 - Vienna basin, 20 - Komárno marginal block, 21 - Komjatice depression, 22 - Humenský chrbát Mts., 23 - Košice basin, 24 - Levoča basin (N part), 25 - Beša-Čičarovce structure, 26 - Dubník depression

Tab. 2 Results of geothermal wells drilled in 1971 - 1994 in Slovakia (Remšík and Fendek, 1994)

Structure area	Number of geothermal wells	Drilling period	Aquifers	Depth of perforated intervals (m)	Discharge (l/s)	Water temperature (°C)	Heat power (MW_t)	T.D.S. (g/l)	Chemical type of waters (over 20 eq. % of 100 % ion sum total)
Komárno block	6	1972-1990	Triassic dolomites, limestones, Neogene sands, conglomerates	77-1761	5.5-70.0	20.0-56.0	0.12-7.33	0.7-90.0	Ca-Mg-HCO_3-SO_4 Na-Cl mixed type
Central depression	34	1971-1990	Neogene sands, sandstones, conglomerates	276-2487	0.3-25.0	23.0-91.5	0.13-6.80	0.5-8.3	Na-HCO_3 Na-HCO_3-Cl Na-Cl
Dubník depression	2	1989-1990	Badenian sandstones, conglomerates	745-1905	1.5-15.0*	52.0-75.0	0.25-2.40	10.0-30.0	Na-Cl Na-SO_4-Cl
Levice block	2	1973-1986	Badenian clastics, Triassic dolomites	995-1740	28.0-53.0	69.0-80.0	6.30-14.42	19.2-19.6	Na-Cl
Komjatice depression	1	1989	Pannonian sands, sandstones	1509-1700	12.0	78.0	2.50	20.1	Na-Ca-Cl-HCO_3
Bánovce basin	2	1984-1985	Triassic dolomites	1512-2025	2.0-17,0*	40.0-55.0	0.33-1.78	0.7-6.0	Na-HCO_3-SO_4 Ca-Mg-HCO_3
Vienna basin	2	1982-1984	Triassic dolomites, limestones	1242-2570	12.0-25.0	73.0-78.0	2.91-6.59	6.8-10.9	Na-Ca-Cl-SO_4 Na-Cl
Upper Nitra basin	1	1979-1980	Triassic limestones, dolomites	1677-1851	26.0	66.0	4.85	0.93	Ca-Na-Mg-HCO_3-SO_4
Liptov basin	4	1976-1991	Triassic dolomites, limestones	1315-2486	6.0-31.0	32.0-62.0	0.43-5.89	0.5-4.8	Ca-Mg-HCO_3-SO_4 Ca-Mg-HCO_3

Massif, 67.8 +/- 24.3mw/m^2; Carpathian Foredeep, 72.2 +/- 19.4mw/m^2; and Western Carpathians, 78.0 +/- 22.9 mw/m^2 (Ref. 1).

Franko (1975, 1980, 1987) describes a substantial effort which has taken place to utilize the hydrothermal resources of the Western Carpathians in Slovakia. 24 perspective areas were proposed in which some 37 exploratory holes were drilled. Surface temperatures from the water issuing from these holes varies from 20 to 92 deg. C. Installations utilizing these waters have been made at Besezova, Vrbov, Galanta, D. Streda, and Podhajska. These are all thermal utilization installations.

In a private communication, Dr. Anton Remsik provided a wealth of recent information regarding activity in Slovakia. This information is provided in the following figure and tables. Clearly, even though Slovakia is a small country with limited financial resources, the fact that they have drilled 25 exploratory wells in the recent past shows a level of significant interest.

Tab. 1 Distribution of low- to high-temperature geothermal waters (Remšík and Fendek 1994)

Type and temperature of geothermal waters	Defined geothermal water structure of area	Number of geothermal water structures and areas
Low-temperature T < 100 °C	Komárno high block, Central depression of the Danube basin, Bánovce basin, Trnava bay, Piešťany bay, Central Slovakian neovolcanics (NW part), Central Slovakian neovolcanics (SE part), Upper Nitra basin, Turiec basin, Žilina basin, Skorušina Mts., Liptov basin, Levoča basin (W + S part), Horné Strháre - Trenč graben, Rimava basin, Trenčín basin, Ilava basin, Levice block, Komárno marginal block, Vienna basin, Komjatice depression, Levoča basin (N part), Humenský chrbát Mts., Košice basin, Beša - Čičarovce structure, Dubník depression	26
Medium-temperature T = 100 - 150 °C	Beša-Čičarovce structure, Central depression of the Danube basin, Košice basin, Humenský chrbát Mts., Levoča basin (N part), Liptov basin, Turiec basin, Central Slovakian neovolcanics (NW part), Bánovce basin, Žilina basin, Ilava basin, Trenčín basin, Piešťany bay, Trnava bay, Vienna basin, Komárno marginal block	16
High-temperature T > 150 °C	Beša-Čičarovce structure, Žiar basin (part of Central Slovakian neovolcanics - NW part), Košice basin, Vienna basin, Central depression of the Danube basin	5

In short, the Czech Republic and Slovakia are developing countries with resources which need further exploration. The need for space heating, greenhousing, and District Heating is substantial across the country, and there is some considerable promise that geothermal resources could be harnessed to accomplish some of this. Energy, in all forms, is scarce in these countries and very expensive. American technology could certainly help.

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FEDERAL REPUBLIC OF GERMANY: EASTERN FEDERAL STATES (FORMERLY EAST GERMANY, OR THE GERMAN DEMOCRATIC REPUBLIC)

The literature regarding geothermal resources in this area of Europe, once again, reflects the political structure prior to the fall of the Berlin Wall. Therefore, addressing the former "East Germany" is the most rationale way to summarize the literature addressing this region.

The Eastern Federal States of Germany do not appear to be particularly promising from the standpoint of Geothermal energy. Yet, interestingly enough, there has been some significant development of hydrothermal resources for baneological (therapeutic bathing)greenhouse, and space heating activities. The Geothermal outflows in Eastern Federal States are few, and their surface temperatures are unimpressive, yet the Germans have done enough scientific work to locate resources below ground of more useable temperatures and apply those resources to the above stated uses.

Geothermal outflows, and their temperatures are as follows (1):

Location	Surface Temperature (Deg. C)	Chemical Contaminants
Bad Elster	<20	Cl
Bad Brambach	<20	Cl
Wiesenbad	24.6	Carbonates
Wolkenstein	23.2	Carbonates

As may be seen in the above Table, the outflows, at their surface temperature, are not enticing for development. However, over the years, studies have been accomplished, going back to 1884 when the world's deepest borehole of the time was drilled outside of Leipzig near the village of Schladebach. The hole was drilled to some 1700 meters, and a temperature of 60 deg C was measured at that depth compared to a surface temperature of 10 deg. C (Ref. - Dunker 1889). Studies since that time have led to the identification and utilization of certain hydrothermal resources in Eastern Germany. These installations are as follows (1):

Location	Well-Head Temperature (Deg. C)	Thermal Megawatts
Neubrandenburg	52	10
Waren-Papenburg	60	5.2
Prenzlau	42	7
Stralsund	56	
Schwerin	76	

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Neustadt-Glewe	95
Neuruppin	60

The above Table shows that German exploration and development was able to identify and access reservoirs of acceptable temperature for some thermal uses.

In the North of the Eastern Federal States, exploratory boreholes were drilled to ascertain temperature distributions with depth. From Glaser, 1983 (Ref.), it was found that temperatures approached 164 Deg C at 5000 meters. A similar hole, designated Friedland 1, showed temperatures of about 170 deg C at 5000 meters (Fricke & Schlosser, 1980).

According to the Geothermal Atlas (1):

> The main potential formations are sandstone layers of Raetian to lower Cretaceous age (Postera Sandstone, Contorta Sandstone, Hettangian, Aalian, Wealden) and of the middle Bunter. The potential aquifers are inhomogeneous regarding their lithology and structural development.... From the economic point of view, most perspective (the most promising formations) are the sandstone formations at a depth between 1000 and 2500 meters (up to over 100 deg C formation temperature).

The literature points out that formations below 2500 meters simply have not been studied up to the present time.

In short, Eastern Germany does not appear to be an area of promise for further geothermal development. Any that occurs will probably be accomplished in a subsidized fashion by the German Government. The best expertise on this subject is thought to be at the Zentralinstitut fur Physik der Erde, in Potsdam. A researcher named S. Glaser is often referenced.

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HUNGARY

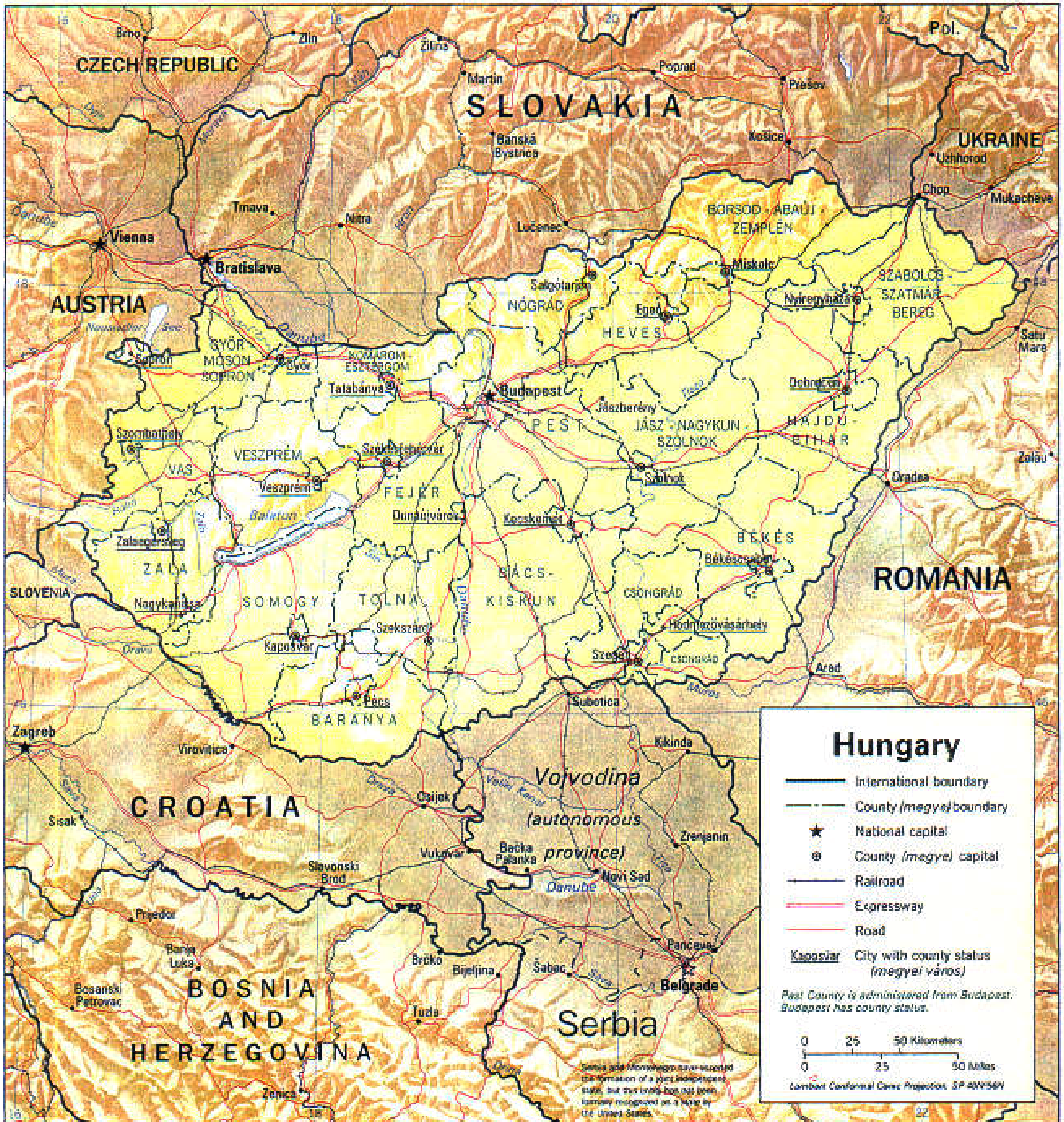
Hungary is a country which is moving forward on infrastructure, standard of living, and other economic improvements faster than virtually any other entity in the Eastern European block. Although Hungary originally had few surface outflows in comparison to neighboring countries, Dovenyi (Ref. 1) reports that Hungary now has over 1200 geothermal wells and outflows which are being utilized in some fashion. Again, there are very few thermal springs, or natural geothermal outflows at the surface in this country, however, at an accessible depth below the surface, there are extensive low enthalpy resources which have been tapped and are now extensively used in a variety of applications. In addition, there is some significant evidence that high enthalpy resources may also be present at depths which will allow electric generation to occur.

The dominant geological feature in Hungary which provides for the hydro geothermal distribution is called the Pannonian Basin. The Upper Pannonian reservoir system extends nearly throughout the entire country, and even extends to adjoining countries, such as the Czech Republic and Slovakia, as well as Austria, Romania, and the countries of the former Yugoslavia. The Basin is surrounded by the Alps, the Carpathians, and the Dinarides. This overall formation results is an extensive, low enthalpy, geothermal aquifer which has been tapped by a few hundred using wells (1). Down to 2000 meters, the temperature gradient seems fairly linear in most regions, with temperatures up to 90 deg. C. Below 3 Km, however, discontinuities occur, and temperatures as high as 250 deg. C have been encountered.

Since World War II, an extensive program has been in place in Hungary to identify and utilize the low enthalpy, widespread, geothermal resources. The applications have been for therapeutic baths, space heating, and agricultural uses. Figure 1 (Korim, 1978) shows the utilization of Geothermal resources in Hungary as of the 1977-1978 time frame. Utilization has increased since that time.

As previously stated, natural, surface, geothermal outflows in Hungary are limited. The more notable ones are as follows:

Location	Flow Rate (l/min)	Temperature (Deg. C)	Chemical Contents
Lake Heviz	17-35	17-42	All Springs
Budapest:			contain SO_3,
Gellert Hill	2 - 4	35-45	Cl, and HCO_3
Jozsef Hill	3 - 7	30-60	ions in signi-
			ficant amounts



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The historical interest in drilling wells to access heated, geothermal waters dates back to the middle 1800's. The following table, showing this interest, is from Ottlik et al (Ref. 3):

Historical Geothermal Wells in Hungary

Location	Year of Drilling	Depth (M)	Formation Drilled	Temperature (Deg. C)	Flow Rate (Liters/min)
Harkany	1866	37.7	Triassic Limestone	61	Unknown
Budapest. Margaret Island of the Danube Number 1	1866	118.5	Eocene Marl	44	6200
Budapest Town Park No. 1	1868-77	970	Triassic Dolomite	74	350-500
(Around 1980, a hole drilled in Permian Limestone, south of Budapest, produced water of 100 deg. C at a depth of 1000M)					
Nagyatad, South of Lake Balaton	1911	413	Pannonian Sediments	32	900

In the early 1900's, the interest in geothermal exploration experienced a lull, but after World War II, it became a national priority, resulting in the installations shown in Figure 1. These geothermal wells are used for a wide variety of thermal purposes in consonance with the areal distribution and hydro geological conditions in which they were drilled. Obviously, use is also based on the needs of the local populace, in line with the dictates of the Hungarian government at the time of development. As of 1985, the following distribution of uses was in place (data from Hungarian Water Authority):

Use	Number of Wells	Flow Rate (m3/hr)
Therapeutic Bathing	277	231.13
Drinking Water	236	186.14
Agricultural Heating	258	255.23
Apartment Heating & Warm Water	14	21.19

Industrial Hot Water	70	61.94
Other Uses	128	68.25
Abandoned	33	19.21

The preceding Table contains a total of 1016 wells with a combined flow rate of 843.1 cubic meters per hour. Approximately 1/3 of the wells exhibit wellhead temperatures above 60 deg. C.

Balneological and therapeutic uses of the geothermal waters is very popular in Hungary as can be seen from the preceding Table. The most famous bathing centers and resorts are Budapest, Heviz, Harkany, Hajduszoboszlo, Gyula, Buk, Debrecen, and Zalakaros. The greatest number of bathing resorts, both bath houses and outdoor pools, are in the Great Hungarian Plain.

Residential and District Heating first occurred near the bathing centers where the geothermal waters were of a high enough temperature to warrant it. Buildings associated with the bathing centers were heated in Budapest, Harkany, Hajduszoboszlo, Debrecen, Gyula, Szolnok, and Gyor. As stated by Ottlik et al, "In 1959, the municipal hospital of Szentes was supplied by thermal water " from a wellhead, the temperature of which was 79 deg. C. The water was used to heat the hospital wards and other rooms. In the late 1960's, Hungary instituted a program to employ geothermal district heating for both hospitals and apartments. "A District Heating project, comprising 1000 flats in Szeged was started in 1962 by the use of thermal water of 89 deg. C coming from a nearby well" drilled to 1900 meters (Ottlik et al). The University at Szeged was then addressed similarly, followed by hospitals at Hodmezovasarhely and Mako as well as the ceramic plant in Hodmezovasarhely. The estimated energy content of the geothermal water used in this fashion in Hungary, in the early 1980's, was about 4MW. Domestic hot water is provided from geothermal resources to about 3000 individual apartments, at an estimated additional 4MW.

Compared to this, agricultural uses in Hungary exceed 500MW. According to Ottlik et al:

> Agricultural use of Geothermal energy is the most important branch of the thermal water utilization in Hungary, especially for horticultural purposes. At present, the majority of horticultural facilities heated by geothermal energy in the world occurs in Hungary. Greenhouses totaling about 500,000 m^2, as well as plastic tents, tunnels, and soil heating of about 1,200,000 m^2 are supplied by thermal water. About 80 percent of all existing greenhouses in the southern part of the Great Hungarian Plain are heated by geothermal energy. In the horticultural use of thermal water, the greenhouses are first heated with thermal water of a temperature ranging from 60 to 100 deg. C. Then the outgoing thermal water of lower temperature is introduced to the plastic tents and tunnels. Finally, the soil heating phase follows.

Animal barns and facilities are also heated by geothermal waters. About 50 such facilities exist, mostly in Southern Hungary. In addition, fish ponds, are warmed, providing more rapid fish growth. A few plants for agricultural drying are supplied with geothermal energy, and in some cases, where mineral content is low, the water is directly applied to fields as irrigation water.

The literature indicates that recent results show the presence of high enthalpy aquifers, and their potential for uses such as electric generation. The mean temperature in the Pannonian Basin is estimated to be 165 deg C at 3km (Ottlik et al), indicating that electric generation temperatures may well be found at 4-5km depths. A well that was being drilled for oil and gas exploration encountered a high temperature geothermal water resource at 3685 meters. According to Horvath (ref. 1):

> Formation fluid was water with a temperature of 190 deg. C and a very high static pressure of 71MPa. Flow rate measurement gave an effective permeability of 70 millidarcy. Later, during technical operations, a dramatic outburst occurred. The well produced a mixture of overheated water and steam, with a yield of 3.6 m^3/min., and a wellhead pressure of 36.5MPa. This seemingly derived from the lower 500m depth interval of the well.

The well blowout went on for 45 days without any measurable decrease in pressure, temperature, or flow rate. The water was saline and a silica geothermometer gave a reservoir temperature of 254 deg. C.

The above occurrence is not unique in Hungary. Authors such as Horvath (1) feel that many such occurrences may be available along major shear zones in the geological "basement". Hungary has a long history of geothermal use and development, and if such high temperature zones do occur, Hungarian engineers are likely to find them.

Two major data bases exist in Hungary describing their geothermal resources. These are computerized and are in the Hungarian language. They are also proprietary, and access to the data bases needs to be negotiated on a case by case basis. The contacts for these data bases are:

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In summary, Hungary has shown and continues to show, as a nation, an unusual interest in the development and utilization of geothermal energy. High enthalpy reservoirs may, in fact, exist in quantity and are likely to be discovered as more drilling occurs below 3500-4000 meters. Since Hungary, like most Eastern European countries, has a great need for both electricity and heat, it is certain that any useable resources found will be employed.

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POLAND

In Poland, there are very few thermal springs, or geothermal outflows at the surface. As a result of this, and the fact that Poland has a long history of using soft coal, the geothermal resources of the region were virtually ignored until the late 1980's. At the present time, there is a significant interest in Poland in tapping underground thermal water resources for district heating, baneological purposes, greenhouses, industrial drying, and other direct uses. Even in the more promising regions of Poland, the water temperature rarely exceeds 70 deg. C, even at depths of 3 Km. In any event, using these waters, combined with natural gas "booster" heat, is being looked at seriously for widespread heating uses.

In the early to mid 1970's, interest in geothermal hydrothermal resources began to increase with the discovery of meaningful thermal reservoirs in the regions of Wielkopolska (central Poland) and in the Podhale depression. After that time, intensive hydrogeothermal activity began.

The Polish thermal reservoirs are exclusively low enthalpy. No evidence has been found, so far, of high enthalpy anomalies. There is one promising factor, however, in that the thermal waters have, generally, a low mineralization content. This enhances their usefulness for direct heating purposes.

The most promising areas of Poland seem to run in a belt from central Poland, West of Warsaw, Northwesterly to the Polish border. The following summaries are from the Geothermal Atlas (1):

> Grudziadz-Warszawa District contains around 2.766 Km^3 of geothermal waters with an energy equivalent of 9.835 MWt of standard fuel in the Cretaceous and Jurassic sediments and, additionally, 344 Km^3 of geothermal waters equivalent to 2.107 Mt of standard fuel in the Triassic sediments. The greatest resources - 1.845 Km^3 - are contained in the Liassic formation (Gorecki et al, 1986). The temperature of the Liassic waters at a depth of 1-3 Km varies from 25 deg. C to 90 deg. C and their salinity, from 2 to 110 gm/l, while their discharges measured by Sokolski et al (1986) ranged from .003 to 0.04 m^3/sec.
>
> Szczecin-Lodz District (67,000 Km^2) contains resources of geothermal waters of about 2.580 Km^3 with an energy equivalent of 16.627 Mt of standard fuel in Cretaceaous and Hurassic sediments. Additional 274Km^3 of geothermal waters (2.185 Mt of standard fuel) have been found in the Triassic sediments. The greatest resources (1.935 Km^3) also are contained in the Liassic formation (Gorecki et al 1986). The temperatures of these waters vary for depths between 700 and 3800 meters from 30 to 114 Deg. C. The mineralization varies from 0.5 to 127 gm/liter and discharges range from .00003 to .01 m^3/sec (Bojarski, 1984; Sokolowski et al., 1986; Sokolowski, 1985).

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Foresudetes-North Swietokrzyski District (39,000 Km^2) contains around 155 Km^3 of geothermal water in Triassic and Permian sediments (995 Mt of standard fuel). These waters are highly mineralized (300 gm/liter).

Coastal District (12,000 Km^2) contains around 21 Km^3 of geothermal waters (162 Mt of standard fuel). The waters occur in several stratigraphic units of the Permian, Carboniferous, and Devonian as well as of Liassic and Triassic ages.

Lublin District (12,000 Km^2) contains around 30 Km^3 of geothermal water (193 Mt of standard fuel) in Carboniferous and Devonian formations, characterized by low permeabilities and low discharges (Sokolowski, 1988).

Baltic District (15,000 Km^2) contains around 38 Km^3 of geothermal water (241 Mt of standard fuel) mainly in Carboniferous and partly in Permian and Mezosoic formations.

Podlasie District (7,000 Km^2) contains around 17 Km^3 of geothermal waters (113 Mt of standard fuel) mainly in Cambrian and Permian formations (Sokolowski, 1988).

In the Sudetes Holy-Cross (Swietokrzyski) Region, geothermal water has been produced by wells in fractured metamorphic rocks. The depth of the wells has not exceeded 750 m, and the temperatures range from 20 to 60 deg. C. The water has been used solely for therapeutic bathing.

In 1981, an event occurred which gave a solid emphasis to the continuing and expanding study of polish geothermal water resources. In that year, the Banska IG-1 well was completed. An artesian aquifer was found between 2.5 and 2.7 Km. Five more exploration wells were then drilled in the area. Wellhead water temperatures were 86-89 deg. C (Ref. 2). This resource was finally used to supply heat to a local building as well as to a greenhouse and agricultural drying facility. In the near future, it will be connected into the district heating system of the villages of Szaflary and Bialy Dunajec.

The Szczecin-Stargard Szczecinski area has been found to have promising reservoirs at depths of 1800-2600 meters, with water temperatures of 76 to 100 deg. C. The salinity ranges from 80 to 125 Kg/m^3 across this depth. In this region, district heating projects have been initiated for the village of Stargard and a greenhouse complex in Szczecin. In the village of Pyrzce, a Danish firm has designed a district heating system using a combination of geothermal water with additional temperature achieved through heating the flow with natural gas. Over a ten year production period, peak capacity of 10 to 12 MW is planned along with a 30 year production period.

The Kolo-Uniejow area is being addressed through the utilization of artesian thermal water formations, accessed by wells in this region. District heating studies have been accomplished for both of these towns. Temperature of the produced water varies from 50 to 70 deg. C, depending on the well. The nearby towns of Gniezno and Tarnow have also been selected for geothermal district heating. Near the town of Krosno in this same region, an exploratory well e\searching for gas produced water with a surface discharge rate of 200 m^3/hr at a temperature of 80-90 deg. C. This is the closest thing to a high enthalpy anomaly that is found in Polish literature.

Piotr et al (Ref. 3) give a detailed and analytical description of the first major, modern, cascading geothermal heating installation in Poland. This occurred in the Podhale region, and is referred to as the Banska-Bialy Dunajec plant. The plant was completed in 1992 and is located about 10 Km north of the city of Zakopane, 90 Km south of the city of Krakow. This particular region was chosen based on data showing substantial geothermal waters of a temperature of 86 deg. C occurring at depths down to 3 Km. Mineral content was found to be 0.5 to 3 gm/liter, which is a clearly manageable range. On a production well, 260 m^3/hr is extracted without the use of any pumping. Using a deep well pump, this production rate has been increased to 500 m3/hr. This Podhale region has one of the longest space heating requirements in all Poland, normally 300 days per year. The population of Zakopane is 35,000, not including the ;large number of tourists who visit the region annually. Temperatures range down to -30 deg. C. Up until 1990, the area was entirely heated by individual central heating stoves and furnaces, using coal and coke, creating tremendous air and water pollution. The pollution level reaches four times the nationally regulated standard.

To date, seven wells have been drilled and utilized, to depths ranging from 192 to 2683 meters. Ph of the a\water ranges from 7.0 to 7.5, with mineral content as described above. In no case does the mineral content exceed 3gm/l.

The geothermal plant, itself, is designed to provide district heating, drying heat for a drying chamber, and heat for a greenhouse, fish breeding pool, and swimming pool. The applications are cascaded, with the highest quality heat going to the highest temperature need, and following down the heat chain until the water is reinjected at a temperature of about 30 deg. C. At this point in time, space heating is provided for 30 dwelling units, with an eventual 225 to be supplied in the Szaflary community (Ref. 3).

Feasibility studies are now underway to use the geothermal resource to heat the entire region, through a system of doublet wells. It is estimated that such a system will cost about $50 million for a market penetration of about 95%. Presently, 400,000 tons of coal per year are used in the region. The geothermal system, should it be fully implemented, would offset 95% of that coal use. It is briefly mentioned that some gas fired “peaking” boilers may have to be installed on the system.

Finally, there is an extensive and detailed study available on the present and potential uses of geothermal waters in the Zyrardow region of Poland (Ref. 4). Hydrothermal resources are available at various depths under Zyrardow as follows:

Depth (meters)	Water Temperature (Deg, C)
1400-1550	41 - 43
1750-2150	50 - 60
2150-2550	60 - 67
2550-2850	67 - 73

Considering the low enthalpy and relatively low temperature values of these resources, it is interesting to note the level and intensity of effort addressing them. It is indicative of the relative lack of energy capacity and clean fuels in Poland.

The Zyrardow study examines the regional demand for thermal energy; the needed plant geothermal power and capacity, by year; the inter-relationship between the geothermal plant and the old, present coal-fired district heating system, and seasonal demand factors. It mentions that heat pumping may well be an effective way to utilize the low enthalpy waters rather than direct use, alone. Although the study results are somewhat understated, they appear logical in that they recommend the best use of these waters for District Heating would be to integrate the geothermal heat into the overall conventional heating system, in a manner which really uses it as a pre-heating source.

In summary then, Poland is a country which would very much like to utilize their geothermal resources for environmental and energy capacity reasons. However, they are greatly handicapped by the temperature and depth of the available resources, even though the resources, themselves, are extensive. Should Poland turn to heat pumping as a solution, U.S. technology might be able to find an opportunity. It appears that the direct uses will be only done with rudimentary technology, and do not offer American firms any opportunity.

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ROMANIA

Romania is not a wealthy country, with an economy which is largely agrarian. Hydrothermal resources have only been exploited sporadically, and largely as a result of a surface manifestation (outflow), or hitting a reservoir by accident while drilling for oil and gas.

No real work has been done focussed on heat flow patterns in the country, but some attempts to locate patterns was accomplished by Demetrescu (1978, 1979, 1983, 1988) and Veliciu et al (1985a, 1987). The data is not considered particularly reliable, since it came largely from oil and gas exploration wells, but it does show some constant properties. Heat flow values are highest in that part of the Pannonian Basin which extends into Romania, and lowest in Transylvania, the Carpathians, and in the Moldavian platform.

Strictly from the heat flow work which has been done, the most promising areas of Romania would appear to be in the Baia Mare region of North Romania, and East of Tg Mures in central Romania.

Some hydrothermal resources have received analysis, even though they are definitely low enthalpy. Descriptions of these resources follow:

In the Pannonian Basin region of Romania, there appear to be four main hydrothermal reservoirs. Under Biharia, Oradea, and Western Banat, the temperatures of the reservoirs can exceed 70 deg. C. Below Satu Mare and Eastern Banat, the temperatures are decidedly below 70 deg. C. The extent of these reservoirs, with regard to depth, does not appear in the literature, but the preponderance seems to be in the 2-3 Km range.

In the Moesian platform, near the towns of Bucuresti-Otopeni and Insuratei-Hirsova, there are some pockets of hydrothermal interest. Near Bucuresti, there is an aquifer between 2200 and 3000 meters with a temperature of 42-67 deg. C. Near Insuratei-Hirsova, the aquifer of interest is much closer to the surface, occurring at depths of 400-1200 meters. The temperature of this second aquifer is slightly lower, but still of some interest.

In the Caciulata-Cozia zone, artesian reservoirs were found at 200-1200 meters, with temperatures around 50 deg. C. A deeper aquifer was found to have a temperature range of 85-90 deg. C.

In the southern Carpathians, some low enthalpy flows have been tapped for therapeutic bathing. The waters range from 30-60 deg. C. and are found at Herculane, Calan, and Mehadia. Aside from these outflows, there is little of geothermal interest in this region.

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The Apuseni Mountains contain several geothermal outflows in the 30-40 deg. C temperature range. No exploration of any magnitude has been undertaken near these resources to see if reservoirs of higher temperature may exist at depth.

Counselor Nicolae Stan of the Romanian Embassy provided the following set of tables concerning drilling, heat utilization, and potential, from activity during the 1964-1994 time period. Clearly, there is now some renewed interest in geothermal applications in Romania.

WELLS DRILLED FROM 1964 TO 1994 IN ROMANIA FOR GEOTHERMAL WATER

TABLE 1

GEOLOGICAL PROVINCE RESERVOIR	PRODUCTION WELLS					Drilled wells 1994 / Depth (m)	Exp. wells	Abandon wells	Reinjection wells
	No.	Depth of reserv. (m)	Flow rate (m^3/h)	Temp °C	kW Energy				
WEST PLAIN Triassic reservoir fracturate carbonate	13	1700-2600	2-30	70-105	250-6800	-	6	1	3
WEST BANAT PANONIAN RESERVOIR granoulos-sand and sandstone	14	1300-2000	4-15	69-85	500-2800	-	46	10	-
MUREȘ-CRIȘUL NEGRU PANONIAN RESERVOIR sand and sandstone	10	800-2000	2-9	62-72	200-1200	1 / 3500	6	6	-
CRIȘUL NEGRU-SOMEȘ PANONIAN RESERVOIR granoulos-sand and sandstone	12	1000-1500	2-8	50-90	84-1300	-	20	23	-
COZIA-CĂCIULATA SENONIAN RESERVOIR fissured sandstone	2	2200-2900	10-17	92-95	2200-3900	1 / 3000	1	-	-
MOESIAN PLATFORM JURASSIC - CRETACEOUS RESERVOIR fissured carbonate	3	400-2900	2-40	40-60	125-4500	2 / 1)2500 2)3000	17	1	1
TOTAL	54					4	96	41	4
TOTAL DRILLED WELLS = 195									

TABLE 2 WELLS DRILLED FOR DIRECT HEAT UTILIZATION OF GEOTHERMAL RESOURCES FROM JANUARY 1, 1990 TO DECEMBER 1, 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)
T = Thermal gradient or other scientific purpose
E = Exploration   I = Injection
P = Production   C = Combined electrical and direct use

(b)
A = Artesian
P= Pumped
F = Flashing

2) Total flow rate at given wellhead pressure (WHP)

3) For 40°C return temperature

Locality	Year Drilled	Well Number	Type of Well[1]	Total Depth m	Max. Temp. °C	Well Output[2] estimated		
						Flow Rate kg/s	WHP (bar or m)	Heat output[3] MW
SATU MARE	1990	4750	E, P	1460	67	3.6	-75 m	0.4
PERIAM	1990	4627	E, A	1400	58	10	-	0.8
VIDELE	1990	1 V	E, P	2231	40	8	-96 m	-
OTOPENI	1990	2672	E, P	3204	72	20	-60 m	2.7
MOARA VLĂSIEI	1990	2676	E, P	3028	76	24	-40 m	3.6
BUFTEA	1990	2679	E, P	3202	40	0.7	-	-
ÎNSURĂȚEI	1990	2107	E, A	1551	60	8	1 bar	0.7
SEMLAC	1991	1683	E, P	1462	55	6	-34 m	0.4
AVITIM	1991	1189	E, P	1304	51	4	-30 m	0.2
COVACI	1991	1190	E, A	1451	53	2.5	-	0.1
SNAGOV	1991	2682	E, P	3273	83	20	-36 m	3.6
BALOTEȘTI	1991	2669	E, P	3304	74	28	-40 m	4.0
MOARA VLĂSIEI	1991	2680	E, P	2829	78	35	-40 m	5.6
CĂLIMĂNEȘTI	1992	1009	E, A	3250	91	28	6 bar	6.0
SNAGOV**	1994	2683	E, P	3200				
AVIAȚIEI**	1994	2642	E, P	2100				
OLĂNEȘTI**	1994	1007	E, A	3000				
Total		17						

* Wellhead temperature   ** Drilling to be completed in 1995

TABLE 3 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 F = Feasability studies (Reservoir evaluation and Engineering studies)

P = Pre-feasability studies U = Commercial utilization

Locality	Location To Nearest 0.5 Degree		Reservoir		Status[3] in Jan. 1995	Reservoir Temp.(°C)	
	Latitude	Longitude	Rock[1]	Dissolved Solids[2] mg/kg		Estimated	Measured
SATU MARE	47.48	22.53	sand	4000	UP		88
CAREI	47.42	22.18	sand	6000	U		90
ACĂȘ	47.55	22.47	sand	4600	U		90
TĂȘNAD	47.29	22.35	sand	10976.9	U		88
SĂCUIENI	47.21	22.06	sand	4500	U		90
MARGHITA	47.21	22.21	sand	2500	U		85
MIHAI BRAVU	47.16	21.57	sand	4500	U		60
BOGHIȘ	47.09	22.44	sand	4200	U		48
BORȘ	47.07	21.49	limestone	12000	F		135
ORADEA	47.04	21.56	limestone	1200	F		100
ALEȘD	47.04	22.24	limestone	5000	U		52
LIVADA	47.03	21.50	limestone	1200	U		107
FELIX	47.00	22.01	limestone	800	U		44
MĂDĂRAȘ	46.50	21.42	sand	1600	U		62
SALONTA	46.48	21.41	sand	3200	F		95
CIUMEGHIU	46.44	21.35	sandstone	4000	F		120
ZERIND	46.38	21.32	sandstone	6200	R		98
MACEA	46.24	21.19	sand	2100	U		72
DOROBANȚI	46.22	21.15	sand	2500	U		74
CURTICI	46.21	21.19	sand	2100	U		65
IRATOȘ	46.19	21.12	sand	1812	U		64
ȘOFRONEA	46.17	21.19	sand	1400	U		70
ARAD	46.11	21.19	sand	1400	UP		42
NĂDLAC	46.10	20.45	sand	2400	U		84
SEMLAC	46.07	20.56	sand	2500	U		65
SÂNICOLAU MARE	46.04	20.35	sand	3100	UF		88
SARAVALE	46.04	20.45	sand	2400	UP		90
PERIAM	46.02	20.53	sand	2000	R		80
VARIAȘ	46.01	20.58	sand	1400	U		65
TOMNATEC	45.59	20.40	sand	3600	U		54
LOVRIN	45.58	20.46	sand	2700	U		91
TEREMIA MARE	45.56	20.31	sand	2800	UP		90
COMLOȘU MARE	45.54	20.37	sand		R		85
GRABĂȚ	45.52	20.48	sand		R		88
LENAUHEIM	45.52	20.48	sand	9500	RP		82
JIMBOLIA	45.48	20.43	sand	2800	U		88
BERECSĂU MIC	45.46	21.01	sand		R		77
TIMIȘOARA	45.45	21.14	sand	12000	U		60
HERCULANE	44.50	22.30	limestone	4500	U		70
OLT VALEY	45.16	24.20	siltstone	12000	U		98
OTOPENI	44.33	26.07	limestone	2200	UF		66

TABLE 4 WELLS DRILLED FOR ELECTRICAL AND COMBINED USE OF GEOTHERMAL 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 T = Thermal gradient or other scientific purpose

P = Production E = Exploration I = Injection C = Combined electrical and direct use

2) Total flow rate at given wellhead pressure (WHP)

Locality	Year Drilled	Well Number	Type of Well[1]	Total Depth m	Max. Temp. °C	Fluid Enthalpy kJ/kg	Well Output[2] estimated	
							Flow Rate kg/s	WHP bar
Sântandrei	1994[*]	1720	E	3500	150[**]		50	5

*) To be finished in 1995 **) BHT

Suffice it to say that utilization of geothermal resources in Romania has been very limited, and present interest in expanding this use seems present but unpredictable.

The Geothermal Atlas (Ref. 1) presents the following geothermal systems in Romania:

Location	Aquifer Depth (m)	Yield (l/sec)	Temperature at Wellhead - deg. C	Mineralization (gm/l)
Carei-Satu Mare	1000-1400	5-15	55-60	3-4
Biharia-Sacueni	1400-1700	70-80	70-80	3.5-5
Oradea-Bors	2400-3000	15-30	80-120	1-14
Ciumeghiu-Varsand	2000-2600	8-15	80-90	5-7
Mures-Crisul Alb	800-1400	15-25	50-60	2-3.5
Eastern Banat	800-1200	5-15	40-55	4-5
Western Banat	1600-2000	15-30	70-85	4-5
Bucuresti-Otopeni	2300-3000	15-20	40-67	1.4-2.5
Insuratei-Hirsova	800-1200	8-16	45-60	2-3.5
Cozia Caciulata	2200-2900	7-20	88	12-13

Present geothermal installations in Romania, for direct heat uses, are as follows:

Location	Temperature Wellhead deg C	Megawatts Thermal
Satu Mare County	46-60	0.6
Bihor County	80-120	24
Arad County	50-60	4
Timis County	70-85	16

Vilcea County	80-90	3
Bucharest-Otopeni	50-70	2

In conclusion, Romanian resources are almost universally low enthalpy, and although developmental interest seems to be present, its extent is unpredictable, at best. This would appear to be a country with significant geothermal opportunities only in geothermal heat pumping and direct utilization.

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THE FORMER YUGOSLAVIA

The former Yugoslavia consists of the present countries of Slovenia, Croatia, Boznia, Yugoslavia (Serbia and Montenegro) and Macedonia. As with other regions of Eastern Europe, the available literature largely addresses the former political boundaries, and therefore, this region will be treated in a manner consistent with the literature.

Once the strife in this part of the world dies down, there may be some considerable opportunities in this region for geothermal entrepreneurs. The former Yugoslavia (hereinafter referred to as "Yugoslavia") has over 170 natural geothermal outflows with temperatures up to about 80 deg. C. Exploration (including that for hydrocarbons) has discovered reservoirs at readily reachable depths (3 Km or so) reaching temperatures well above 100 deg. C. The promising and proven Pannonian Basin (shared with Romania and Hungary) covers a large portion of northern Yugoslavia, and as in the other countries, the Basin consists largely of sedimentary fill.

Substantial efforts to utilize the geothermal resources began in the mid to late 1970's when much of the world was addressing the energy crisis. Worldwide interest in renewable resources provided me\omentum for the effort. In 1979, Cermak and Hurtig (In: Cermak and Rybach, 1979) published a first paper describing the general geothermal characteristics of Yugoslavia. The paper pointed out the promise of the Pannonian Basin, based on the discoveries mostly in Hungary, and of areas closer to proven geothermal regions of Greece (Ref. 1).

Thermometric measurements in Northern Yugoslavia, down to 5 kilometers, has produced temperatures as high as 240 deg. C. At 3 Km, temperatures close to 150 deg. C have been found in the Pannonian Basin, the Vardar Zone, and the Serbo-Macedonian Massif. These areas are considered to hold "high temperature" geothermal resources. Not surprisingly, heat flows above 80 mW/m^2 are abundant in these regions, as well.

The crustal structure of Yugoslavia has abundant anomalies and "large scale" (Ref. 1) underground water movements. This further points to promise of, as yet, undiscovered geothermal opportunities.

The Geothermal Atlas (Ref. 1) lists some 167 geothermal outflows in Yugoslavia. Milojevic (ref. 2) has provided us with a priority list of 37 presently operating geothermal springs with temperatures above 30 deg. C. This listing is provided in Table 1 as follows:

Former Yugoslavia

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Table 1

Geothermal Springs with water temperature above 30 degrees C.

Location	Temperature (degrees C)	Flow Rate (liters/sec)
Vranjska banja	95.0	65.0
Banja Rusanda - Melenci	92.0	unknown
Josanicka banja	78.5	7.0
Sijarinska banja	71.5	5.01
Becejska banja	65.8	unknown
Kursumlijska banja	59.0	1.01
Banja "Junakovic" - Apatin	55.5	unknown
Palanacki kiseljak	55.0	2.0
Novopazarska banja	54.0	1.01
Banjska	54.0	2.5
Kupinovo	51.0	25.00
Pecka banja	48.0	4.00
Mataruska banja	42.8	4.9
Jugovo	42.0	3.0
Brestovacka banja	41.0	7.5
Gamzigradska banja	40.0	5.5
Ribarska banja	38.0	1.5
Malo Laole	37.5	20.0

Table 1 - continued:

Location	Temperature (degrees C)	Flow Rate (liters/sec)
Niska banja	37.4	23.0
Biostanska banja	37.1	35.0
Banja Topilo	37.0	1.0
Pribojska banja	37.0	48.0
Ovcar banja	36.5	49.5
Pozarevac	36.0	2.0
Nikolocevska banjica	34.0	0.45
Sisevac	34.0	10.0
Miljakovac	33.0	10.0
Banja Vrdnik	33.0	45.0
Rgoska banjica	32.0	40.0
Gornja Trepca	31.0	20.0
Pirotska banjica	31.0	35.0
Bukovicka banja	31.0	unknown
Miakovac	30.0	unknown
Sarbanovacka banja	30.0	unknown
Banja Vuca	30.0	0.80
Banja Koviljaca	30.0	unknown
Grocka	30.0	0.05

Additionally, Basovic (Ref. 3) provided an expanded listing describing the number of springs and wells (boreholes) at key locations. Basovic additionally has provided some figures on mineral content. His information is presented in Table 2

Table 2:

Developed Geothermal Resources in Yugoslavia (Basovic - Ref. 3)

Location	Boreholes (B) and Springs (S)	Flow Rate (liters/sec)	Temperature (degrees C)	Mineralization (gm/l)	Chemicals
Bogatic	6B	61	78	.531	HCO_3, Na
Matkovic	1B	11	62.8	unknown	unknown
Dubije	4B	15	50.5	unknown	unknown
Mataruska banja	2S,6B	5	52	1.33	HCO_3, Na
Josanicka banja	2S,9B	36	79	.287	HCO_3,Na
Novopazarska banja	5S,2B	4.5	52	1.726	HCO_3,Na,H_2S
Pecka banja	4S,3B	4.5	49	2.04	HCO_3,Na,CO_2
Lukovska banja	20S,5B	4.5	64	1.559	HCO_3,Na,Ca
Ribarska banja	8S,2B	9	50	.307	HCO_3,Na,H_2S
Kursumlijska banja	5S,7B	8	55	2.065	HCO_3,Na
Sijarinska banja	13S,2B	30	76	4.767	HCO_3,Na,CO_2
Vranjaka banja	8S,2B	70	72-106	1.1-1.22	HCO_3,SO_4,Na
Bujanovacka banja	2S,7B	6	43	4.98	HCO_3,Na
M. Laole	1B	19	40	.624	HCO_3,Ca,Na
Sokobanja	3S,6B	12	42	.388	HCO_3,Na
Garnzigradska banja	3S,10B	20	43	.555	HCO_3,Ca,CO_2

Geothermal heat pumps are being used, presently, in parts of northern Yugoslavia, especially connected to reservoirs of very low enthalpy (5 - 25 deg. C). The maximum depth to which drilling has been done for these heat pump applications is 100 meters, which would be deep by American standards. Nevertheless, American technology may well be able to play a role in Yugoslavia as interest in geothermal heat pumping increases.

To date, some deep hydrocarbon exploration wells have encountered aquifers with temperatures of 110-180 deg. C with strong discharge rates. To date, these aquifers have not been exploited due to economic uncertainties but they may provide the potential for electric generation.

The medium temperature resources (50 - 150 deg. C) in Yugoslavia have gotten the vast majority of development attention to date. The geothermal installations are almost entirely in the Northeastern portion of the country, in the Pannonian Basin, the Inner Dinarides, the Vardar Zone, and the Serbo-Macedonian Massif. Virtually all of these installations occurred in the immediate regions surrounding natural outflows. As with other Eastern European countries, the resources are used for space heating, greenhouses, and (when cascaded) bathing. Lower temperature resources and springs are commonly used for balneological purposes; again, since pre-Roman times.

A personal communication from Miklavz Borstnik, First Secretary of the Embassy of the Republic of Slovenia, transmitted the most recent data available from geothermal exploration in this Northwestern country of the former Yugoslavia. Mr. Borstnik states that in Slovenia, alone, geothermal plants are operating at a level of 128 MW (thermal). He states that resources capable of operating geothermal power plants exist at depths of 3-5Km, but that no electric generation plant is yet in operation. He describes high temperature sources at these depths with temperatures of 150-200 Deg. C.

Borstnik describes 37 wells and outflows in Slovenia, used for industrial process heat, air conditioning, room heating, balneology, greenhouses, and "other". The regions and their uses follows:

Slovenia Resource Uses:

General Location	No. of Wells/ Outflows	Temperature (Deg. C)	Uses
Julian Alps and Dinarides	1	22	Therapeutic
Nova Gorica and Coast area	3	18-28	Therapeutic

Slovenia Resource Uses (cont.):

General Location	No. of Wells/ Outflows	Temperature (Deg. C)	Uses
Posavje's Faults/ Ljubljana's Hollow	6	18-23	Bathing/Industrial
Tuhinje Valley	2	22-28	Bathing
Zagorje Valley	2	25	Bathing, Room Heating, Industrial
Lasko Valley	4	32-41	Bathing, Room Heating
Celje's Hollow	1	20	Therapeutic
Krisko's Hollow	8	23-62	Bathing, Room Heating, Greenhouse
Rogatec Area	3	24-62	General
Eastern Karavanke area	6	18-48	Bathing, HVAC
Pannonian Basin	10	25-66	Bathing, Greenhouse, Room Heating, A/C, Industrial

In conclusion, the countries of the former Yugoslavia may well represent an inviting opportunity for American technology and geothermal entrepreneurs, once political stability returns. Higher enthalpy resources are available, and heat pump technology has already been implemented, but in more rudimentary form than American technology. The situation in this new set of countries deserves watching, from a geothermal standpoint.

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CONCLUSION

As may be seen in the foregoing pages, the geothermal resources of Eastern Europe are extensive, relatively well known, and low enthalpy. The opportunities for electric generation are rare to non-existent, at least with presently defined reservoirs and available technologies. Direct uses, however, are desirable and being developed. Space heating, industrial process heat, greenhousing, hot water, air conditioning (with absorption units), and therapeutic balneology are all viable candidates for future development with a growing market. Finally, geothermal heat pumping may find extensive use in this region due to the large geothermal reservoir structure and the large and growing demand for creature comforts.

This is a region that deserves watching, in the interests of American geothermal entrepreneurs.