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Geothermal energy country update for Romania

by Ioan Cohut & *Miklos Antics

GEOFLUID S.A., 11 Parc S. Petofi, 3700 Oradea, Romania

ABSTRACT

The main geothermal systems discovered on the Romanian territory are found in porous permeable formations such as sandstones and siltstones (Western Plain and the Olt Valley) or in fractured carbonate formations (Oradea, Bors, North Bucharest).

The exploration for geothermal resources began, in Romania, in the early 60's based on a detailed geological exploration program for hydrocarbon resources that had extensive budgets, which also enabled the identification of eight geothermal areas. There are over 200 wells drilled with depths between 800÷3500 m, that show the presence of low enthalpy geothermal resources (40÷120°C). The completion and experimental exploitation of over 100 wells, in the past 25 years, enabled the evaluation of the exploitable heat resources from geothermal reservoirs.

The total thermal capacity of the existing wells is about 480 MWt (for a reference temperature of 25°C). Out of this, only 152 MWt are currently used, fi-om 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 1998, the annual energy utilisation fi-om these wells was about 2,900 TJ. More than 80% of the wells are artesian producers, 18 wells require anti-scaling chemical treatment and 6 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 1990-1999 were drilled and completed 26 exploration-production geothermal wells (of which two dry holes), financed by the geological exploration fund of the State's Budget, with depths varying between 1500÷3500 m. Currently there are 3 new geothermal wells in the phase of drilling.

KEYWORDS

Geothermal energy, low enthalpy resources, direct use, Romania

1. Introduction

Romania, as other Central and Eastern European Countries, has significant low enthalpy (50-120°C) geothermal resources suitable for direct heat utilisation: space heating, tap water heating, greenhouse heating, fish farming, animal husbandry; aquaculture, bathing, balneology, etc.

Until the seventies these resources have only been partially used, mainly for health and recreational bathing; the use of natural hot springs in the Precarpathian area of Romania has been known since the time of the Roman Empire when Dacia province had famous health spas: Geoagiu, Calan, Herculane and Felix Spas. During the last hundred years geothermal health bathing flourished especially in Western part of Romania.

The main geothermal systems discovered on the Romanian territory are found in porous permeable formations such as sandstones and siltstones (Western Plain and the Olt Valley) or in fractured carbonate formations (Oradea, Bors, North Bucharest).

Many geothermal operations have been completed between 1975 and 1990, mainly for greenhouse heating, dwelling and hot tap water heating, some industrial applications and for health and recreational bathing. The thermal water and geothermal energy has been delivered to the users free of charge and the disposal of spent water has been done straight into the surface waters.

The utilisation of these energy resources has been delayed due to the high investment costs and the very low price of the hydrocarbons. At present, at the current international market prices of fossil fuels, the dramatic decrease of the domestic oil and gas production, the geothermal development has favourable conditions.

The large majority of the geothermal projects currently operating in Romania have low efficiencies, lagging behind in technology, infrastructures and equipment may be regarded as obsolete.

The present geothermal production status stands far below the expectations allowed by the locally assessed potential because of non sustained production (self flowing mode instead of artificial lift) and the lack of injection into the source reservoir of the heat depleted brine (no resource conservation nor reservoir pressure maintenance). Some systems operated, on a limited basis though, are applying the doublet concept (i.e. combining a production/injection well pair) of heat mining (Oradea, Bors, Otopeni). These first projects have enabled to build up a nucleus of expertise in modem reservoir exploitation management techniques.

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

2. Geothermal resources of Romania

In Romania, thermal springs are the only manifestation of geothermal resources. From prehistory to the present, the human community continued to live near and develop a variety of geothermal areas: 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 well 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 **60's,** based on a detailed geological program for hydrocarbon resources (that had extensive budgets). There are over 200 wells drilled with depths between 800÷3,500 m, that shows the presence of low enthalpy geothermal resources (40÷120°C), which enabled the identification of 8 geothermal areas, 6 in the Western part and 2 in the Southern part. The completion and experimental exploitation (as part of geological investigations) of over 100 wells in the past 25 years made possible the evaluation of exploitable heat from geothermal reservoirs. The proven reserves, with the already drilled wells, is estimated at about 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 25°C). Out of this only about 150 MW_t is currently used, from 65 wells that are producing hot water in temperature range of 55÷115°C (Cohut & Bendea, 1997).

For 1998, the annual energy utilisation for direct use was about 2,700 TJ, from which health and recreational bathing was 870 TJ. The main direct uses of geothermal heat are: space and tap water heating for domestic uses 36%, health and recreational bathing 32 %, greenhouse heating 23%, industrial processes heat (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 5 are reinjection wells.

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, the water temperatures in the rage of 35÷65°C. The geothermal water is also used in 24 outdoor and 7 indoor pools.

The geothermal systems discovered on the Romanian territory are located in porous permeable formations such as sandstones and Pannonian siltstones, interbedded with clays and shales specific for the Western Plain and Senonian specific for the Olt Valley or in carbonate formations of Triassic age in the basement of the Pannonian Basin and of Malm-Aptian age in the Moesian Platform (Figure 1).

The Pannonian geothermal aquifer is multilayered, confiied and is located in the sandstones at the basement of the Upper Pannonian (late Neogene age), on an approximate area of 2,500 km^2 along the Western border of Romania, from Satu Mare in the North to Tiinisoara and Jimbolia in the South. The aquifer is situated at the depth of 800 to 2,100 m. The thermal gradient is 45÷55°C/km and the surface water temperature varies between

50 and 85°C. The mineralization of the geothermal waters is 4÷5 g/l (sodium-bicarbonate-chloride type) and most of the waters show carbonate scaling, prevented 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.

Figure 1: Location of the Romanian geothermal reservoirs

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 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 7 places (crop drying, hemp processing, ceramics drying, timber drying, Bendea and Rosca, 1999).

The Oradea geothermal reservoir is located in the Triassic limestone and dolomites at depths of 2,200÷3,200 m, on an area of about 75 km^2, and it is exploited by 12 wells with a total artesian flow rate of 140 l/s geothermal water with well head temperatures of 70÷105°C. There are no dissolved gases, and the mineralization is lower than 0.9÷1.2 g/l. The water is of calcium-sulphate-bicarbonate type. Both aquifers, the Triassic aquifer Oradea and the Cretaceous aquifer Felix Spa, are hydrodynamically connected and are part of the active natural flow of water. The annual utilisation of geothermal energy in Oradea is 415 TJ representing 15% of the total geothermal heat produced in Romania.

The Bors geothermal reservoir is situated about 6 km north-west to Oradea. This reservoir is completely 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 12 ha of greenhouses.

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 well head 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 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 to Bucharest. It is only partially delimited (about 300 km^2). The 13 wells that were drilled show a huge aquifer located in fissured limestone 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 80 m below surface. At present, only **3** wells are in production (5 MW_t), 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 6 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 per well with and well head 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 15 years, there is no interference between the wells and no pressure draw down. The thermal potential possible to be achieved from the **3** wells is 18 MW_t **(3.5** MW_t from gases), 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.

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	12	34	-	-
industrial uses	operations	6	-	7	-	-
health bathing	operations	5	-	8	3	2

3. Utilisation of geothermal energy

Due to the difficulties encountered by the Romanian econoiny, during 1995-1999, only three new geothermal projects were completed. The geothermal operations completed before 1995 continued to operate, with some exceptions due to the vanishing of the users, situation obviously created by the reduction (about 50%) of the greenhouse area heated by geothermal energy. The present utilisation of geothermal energy is shown in Table 2.

Table 2: Utilisation of geothermal energy for direct heat

Locality	Type"	Maximum Utilisation			Capacity		Annual Utilisation	
		Flowrate (kg/s)	Temperature (°C) Inlet	Outlet	(MWt)	Ave. Flow (kg/s)	Energy (TJ/yr)	Capacity Factor''
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
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
[ratos	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
l'omnatic	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
Rmbolia	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	

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In the 38 "geothermal localities" are operating 96 wells (of which 37 exclusively for bathing or balneology) totalling -at maximum utilisation- 890 l/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 2870 TJ. 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%, the capacity factor being 0.6.

4. Conclusions

The development of direct utilisation of geothermal resources is very much slowed down by the difficulties encountered during the transition period from centrally planned to free market economy; the present geothermal production status stands far below the expectation allowed by the assessed potential, the geothermal operations lagging behind in technology.

For 1998, the annual energy utilisation for direct use was about 2,700 TJ, from which health and recreational bathing was 870 TJ. The main direct uses of geothermal heat are: space and tap water heating for domestic uses 36%, health and recreational bathing 32 %, greenhouse heating 23%, industrial processes heat (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 5 are reinjection wells.

During the last 10 years, 26 exploration - production geothermal wells were drilled, completed and tested (of which only two dry holes), financed from the geological exploration fund of the State Budget, with depths varying between 1,500 and 3,500 m, and 9 of them are used for district heating. Three new geothermal wells are currently in drilling.

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

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