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ROMANIA UPDATE REPORT FOR 1995-1999

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ABSTRACT

Exploration for geothermal resources began in Romania in the early 1960's, arising from a hydrocarbon search program which as an unexpected benefit also identified eight promising geothermal areas. Within these areas, over 200 wells, drilled to depths between 800-3500 m, show the presence of low- enthalpy geothermal resources (40-120°C). Completion and experimental exploitation of over 100 wells during the past 25 years has enabled evaluation of the exploitable heat available from these geothermal resources.. Proven geothermal reserves in Romania are currently about 200,000 TJ for 20 years.

The principal Romanian geothermal resources are found in porous and permeable sandstones and siltstones (for example, in the Western Plain and the Olt Valley), or in fractured carbonate formations (Oradea, Bors, North Bucharest).

The total thermal capacity of the existing wells is about 480 MW_t (for a reference temperature of 25°C). Of this total, only 152 MW_t are currently used, from 96 wells (of which 35 wells are used for balneology and bathing) that are producing hot water in the temperature range of 45-115°C. For 1999, the annual energy utilisation from these wells was about 2,900 TJ, with a capacity factor of 0.6. More than 80% of the wells are artesian producers, 18 wells require anti-scaling chemical treatment, and six are reinjection wells. The main direct uses of the geothermal energy are: space and district heating -- 37%; bathing -- 30%; greenhouse heating -- 23%; industrial process heat -- 7%; fish farming and animal husbandry -- 2%.

During 1995-1999, Fourteen geothermal wells were drilled in Romania with National financing; three additional wells are in progress at this writing. Of the first fourteen, drilled to depths ranging from 1500 m to 3500 m, only two were non-producers, for a success rate of 86%.

The development of direct utilisation of Romanian geothermal resources has been hindered considerably by the inevitable difficulties attending transition from a centrally planned to a free market economy, as well as by operational capabilities which in some cases have not kept pace with recent technological advances. As a result, current geothermal production falls far short of the country's considerable demonstrated potential.

1. INTRODUCTION

Romania, along with other Central and Eastern European (CEE) Countries, has significant low-enthalpy (50-120°C) geothermal resources suitable for direct heat utilisation: space heating, culinary water heating, greenhouse heating, fish farming, animal husbandry; bathing, balneology, and many other applications Prior to the 1970's, these resources were only sparingly used, mainly for health and recreational bathing. Natural hot springs in the Precarpathian area of Romania have been known since the time of the Roman Empire, when Dacia province boasted several famous health spas including Geoagiu, Herculane and Felix. As an outgrowth of this tradition, geothermal health bathing has flourished in the country (particularly its western region) during the last 100 years.

Well-funded geological exploration for hydrocarbon resources carried out in Romania after World War II, particularly during the oil crisis of the 1970's, led to the discovery of extensive, low-enthalpy geothermal resources. Exploitation of these resources has to date been at relatively modest levels. Principal direct-use applications have been greenhouse heating, dwelling and culinary water heating, recreational bathing, and various industrial applications. The thermal water and geothermal energy has been delivered to users free of charge, with the spent fluids being discharged directly into surface waters.

Utilisation of these energy resources has been hampered due to high investment costs and the very low price of hydrocarbons. The current international market prices of fossil fuels, along with a dramatic decrease in domestic oil and gas production, has clearly set the stage for more ambitious geothermal development.

The large majority of geothermal projects currently operating in Romania are of low efficiency, and lag behind in technology, infrastructure and equipment, much of which is out of date or obsolete. Delivered geothermal energy falls far short both of demand and the considerable potential of the country's resources. The absence of an efficient management, the lack of adequate maintenance, and mainly the shortage of funds required for technologically upgrading the geothermal operations has not allowed full development of the exploitable resources. Only about 30% of the resources identified and confirmed by geothermal wells are currently in use..

Properly implemented, geothermal energy is both sustainable and environmentally. A variety of domestic and industrial consumers provide good opportunities for the development of direct uses of geothermal energy. Even so, practical accomplishments in this regard during the last ten years have been rather modest, and confined to the Snagov, Cighid, Oradea and Calimanesti projects. These projects were intended either for modernising equipment and managing existing geothermal systems, or for the exploitatiing new reservoirs. Some of these undertakings involved consultants from Western European countries, and have been awarded financial support from the European Union. Completion of these projects has taken a long time and great effort, as the work required legal and financial conditions quite new for this part of Europe, where the countries are in different stages of the transition from a centrally planned to a free market economy.

Geothermal production in Romania is far below the demonstrated potential because of non-sustained production (self-flowing [artesian] mode instead of artificial lift [pumping]) and the failure to reinject into the source reservoirs, resulting in neither resource conservation nor reservoir pressure maintenance. Some systems operating on a limited base are applying the doublet concept (i.e. combining a production/injection well pair) of heat mining (Oradea, Bors, Otopeni). These inaugural projects enabled the country to build up a nucleus of expertise in modern reservoir exploitation and management techniques.

The difficulties encountered during injection into sandstone reservoirs (mostly in the Pannonian Basin) cause environmental problems (requiring higher costs to solve), as well as a decline in reservoir pressure. Because of restrictions imposed by legislation regarding environmental protection, most of the country's proven geothermal resources would not be exploited if reinjection problems cannot be solved. The technology of reinjection is, at present, one of the most important tasks for research in Romanian geothermal energy production.

The main obstacle to geothermal development in Romania is the scarcity of domestic investment capital. In order to stimulate the interest of potential investors from developed countries, and to comply with requirements of the large international banks, an adequate legal and institutional framework has been created, adapted to a market-oriented economy.

2. GEOTHERMAL RESOURCES OF ROMANIA

In Romania, thermal springs are the only surface manifestation of geothermal resources. From prehistory to the present, the human community has continued to live near and to develop a variety of geothermal areas, including: Oradea, Felix Spa, Herculane Spa, Geoagiu, Calan, Caciulata, Mangalia (Cohut and Arpasi, 1995).

The first geothermal well in Romania was drilled in 1885 at Felix Spa, near Oradea. The well was 51 m deep, with a flow rate of 195 l/s and a temperature of 49°C. This first well is still in operation. It was followed by the wells drilled at Caciulata (in 1893 - 37°C), Oradea (in 1897 - 29°C) and Timisoara (in 1902 - 31°C).

The search for geothermal resources for energy purposes began in the early 1960's, based on a detailed and well-funded geological program for hydrocarbon exploration. There are over 200 wells, drilled to depths between 800m and 3,500 m, that have encountered low-enthalpy geothermal resources (40 -120°C). These drilling results have led to identification of eight geothermal areas, six in the western part and two in the southern part of the country. The completion and experimental exploitation (as part of geological investigations) of over 100 wells in the past 25 years has made possible the evaluation of exploitable heat from geothermal reservoirs. Proven reserves, based on evaluation of data from completed wells, is estimated at 200 PJ for the next 20 years. The total installed capacity of the existing wells is about 480 MW_t (for a reference temperature of 30°C). Out of this, only 140 MW_t is currently used, from 65 wells that are producing hot water in the temperature range of 55-115°C (Cohut & Bendea, 1997). For 1997, the annual energy utilisation for direct use was about 2,700 TJ, from which health and recreational bathing was 870 TJ, with a load factor of 63 %. The main direct uses of geothermal heat are: space and culinary water heating for domestic uses -- 36%; health and recreational bathing -- 32 %; greenhouse heating -- 23%; industrial process heating (wood and grain drying, milk pasteurisation, flax processing) -- 7%,; fish farming -- 2%. More than 80 % of the wells are artesian producers; 18 of them require anti-scaling chemical treatment; and five are reinjection wells (Panu, 1995).

About 40 wells are used for health and recreational bathing in 16 spas that have a treatment capacity of over 850,000 people per year. In 1997, the average flow rate was 275 l/s, with water temperatures in the range 35-65°C. Geothermal water is also used in 24 outdoor and seven indoor pools.

During the last ten years, with financing from the National Budget, 26 exploration-production geothermal wells were drilled to depths ranging from 1500 to 3500 m, completed and tested; only two were dry holes. Nine wells are currently used for district heating. An additional three deep wells are in progress at this writing.

The geothermal systems discovered on Romanian territory are located in porous, permeable formations such as sandstones and siltstones (interbedded with clays and shales) or carbonate strata. Examples of the first type occur in the Western Plain and in the Senonian of the Olt Valley. Carbonate aquifers included those of Triassic age in the basement of the Pannonian Basin, and of Malm-Aptian age in the Moesian Platforms (Figure 1 and Table 1).

The Pannonian geothermal aquifer is multilayered and confined, and is located in the sandstones of the basement of the Upper Pannonian (late Neogene age), with an approxiamte areal extent of 2,500 km^2 along the Western border of Romania, from Satu Mare in the north to Timisoara and Jimbolia in the south. The aquifer occurs between depths of 800 m and 2,100 m. It has been investigated by 80 geothermal wells, all possible producers, of which 37 are currently exploited. The thermal gradient is 45-55°C/km. The surface water temperature varies between 50 and 85°C. The total dissolved solid (TDS) content of the geothermal waters is 4-5 g/l (sodium-bicarbonate-chloride type) and most piping through which these waters flow shows carbonate scaling, fortunately preventable by downhole chemical inhibition. The combustible gases, mainly methane, are separated from the geothermal water. The wells are produced mainly artesian, but also with downhole pumps.

The main geothermal areas are - from north to south - Satu Mare, Tasnad, Acas, Marghita, Sacuieni, Salonta, Curtici, Lovrin, Tomnatic, Sannicolau Mare, Jimbolia and Timisoara. The main uses for the produced geothermal waters are: heating of 31 hectares of greenhouses; space heating of 2,460 flats and sanitary hot-water preparation for 2,200 flats; industrial uses in seven places (crop drying, hemp processing, ceramics drying, timber drying, Bendea and Rosca, 1999).

The Oradea geothermal reservoir is located in Triassic limestone and dolomite at depths of 2,200-3,200 m, with an areal extent of about 75 km^2, and it is exploited by 12 wells with a total flow rate of 140 l/s of geothermal water with wellhead temperatures of 70-105°C. There are no dissolved gases, and the TDS is lower than 0.9-1.2 g/l. The water is of calcium-sulphate-bicarbonate type. Both aquifers, the Triassic Oradea aquifer and the Cretaceous Felix Spa aquifer, are hydrodynamically connected and are part of the active natural flow of water. The water is about 20,000 years old and the recharge area is in the northern edge of the Padurea Craiului Mountains and the Borod Basin. Although there is a significant recharge of the geothermal system, the exploitation, with a total flow rate of 300 l/s, naturally causes pressure drawdown in the system, but fortunately that drawdown can be prevented by reinjection. Reinjection is the result of the successful completion and operation of the first geothermal doublet in the Nufarul district in Oradea city, in October 1992 (Lund, 1997). The Felix Spa reservoir is currently exploited by 6 well, with depths between 50 and 450 m. The total flow rate available from these wells is 210 l/s. The geothermal water has wellhead temperatures of 36-48°C, and is potable. The annual utilisation of geothermal energy in Oradea is 415TJ representing 15% of the total geothermal heat produced in Romania.

The Bors geothermal reservoir is situated about 6 km north-west of Oradea. This reservoir is significantly different from the Oradea reservoir, although both are located in fissured carbonate formations. The Bors reservoir is a tectonically closed aquifer, with a small surface area of 12 km^2. The geothermal water has 13 g/l TDS, 5 Nm^3/m^3 GWR and a high scaling potential. The dissolved gasses are 70% CO_2 and 30% CH_4. The reservoir temperature is higher than 130°C at the average depth of 2,500 m. The artesian production of the wells can only be maintained by reinjecting the whole amount of extracted geothermal water. At present, three wells are used to produce a total flow rate of 50 l/s, and two other wells are used for reinjection, at a pressure that does not exceed 6 bar. The geothermal water is used for heating 12ha of greenhouses. The dissolved gasses are partially separated at 7 bar, which is the operating pressure, and then the fluid is passed through heat exchangers before being reinjected. The Romanian PONILIT anti-scaling solution is injected at 450 m depth, using an electric driven metering pump. The installed power is 15 MW_t, and the annual energy savings is 3,000 toe.

The Ciumeghiu geothermal reservoir is also located in the Western Plain, 50 km south to Oradea. Geothermal water is produced by artesian flow with a wellhead temperature of 105°C and 5-6 g/l TDS, with strong carbonate scaling prevented by chemical inhibition at the depth of 400 m. The aquifer is located in Lower Pannonian age gritstones, at an average depth of 2,200 m. The main dissolved gas is CH_4, the gas water ratio (GWR) being 3 Nm^3/m^3. The reservoir was investigated by 4 wells, but only one is currently in use, with a capacity of 5 MW_t (1 MW_t from gasses).

The Otopeni geothermal reservoir is located north of Bucharest. It is only partially delimited (about 300 km^2). The 13 wells that were drilled show a huge aquifer located in fissured limestones and dolomites. The aquifer, situated at a depth of 1,900-2,600 m, belongs to the Moessic Platform. The geothermal water has temperatures of 58-78°C, and 1.5-2.2 g/l TDS, with a high content of H_2S (over 25 ppm). Therefore, reinjection is compulsory. The production is carried out using downhole pumps, because the water level in the wells is at 80m below the surface. The total flow rate is 25-30 l/s. At present, only three wells are in production (5 MW_t), for heating 1,900 dwellings (annual savings 1,900 toe), and 2 wells are used for reinjection. The development is hampered by technical and, mostly, by financial difficulties. It is to be mentioned that there are potential users, and six wells are already drilled, the last 2 wells being situated near the Snagov Lake, producing water with temperatures of 75-80°C, and significant flow rates.

The Cozia-Calimanesti geothermal reservoir (Olt Valley) produces artesian geothermal water, with a flow rate of 10-20 l/s and wellhead pressure of 16-20 bar, from fissured siltstones of Senonian age. The reservoir depth is 1,900-2,200 m, the well head temperature is 90-95°C, the TDS is 14 g/l, and there is no scaling. The GWR is 2.0 Nm^3/m^3 (90% methane). Although the reservoir was exploited for 10 years, there is no interference between the wells and no pressure drawdown. The thermal potential possible to be achieved from the 3 wells is 18 MW_t (3.5 MW_t from gasses), but only 8 MW_t is used at present. The energy equivalent gained in this way is 2,500 toe/year. The utilisation is mainly for space heating, but also for health and recreational bathing.

3. WELLS DRILLED FOR DIRECT USE OF GEOTHERMAL RESOURCES

During 1995-1999 14 wells were drilled with total depth of 33.2 km (Table 2), financed from the State Budget, within the framework of the national geological exploration program. Five wells were exploration wells, being drilled in areas not yet explored, and eight wells were drilled in areas where geothermal resources were already identified.

Out of the 14 wells only one was a dry hole, low flowrate, high mineralisation: 32 g/l, low temperature 65ºC, and dynamic water level below 200 m of the ground. All the other wells had flow rates and temperatures of commercial interest,, and are currently the subject of feasibility studies for direct-use projects

4. UTILISATION OF GEOTHERMAL ENERGY

Due to the difficulties encountered by the Romanian economy, only three new geothermal projects were completed during 1995-1999 -- one for direct use and two for bathing and swimming. The geothermal operations completed before 1995 continued to operate, with some exceptions due to decreased use, a situation created by the reduction (about 50%) of the greenhouse area heated by geothermal energy. The utilisation of geothermal energy as of 31 December 1999 is shown in Table 3.

In the 38 “geothermal localities” that are operating, 96 wells (of which 37 exclusively for bathing or balneology) totalling - at maximum utilisation- 890 kg/s flowrate, and weighted average temperatures of 71°C for inlet and 28°C for outlet.

The total capacity is 152 MW_t that produces annually 2870TJ. The main direct uses of geothermal heat are: space heating -- 37.4%; bathing and swimming including balneology -- 30.4%; greenhouse heating -- 23,1%; industrial process heat -- 7%; and fish farming and animal husbandry -- 2.1%, with the capacity factor being 0.6. By type of utilisation the actual situation in Romania is shown in Table 4.

Referring to the personnel allocated to geothermal activities (Table 5) it is observed that there has been a decrease of about 20% in personnel with university degrees, especially in industry (represented by Foradex and Transgex, both in the process of privatisation) where during the last five years the decrease has been 25%.

During 1995-1999 the total investments in geothermal projects (Table 6) were 24 million $US, 12% less than during 1990-1994 and 28% less than during 1985-1989 respectively, all projects being funded from the State Budget.

Out of the total investments in geothermal projects the cost of drilling the 14 wells represents 70%, the rest (30%) being invested in direct use.

5. CONCLUSIONS

During 1995-1999 geothermal activity in Romania stagnated due to the economic difficulties with which the country is faced. Compared to the period of 1990-1994 there are no changes as to geothermal energy use (2870 TJ in 1999 compared to 2753 TJ in 1994), only the installed capacity increased from 137 MW_t in 1994 to 152 MW_t in 1999 regarded to technologically upgrading some operations and completing three new ones.

Compared to the period of 1990-1995, there has been a decrease in allocation of professional personnel (by ca. 20%) due to the reduction of geothermal activity at both State-owned companies (Foradex and Transgex).

The decrease in investments in geothermal projects during 1995-1999 is 12% compared to the previous period of 1990-1995. All investments were completed exclusively from funds allocated from the State Budget.

The main obstacle to geothermal development in Romania is the scarcity of domestic investment capital. In order to stimulate the interest of potential investors from developed countries, and to comply with the requirements of large international banks, an adequate legal and institutional framework has been created, adapted to a market-oriented economy.

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Figure 1: Location of the Romanian geothermal reservoirs

Table 1: The main parameters of the Romanian geothermal systems.

Parameter	U/M	Oradea	Bors	Western Plain	Olt Valley	North Bucharest
Type of reservoir		fissured carbonate	fissured carbonate	sandstone	gritstone	carbonate
Area	km^2	75	12	2,500	28	300
Depth	km	2.2-3.2	2.4-2.8	0.8-2.1	2.1-2.4	1.9-2.6
Drilled wells	(total)	14	6	88	3	11
Active wells		12	5	37	2	5
Well head temperature	°C	70-105	115	50-85	92-96	58-75
Temperature gradient	°C/100	3.5-4.3	4.5-5.0	3.8-5.0	4.6-4.8	2.8-3.4
TDS	g/l	0.8-1.4	12-14	2-7	13	2.2
GWR	Nm^3/m^3	0.05	5-6.5	0.5-2.5	2-2.8	0.1
Type of production		Artesian	Artesian	Artesian + Pumping	Artesian	Pumping
Flow rate	l/s	4-20	10-15	4-18	12-25	22-28
Operations		11	2	37	2	2
Annual savings	toe	9,700	3,200	18,500	2,600	1,900
Total installed power (with existing wells)	MW_t	58	25	210	18	32
Exploitable reserves (for 20 years)	MW/day	570	110	4,700	190	310
Main uses:						
• space heating	dwellings	2,000	-	2460	600	1,900
• sanitary hot water	dwellings	6,000	-	2,200	600	1,900
• greenhouses	ha	1.8	6	34	-	-
• industrial uses	operations	6	-	7	-	-
• health bathing	operations	5	-	8	3	2

Table 2: Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 1995 to December 31, 1999

Purpose	Wellhead Temperature	Number of Wells Drilled: Electric Power	Direct Use	Combined	Other (specify)	Total Depth (km)
Exploration[1)]	(all)		6			14.8
Production	>150° C					
	150-100° C <100° C		8			18.4
Injection	(all)					
Total			14			33.2

Table 3: Utilisation of geothermal energy for direct heat as of 31 December 1999

Locality	Type[1)]	Maximum Utilisation: Flow Rate (kg/s)	Temperature (°C) Inlet	Temperature (°C) Outlet	Capacity[3)] (MWt)	Annual Utilisation: Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
Satu Mare	HB	12	65	30	1.8	7	32.3	0.58
Carei	BI	5	45	30	0.3	3	5.9	0.60
Acas	GB	15	65	30	2.2	8	36.9	0.53
Tasnad	HBG	10	70	25	1.9	7	41.5	0.70
Beltiug	B	6	75	30	1.1	4	23.7	0.67
Sacuieni	HBGFI	22	80	25	5.1	12	87.1	0.55
Marghita	HB	12	65	25	2.0	10	52.8	0.83
Boghis	BH	12	45	25	1.0	10	26.4	0.83
Mihai Bravu	GF	6	65	25	1.0	3	15.8	0.50
Bors	G	25	115	40	7.8	12	118.7	0.48
Oradea	IHGBF	85	83	30	18.8	65	415.0	0.69
Livada	HBF	10	88	35	2.2	5	35.0	0.50
Felix	BH	140	45	25	11.7	115	216.0	0.54

Table 3 continued

Locality	Type[1)]	Maximum Utilisation			Capacity[3)]		Annual Utilisation	
		Flow Rate (kg/s)	Temperature (°C) Inlet	Outlet	(MWt)	Ave. Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
Madaras	BH	5	46	25	0.4	3	8.3	0.60
Ciumeghiu	G	12	92	35	2.9	6	45.1	0.50
Cighid	HBG	10	72	25	2.0	6	37.2	0.60
Beius	HB	25	83	30	5.5	15	104.9	0.60
Macea	HGB	15	65	25	2.5	8	42.2	0.53
Curtici	HGB	22	63	25	3.5	14	70.2	0.64
Dorobanti	GB	18	60	25	2.6	9	41.5	0.50
Sofronea	HB	6	42	25	0.4	3	6.7	0.50
Iratos	IB	5	40	20	0.4	3	7.9	0.60
Arad	B	12	40	25	0.8	7	13.8	0.58
Nadlac	IHB	10	78	30	2.0	8	50.6	0.80
Sannicolau	IHBG	50	78	30	10.0	35	221.6	0.70
Saravale	HB	8	75	25	1.7	5	33.0	0.62
Tomnatic	GB	45	80	30	9.4	22	145.1	0.49
Lovrin	HGB	40	81	30	8.5	30	132.0	0.49
Periam	HB	10	70	25	1.9	6	35.6	0.60
Jimbolia	IHGB	50	82	30	10.9	35	240.1	0.70
Teremia	IHB	15	85	30	3.5	6	43.5	0.40
Comlosu	HB	10	81	25	2.3	6	44.3	0.60
Grabat	IB	6	80	30	1.3	3	19.8	0.50
Beregsau	IB	6	75	25	1.3	3	19.8	0.50
Timisoara	HB	15	45	25	1.3	10	26.4	0.67
Herculane	B	75	52	25	8.5	50	148.0	0.67
Olt Valley	HB	25	92	30	6.5	16	130.8	0.64
North Bucharest	HB	35	62	25	5.4	15	65.0	0.43
	TOTAL		890		152.4	585.0	2870.7	

Table 4: Summary table of geothermal direct heat uses as of 31 December 1999

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr)	Capacity Factor[3)]
Space Heating[4)]	53	1073	0.64
Air Conditioning (Cooling)			
Greenhouse Heating	40	665	0.52
Fish and Animal Farming	3	60	0.63
Agricultural Drying[5)]			
Industrial Process Heat[6)]	14	201	0.45
Snow Melting			
Bathing and Swimming[7)]	42	871	0.65
Other Uses (specify)			
Subtotal	152	2870	0.60
Geothermal Heat Pumps			
TOTAL	152	2870	

Table 5: Allocation of professional personnel to geothermal activities (restricted to personnel with a university degrees)

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

Year	Professional Person-Years of Effort (1)	(2)	(3)	(4)	(5)	(6)
1995	2	8	9			21
1996	2	8	8			20
1997	2	7	10			17
1998	2	5	11			16
1999	2	4	11			16
Total	10	32	49	0	0	90

Table 6: Total investments in geothermal in (1999) USD

Period	Research &Development Incl. Surface Exploration & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilisation Direct Million US$	Electrical Million US$	Funding Type Private %	Public %
1985-1989	21	7	5			100
1990-1994	15	5	7			100
1995-1999	8	10	6			100