Geothermal Energy Use, Country Update for Romania

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ABSTRACT

This country update regarding the geothermal energy use in Romania deals with both deep and shallow geothermal energy. The document presents the latest developments in this field, such as: the evaluation and the possible exploitation of the Bucharest geothermal reservoir, the modernization of the existing deep geothermal wells, and the constant evolution and growth of the shallow geothermal sector - mainly represented by the biggest application in Europe (ELI NP Magurele, near Bucharest), and of the construction of the first data base with the GSHP systems in Romania.

1. ROMANIAN DEEP GEOTHERMAL ENERGY RESOURCES AND EXPLOITATION

1.1. General overview

The geothermal systems discovered on the Romanian territory are located in porous permeable formations such as Pannonian sandstone, interbedded with clays and shales specific for the Western Plain, and Senonian specific for the Olt Valley. Some geothermal systems are located in fractured carbonate formations of Triassic age in the basement of the Pannonian Basin (Oradea, Bors,), and of Malm-Aptian age in the Moesian Platform (North Bucharest) – see Figure 1.

Figure 1. Location of the main deep geothermal energy resources of Romania (including the Bucharest reservoir)

The total capacity of the existing wells is about 480 MWt (for a reference temperature of 25°C). Of these total, currently only 96 wells are used (of which 40 are used only for balneology and bathing), that are producing hot water in the temperature range of 40÷115°C, equivalent of 200 MW_{th}.
For 2015, the annual energy utilisation from these wells was about 400 GWh. More than 80% of the wells are artesian producers, 18 wells require anti-scaling chemical treatment, and 6 are used for reinjection. The main direct uses of the geothermal energy are: space and district heating; bathing; greenhouse heating; industrial process heat; and fish farming.

In 2016, two geothermal wells have been drilled in Romania, a production well in Balotesti (North Bucharest) and a reinjection in Oradea, in two projects financed by the European Economic Area Grants and the Romanian Environmental Fund Administration in the RONDINE programme.

To increase the thermal power related to the deep geothermal energy resources, a combination of technologies related to the two categories of geothermal energy (deep and shallow) can be done. Thus, if we consider the use of heat pumps and water reinjection into the ground with a max temperature of 10°C, the thermal power of current wells can increase up to 625 MWth, value that creates a potential annual energy of 282 thousand teo/year (1teo = 11,63MWh).

1.2. Reservoirs characteristics and exploitation

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 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 60's, based on a detailed geological program for hydrocarbon resources (that had extensive budgets). There are over 250 wells drilled with depths between 800 and 3,500 m, that show the presence of low enthalpy geothermal resources (40÷120°C), which enabled the identification of many geothermal areas, most of them in the Western part and 3 in the Southern part of Romania. The completion and experimental exploitation (considered as part of geological investigation) of over 100 wells in the past 30 years made possible the evaluation of exploitable heat from geothermal reservoirs. More than 80% of the wells are artesian producers, 18 of them require anti-scaling treatment (Panu, 1995), and 6 are reinjection wells.

The proven reserves, with the already drilled wells, are 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 200 MW_t is currently used, from 96 wells that are producing hot water in temperature range of 40÷115°C.

For 2015, the average flow rate was about 340 l/s, the annual energy utilisation for direct use was about 400 GWh, with an average capacity factor of about 18% due to an unusually mild winter. 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 2016, two geothermal wells have been drilled in Romania, a production well in Balotesti (North Bucharest) and a reinjection in Oradea, in two projects financed by the European Economic Area Grants (EEA Grants) and the Romanian Environmental Fund Administration (EFA) in the RONDINE programme.

The geothermal systems discovered on the Romanian territory are located in porous permeable formations such as Pannonian sandstone, interbedded with clays and shales specific for the Western Plain, and Senonian specific for the Olt Valley. Some geothermal systems are located 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, confined and is located in the sandstones at the basement of the Upper Pannonian (late Neocene age), on an approximate area 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 is situated at the depth of 800 to 2,400 m. It was investigated by more than 100 geothermal wells, all possible producers, out of which 37 are currently exploited. The thermal gradient is 45÷55°C/km. The wellhead temperatures range between 50 and 85°C. The mineralisation (TDS) 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 and not used (yet). The wells are produced mainly artesian, and very few of them with downhole pumps.

The main geothermal areas are - from North to South - Satu Mare, Tasnad, Acas, Marghita, Sacuieni, Salonta, Curtici-Macea-Dorobanti, Nadlac, Lovrin, Tomnatic, Sannicolau Mare, Jimbolia and Timisoara. The main uses are: heating of about 10 hectares of greenhouses; district heating for about 2,500 flats, only sanitary hot water supply for 2,200 flats, health and recreational bathing, and fish farming. Other applications, such as ceramics drying, timber drying; hemp and flax processing, went broke and stopped operations (Bendea and Rosca, 1999).

The Oradea-Felix Spa geothermal reservoir is located in the Triassic limestones 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 potential flow rate of 140 l/s geothermal water with well head temperatures of 70÷105°C. There are no dissolved gases, the mineralisation is 0.9÷1.2 g/l, the water being of calcium-sulphate-bicarbonate type. The Oradea Triassic aquifer is assumed to be hydrodynamically connected to the Felix Spa Cretaceous aquifer, but not scientifically proven, and together are part of the active natural flow of water. The water in the Oradea reservoir 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 over 300 l/s generates pressure draw down in the system that is prevented by reinjection. Reinjection is the result of successful completion and beginning operation of the first doublet in the Nufarul district in Oradea city, in October 1992 (Lund, 1997). The new well drilled in 2016 is 2,900 m deep. After acidizing, it produced in artesian discharge 38 l/s geothermal water with a well head temperature of 80°C. This well is intended to be used for reinjecting the heat depleted geothermal water produced by the well in the University of Oradea campus (about 1.2 km away).

The Felix Spa reservoir is currently exploited by six wells, with depths between 50 and 450 m. The total flow rate available from these wells is 210 l/s. The geothermal water has wellhead temperature of 36÷48°C and is potable. The annual utilisation of geothermal energy in Oradea is representing almost 35% of the total geothermal heat produced in Romania.

The Bors geothermal reservoir is situated about 6 km north-west of 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, prevented by chemical inhibition. 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 could only be maintained by reinjecting the whole amount of extracted geothermal water, and of colder water from shallower wells during the summer. In the past, three wells were used to produce a total flow rate of 50 l/s, and two other wells were used for reinjection, at a pressure that did not exceed 6 bar. The geothermal water was used for heating 12 ha of greenhouses (now bankrupt, stopped operation). The dissolved gasses were partially separated at 7 bar, which is the operating pressure, and then the fluid is passed through heat exchangers before being re-injected. The installed power is about 8 MW_t, and the annual energy savings was about 3,000 toe. In 2014 one well was put in production for heating a metal factory located in Bors industrial park. The well is used in artesian flow, with 3 l/s and the well head temperature does not exceed 85°C (even if at the maximum artesian flow 15 l/s the well head temperature is over 110°C)

The Beius geothermal reservoir is situated about 60 km south-east of Oradea. The reservoir is located in fissured Triassic calcite and dolomite 1,870 – 2,370 m deep. The first well has been drilled in 1996, down to 2,576 m. A line shaft pump was set in the well in 1999, now producing up to 45 l/s geothermal water with 72°C wellhead temperature. The consumers of the geothermal water yearly increased in Beius and now the pump in the first well was replaced with a bigger capacity one of 60 l/s. A second well has been drilled in early 2004, and a line shaft pump was being installed later that year and can also produce up to 45 l/s geothermal water with 85°C wellhead temperature. The geothermal water from these wells has a low mineralization (462 mg/l TDS), and 22.13 mg/l NCG, mainly CO_2 and 0.01 mg/l of H_2S. The geothermal water from both wells is currently used to supply district heating to part of the town of Beius (for a district heating system with 22 substations supplying a block of flats area, two hospitals, two schools, public buildings, for heating system of many individual houses in open loop, swimming pool, etc.).

The Sacuieni geothermal reservoir is located in the Pannonian sandstones at 1,800 – 2.200 m depth, 56 km north from Oradea. The main dissolved gas is CH_4, the GWR being 0,9 Nm^3/m^3. In Sacuieni there are 8 geothermal wells, of which 3 are in production. The wells are exploited in artesian flow and the geothermal water is treated with inhibitors against scaling. The geothermal water is used for heating purposes in the block of flats down town, the city hall, schools, kindergarten, individual houses, public institutions.

The Ciumeghiu geothermal reservoir is also located in the Western Plain, 50 km South to Oradea. The geothermal water has a wellhead temperature of 105°C and high mineralization (5-6 g/l TDS), with strong carbonate scaling potential (prevented by chemical inhibition at the depth of 400 m). The aquifer is located in Lower Pannonian age gritstone, 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 was in use (until the greenhouses in the area have been closed), with a capacity of 5 MW_t (of which 1 MW_t from the separated combustible gasses). The geothermal water was used for heating greenhouses (bankrupt, stopped operation).

The Cozia-Calimanesti geothermal reservoir (Olt Valley) produces artesian geothermal water, with flow rates between 8.5 and 22 l/s, and shut-in wellhead pressures of 30÷33 bar, from fissured siltstones of Senonian age. The reservoir depth is 2,700÷3,250 m, the well head temperature is 70÷95°C, the TDS is 15.7 g/l, and there is no major scaling (only minor deposition and some corrosion were observed during years of operation). The GWR is 1÷2.0 Nm^3/m^3 (90% methane). Although the reservoir was exploited for more than 25 years, there is no interference between the wells and no significant pressure draw down. The thermal potential possible to be achieved from the 4 wells is about 14 MW_t (of which 3.5 MW_t from the combustible gases – if used), but only about 7 MW_t is used at present. The energy equivalent gained in this way is 3,500 toe/year. The geothermal water is mainly used for district heating (2,250 equivalent flats), and for health and recreational bathing.

The Otopeni geothermal reservoir is located North to Bucharest. It is only partially delimited (about 300 km^2). The 7 drilled wells (all potential producers or injectors) show a huge aquifer located in fissured limestone and dolomites, situated at a depth of 2,000÷3,200 m, belonging to the Moesian Platform. The geothermal water has wellhead temperatures of 58÷84°C, and a rather high TDS (1.5÷2.2 g/l), with a high H_2S content (up to 30 ppm). Therefore, reinjection is compulsory for environmental protection. The production was carried out in the Otopeni area using downhole pumps, because the water level in the wells is at 80 m below surface. The total flow rate was 22÷28 l/s. At present, one well is in use (up to 3.5 l/s), almost all year round, for health and recreational bathing. The new well, drilled in 2016, is 3140 m deep. A line shaft pump has been launched into the well, that can produce up to 32 l/s. Up to 25 l/s will be used for a small district heating system for a hospital complex in the vicinity.

The Romanian strategic documents - National Strategy of Energy, RES Strategy and NREAP - do not specifically take into consideration the ***shallow*** geothermal energy and its potential. Currently, the figures that quantify the geothermal energy in all these documents refer to ***deep*** geothermal energy only. The geothermal maps present the location of deep geothermal reservoirs, without any concern about the shallow geothermal energy which is considered to be accessible everywhere in the country. The GEOTRAINET project documents (2008-2011 www.geotrainet.eu) include a map of Europe in which the underground temperatures at more than 12-15 m in Romania in the present times are between 12 – 16°C. These values were stated by the GSHP specialists that monitored the temperatures acquired in the implemented applications and test drills.

1.3. Bucharest deep geothermal resources and exploitation capabilities

As presented in Figure 2, based on recent research and hidro-geological tests of FORADEX, there is, apart from the known Otopeni deposit, an aquifer situated under at a depth of 800÷1000m and with a temperature at the top of well around 40°C (currently unused), which lays under the entire area of Bucharest, with important expansion toward south. We call this "Bucharest geothermal" and we know about it:

- Flow direction: South – North;
- Aquifer velocity: 3÷4 m/year;
- Max flow rate per well: 35 l/sec;
- Mineralization: 1÷2 g/l;
- Aquifer temperature: 40°C

The estimated energetic potential of the Bucharest geothermal deposit is of 260 th teo/year, for a total of about **45** geothermal wells connected to the thermal points equipped with HP & CHP with a **min**. thermal power of 800 MW_{th}.
The thermal capacity of the GeoDH/C systems located in Bucharest may cover over **40%** of the thermal capacity currently used for keeping the ultra-centralized district heating system functioning.

It is possible to exploit this deposit by means of "Geothermal district heating/cooling" modules which are using geothermal heat pumps electrically driven by CHP units installed locally.

This technical solution can be a viable alternative to the current inefficient district heating system, being able to supply both heating and cooling to Bucharest and its metropolitan area

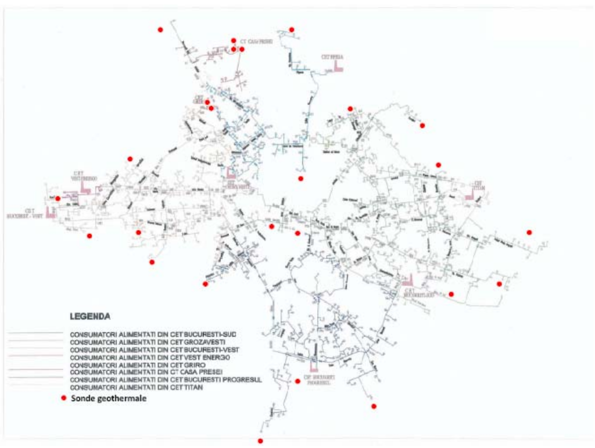

Figure 2. Map of Bucharest with locations of geothermal wells compared to current district heating network

1.4. Utilisation of deep geothermal energy

By far, the most interesting project is a binary cycle ORC geothermal power plant. In spite of its small installed capacity (Tables A and B in Appendix) it represents the first step in this direction (of producing electricity from geothermal water) after many years. Other new projects are a district heating in open loops, and one geothermal project for bathing and swimming. Also, some existing district heating systems were developed. Many of the geothermal operations completed before 2007 continued to operate, with some exceptions where the users went broke and closed their operations (mainly greenhouses).

The main direct uses of geothermal heat are (Table C): district heating and individual space heating, and health and recreational bathing. In a few places geothermal energy is also used for greenhouse heating (about 10 ha), fish farming (a few farms), industrial processes, and drying. Detailed data on installed capacity and annual energy used is not available by type of utilisation. In areas where the available wellhead temperature is rather low, geothermal water is only used for health and recreational bathing (e.g. Felix spa), or for fish farming, depending on the chemical composition. In other areas, even if the temperature is higher, the geothermal water is still used only for bathing (e.g. Acas-Beltiug and Tasnad), or for fish farming (e.g. Santandrei). In other areas, with higher temperatures and in larger communities, geothermal water is first used for district heating (Table D), some industrial processes, and only a part of the heat depleted water is used for bathing (or for fish farming), the rest being reinjected.

There is only one public utility actually operating deep geothermal systems, the Ilfov County Council for the new system in Balotesti (North Bucharest). Geothermal district heating systems are operated only by one of the two companies mentioned before (Transgex). In all cases though, the distribution network is public property, according to the Romanian legislation. For this reason, the public utilities that have part or all their heat supplied form geothermal resources (e.g. the town of Beius) have at least one person in charge of supervising the geothermal part of the system.

During 2013-2016, the investment and employment in geothermal projects totalled about 8 million EUR, less than in any 5 years interval before, mainly from EEA Grants and the EFA, for the two projects in Balotesti and Oradea. Out of the total investments in geothermal projects, the cost of drilling the two wells represents almost 75%.

Transgex plans to develop some existing district heating systems (Sacuieni, Tasnad, Livada, etc), and mainly to increase the production from the Oradea reservoir to its maximum capacity. For this last plan, at the time of this writing, Transgex, together with the Municipality of Oradea, is developing a geothermal district heating project in Nufarul neighbourhood of heat pump assisted type.

Foradex S.A. reports the following geothermal water production data for 2015:

- Olt Valley perimeter: 451000 cubic meters from 3 wells, water temperature 90-95 ^{0}C, equivalent to cca. 26 000 Gcal/year
- Western Romania perimeter : 172 000 cubic meters, water temperature 57-74 ^{0}C, equivalent to cca. 6 100 Gcal/year.

2. ROMANIAN SHALLOW GEOTHERMAL ENERGY RESOURCES AND EXPLOITATION

2.1. General overview on the shallow geothermal energy use in Romania

The market for ground source heat pumps GSHP practically opened in Romania only in the late 1990' and is now developing quite well.
At the beginning, in the first 7-8 years after 1990, the favoured solutions in GSHP applications were ground water wells and rarely horizontal heat exchangers. These technologies were suitable for small applications and for specific geographic and climatic areas in the country. In the last years, the larger applications required larger water flows that are not accessible in all potential locations. This is why the borehole heat exchangers became more and more common especially for commercial buildings. Table 1 presents the total length of largest GSHP systems built in Romania.
A lot of foreign investors or dealers of products manufactured abroad "imported" in Romania the GSHP technology from the manufacturers' country (Germany, Austria, USA, Canada, etc.). Nowadays the total price for drilling, "U" pipe mounting and cementing the geothermal heat exchanger is in the range 15-35 Euro/m and depending on the depth, the diameter, the number of drillings, the soil type and drilling technology, the accessibility in the site etc. The drilling for both open and closed systems is not specifically regulated by the authorities but is considered as any regular water supply drilling. For closed-loop systems the current drilling depth is 70 ÷ 120 m.

The only Governmental project involving shallow geothermal energy was initiated in 2006 by a Government decision and was targeted to 10 rural schools. The chosen solution was "open loop technology" (in order to use the existing water supply well and to drill only the reinjection well), but the "standard" project was not suitable for all the 10 locations. For this reason, nowadays only 5 from 10 of applications are still functional. None of these are monitored for metering the performance and quantity of renewable energy extracted. All these applications were for heating-only purposes (in summer time, the schools are not open for recreational activities especially in rural areas). The total allocated amount was under 1 million Euro, equally shared between the 10 projects, and it included the cost of indoor distribution sub-systems, too.

1. Table 1: Large GSHP systems with borehole heat exchangers (BHE) longer than 10000 m

City, Name	No. of BHE	Depth BHE [m]	Total BHE [m]
Magurele – Bucharest, ELI-NP (under constr.)	1080	125	135000
Valul lui Traian, Cardinal Motors (2009)	357	70	24990
Snagov, Vila 23 Hotel (2008)	224	70	15680
Focsani, ARTIFEX (2012)	120	125	15000
Bucharest, Midocar Est (2008)	144	75	10800

Today, the most complex and largest application (close to full completion) and state of the art for Europe is ELI-NP Extreme Light Infrastructure, which was built in Bucharest-Magurele. ELI-NP is the first pan-European research facility built in Eastern Europe which is oriented on high-level research on ultra-high intensity laser. The heating and cooling output is in the range of 5.4 MW, for a total air-conditioned area of 27000 m². The ground source heat exchanger consists of 1080 boreholes at 125 m depth, the whole borehole length is 135000 m.

The total investment cost of about 356 million € is paid mainly from Romania's allocation of EU structural funds.

Figure 3. ELI-NP Project (Bucharest – Magurele)

2.2. First Romanian data base for ground source heat pump systems

Building up a data base for ground source heat pumps systems in Romania has become a duty and a challenge at the same time. A duty – because Romania is absent from European statistics with regard to this matter, and it must fulfill its obligations imposed by the 20-20-20 targets set by the European Union in terms of using the renewable energy sources. A challenge – because the Romanian Geoexchange Society managed to aggregate the knowledge and information provided by numerous Romanian companies active in the field of shallow geothermal energy, and to persuade them to join this common effort. The data base will allow – among others – to calculate Romania's contribution in terms of primary energy savings and CO_2 emissions reduction.

One of the REGEOCITIES Project's deliverables was a data base for all the ground source heat pump systems (abbreviated GSHPs) implemented in Europe. As partner in this project, the Romanian Geoexchange Society has taken over the model proposed by Regeocities and adapted it to the Romanian "environment". The proposed format for this data base is in the form of an Excel file, which can easily be filled in and concatenated with the existing data – for an easy analysis of the data. The data base contains the following fields that have to be filled in: No.; Year of achievement; Client (name); Application and address; GSHP specialized designer; GSHP specialized installer; Heating load [kW]; Cooling load [kW]; DHW load [kW]; System type (closed loop, open loop, horizontal, vertical, etc.); Closed loop systems (Total number of boreholes, Depth of a borehole, Total boreholes depth); Open loop systems (Total number of wells, No. of extraction wells, No. of injection wells, Total extracted flow rate); Heat pumps (Number, Installed capacity for heating/cooling, COP/EER, Temperature primary fluid winter/summer, Temperature secondary fluid winter/summer); Financing source; Information source.

2.3. Statistical analysis with regard to the information presented in the data base

The data introduced in the data base permitted to perform an interesting analysis with regard to different information about the GSHPs systems implemented in Romania so far. This analysis is presented further on, in graphical form.

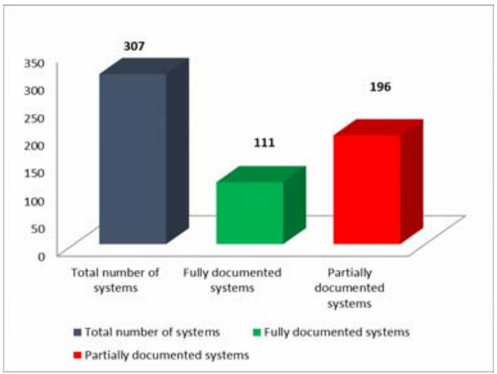

Figure 4. Reliability of information provided by the data base

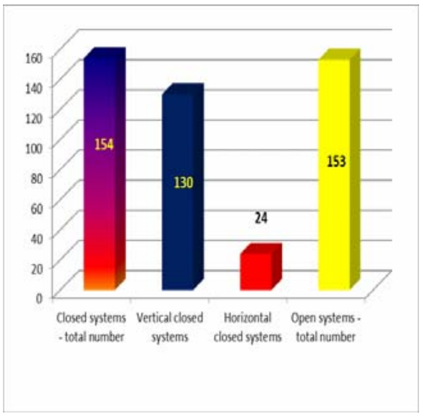

Figure 5. Closed versus open GSHP systems

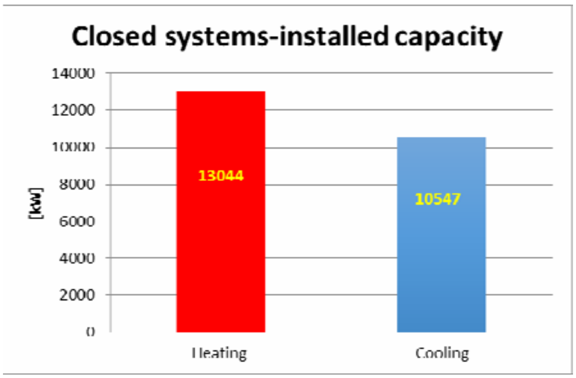

Figure 6. Installed capacity of the closed GSHP systems

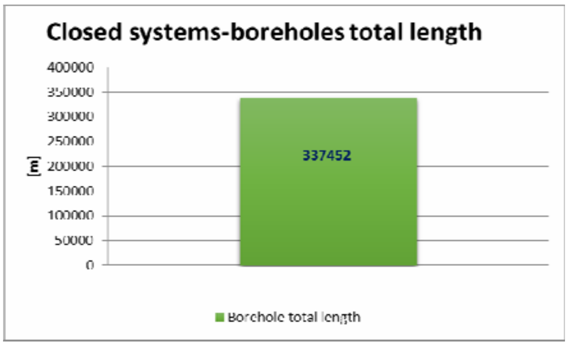

Figure 7. Boreholes total length for the closed systems

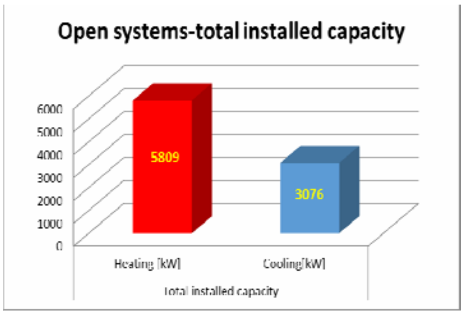

Figure 8. Total installed capacity of the open GSHPs systems

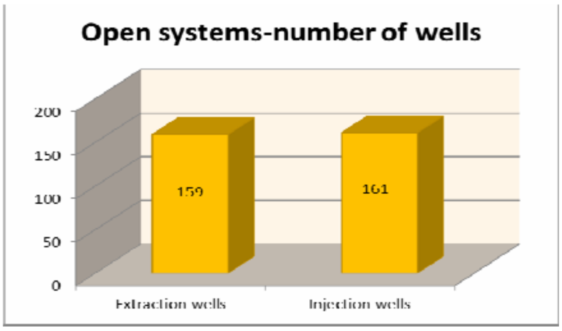

Figure 9. Wells for the open GSHPs systems

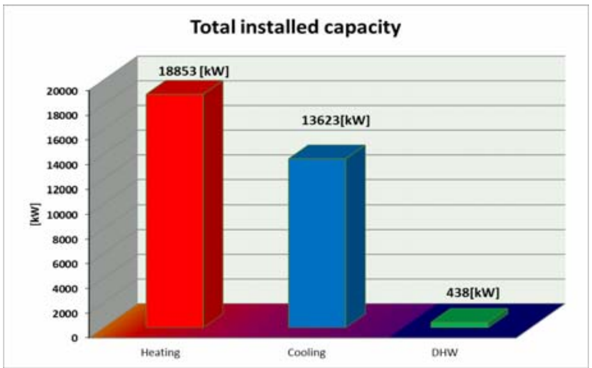

Figure 10. Total installed capacity for heating, cooling and DHW production

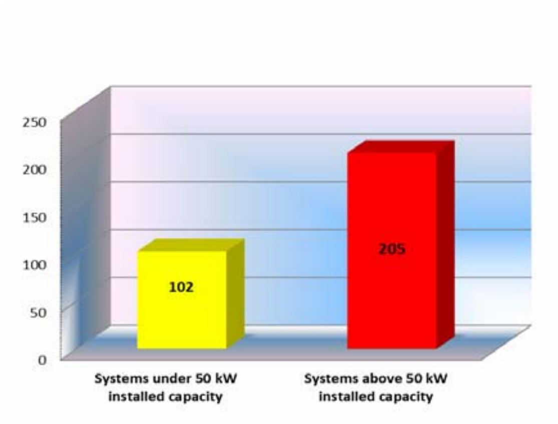

Figure 11. Small (< 5okWt) and large (>50kWt) GSHPs systems

The analysis of figure 4 to 11 allow the following conclusions:

a. The real total number of installed GSHPs systems in Romania is estimated to be at least 2 to 3 times bigger than the total number of fully documented systems. The lack of fully documented data is due to the following causes:

- The Romanian legislation lacks clear prescriptions with regard to the geothermal boreholes and the water wells for energy extraction purposes. The owners of such systems are afraid to make them public because of the legal penalties they may encounter.
- Many companies which were "pioneers" in the domain of GSHPs systems (and promoted such systems due to their high energy performances in the long term) went bankrupt, and their projects' portofolio was lost.

b. There is a certain balance between the closed loop systems and the open loop systems, expressing the balance between the higher energy performances of the closed systems, versus the lower costs of the open systems.

c. **All GSHPs systems from the data base are used exclusively for buildings, or buildings' related purposes!!!**

d. The systems are predominantly heating oriented. The cooling capability of the GSHPs systems must also be valued, as this may increase the overall energy performance of such systems – this can be done through the training activity with regard to designers.

e. The total length of boreholes (for closed loop systems) and the total number of wells (for open loop systems) prove the need for both regulatory activity and training activity in the domain of GSHPs systems.

f. The predominance of larger GSHPs systems (having installed capacities larger than 50 kWt) proves the need for the thermal response test (TRT), which may insure a proper design of such systems, with important financial savings.

2.4. Application of the european legislation on renewable energy sources in the member state Romania

For EU statistical purposes, the renewable (geothermal) contribution to the heating capacity from now on should be calculated according to the EU Directive 2009/28/EC "Renewable Energy", Annex VII, by using the equation [1].

$$\mathbf{E_{RES} = Q_{usable}\,(1 - 1/SPF)} \qquad [1]$$

E_{RES} Energy from renewable sources

Q_{usable} Estimated total usable heat generated by the heat pumps that obey the requirement $SPF > 1.15 * 1/\eta$

SPF Estimated average seasonal performance factor for the heat pump

η Estimated efficiency for the electricity production

In Romania, SR1907 states a number of climatic zones for design of heating and cooling systems. However, for application of 2013/114/EU, the overall map as shown in figure 8 seems to be applicable.

In order to apply Eq. [1] at European level for statistical purposes, the EC issued the Decision 2013/114/EU in March 2013. According to this decision and as a default (i.e. if no better data from actual measurements are available), Q_{usable} shall be calculated as follows:

$$\mathbf{Q_{usable} = H_{HP} * P_{rated}} \qquad [2]$$

Q_{usable} *estimated total usable heat (in GWh)*
H_{HP} *full-load hours of operation*
P_{rated}: *capacity of heat pumps installed*

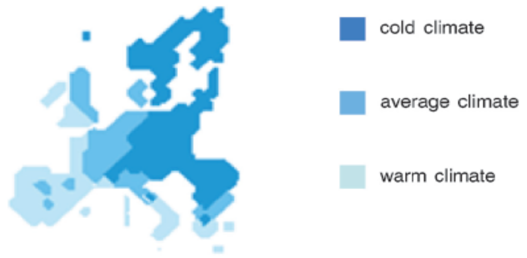

Figure 12: Climatic conditions areas (from EC Decision 2013/114/EU).

For Romania, located in the “average climate” zone therein, the default values for H_{HP} and SPF given in 2013/114/EU are as follows: H_{HP} is considered as 2070 h/year (a rather high value), and SPF for Ground-Water and Water-Water heat pumps as 3.5. Then the full calculation is:

Q_{usable} = 19,291 MW * 2070 h/yr = 39932 MWh/yr [3]

E_{RES} = 39932 MWh/yr*(1–1/3.5) = 28523 MWh/yr [4]

The pure geothermal contribution from ground source heat pump systems in Romania can be estimated to be 28523 MWh_{th} in 2016, according to the new EU calculation rule.

It is also possible to calculate the amount of CO_2-emmissions saved by using ground source heat pumps instead of natural gas burners, still the most popular heat source in Romania.

Using the emission factors of 0.202 g/kWh for natural gas and 0.701 g/kWh for the electricity in Romania, and assuming the (low) average SPF of 3.5 as given by Eurostat, the total emission reductions would amount to about 69 t in 2015.

3. REGULATORY ASPECTS AND IMPORTANT STAKEHOLDERS REGARDING THE GEOTHERMAL ENERGY IN ROMANIA

At present, the Romanian legislation is harmonized with European Union principles and supports renewable energy sources, geothermal being specifically mentioned.

The Kyoto objectives imply for the European Union, between 2008 and 2012, a reduction by 8% of the greenhouse gases emission compared to the 1990 level (corresponding to about 600 million tons per year of CO_2 equivalent). The European Renewable Energy Roadmap adopted in 2007, which defines clear targets and goals to reach a 20% contribution of renewable energy to the energy mix by the year 2020, has also been adopted by Romania and included in the Energy Strategy for the 2007-2020 period. These targets are also mandatory for Romania, after joining the European Union in 2007.

The underground mineral resources (including geothermal) are owned by the State. The Romanian Constitution, adopted in 1991, stipulates that “resources of any nature occurring in the underground, [and] the water with useful energy content, etc., are exclusively public property.” Mineral rights are excluded from private ownership. Their exploration and exploitation is regulated by the Mining Law (No. 61/1998, old version, modified by Law no. 85/2003).

Obtaining concession licenses (from the National Agency for Mineral Resources, see below) for exploration and exploitation is regulated by the Concession Law No. 219/1998.

The Environment Protection Law (No. 137/1995 old version, modified by Law No. 265/2006), stipulates that the activity of drilling wells for underground fluid production is subject to the environmental authorization procedure. Only water wells for domestic use (residential areas, family houses) with depths of less than 50 m are excepted from this procedure. Wells for (vertical loop) borehole heat exchangers are not specifically mentioned (this is still an unusual technical solution in Romania, most ground source heat exchangers are horizontal, being less expensive). The drilling process is still under the incidence of the Environmental Protection Law for the storage and disposal of hazardous fluids (fuels, lubricants, drilling mud), as well as air and noise pollution.

The Water Law (No. 107/1996, old version, modified by Law No. 310/2004) regulates the use and protection of Romania’s water resources. All waters - ground and underground - belong to the state. They can be used free for drinking, washing, irrigation and other needs, even in small installations, but cannot be sold. Otherwise, the right of using both ground and underground waters is subject of authorization. In order to stimulate the development of small and medium enterprises Law No. 346/2004 stipulates that for some small size works and activities (flow rates below 36 m^3/h) a notification at the Competent Authority is enough.

The Thermal Energy Law No. 325/2006 sets the general rules for district heating systems, and is intended to stimulate the use of renewable energy sources, among which geothermal is specifically mentioned. According to this law, all district heating systems have to be public property, but the operation can be licensed to a specialized private company or to a public - private joint venture. The district heating company purchases heat from any producer (public or private), transports, distributes and supplies it to consumers.

The Law for the Promotion of Energy Production from Renewable Energy Sources No. 220/2008 regulates all aspects regarding the “green certificates” issued for electric energy produced from renewable energy sources, geothermal included. For 1 MWh electric energy produced from geothermal energy the producer receives now 2 green certificates. One additional green certificate is awarded for co-generation systems. Unfortunately, the National Agency for Energy Regulation does not award, yet, any green certificates for geothermal power claiming that there are too few producers and not enough information to notify the European Commission. Some restrictive conditions apply, different for some renewable energy sources, mainly as minimum or maximum installed capacity and first year of operation. The green certificates can be sold on the Green Certificates Exchange. The maximum price for one green certificate is, for 2012, 55 €. The producers of energy from fossil fuels have annual quotas of green certificates they have to acquire, function of their annual energy production, otherwise they have to pay a fine. These quotas are fixed for each year until 2020, and increase every year. As the available green certificates are much below the demand, their selling price is the maximum one. At the end of the year, the money obtained from fines is distributed to the green energy producers proportional to the number of green certificates they sold, providing an additional income on top of the one from the certificates.

In the shallow geothermal domain the market outruns the national regulation framework for GHP applications. The Law No. 372/2005 on the Energy Performance of Buildings that transposed the EPBD into the national legislation entered is applicable since January 1, 2007. It contains a mandatory request regarding the presence of heat pumps as an alternative in the feasibility study for new buildings larger than 1.000 m^2. In fact, this provision is not yet applicable, because the responsible with awarding construction licenses, the local authorities, lack the knowledge and the management structure for analyzing this kind of feasibility studies.

The National Agency for Mineral Resources (NAMR), established in 1993, is the regulatory authority to administer the mineral resources as well as the Competent Authority which coordinates the mining operation under the Mining Law, according to the provisions of the Concession Law. In particular, the Agency is authorized to institute hydro-geological protection perimeters, for the underground waters (mineral and thermo-mineral), to negotiate the terms and conclude agreements for the exploration and production of mineral resources and to select, finance, and follow up on all geological exploration and exploitation works for geothermal resources.

The Order No. 97/20.05.2008 of the President of NAMR on the technical instructions for classifying and assessing the resources/reserves of natural mineral water, therapeutic mineral water, geothermal water, gases that accompany them, and noncombustible gases defines all these mineral resources, and geothermal waters are defined as "renewable useful mineral substance, represented by the totality of underground water which have the role of transporting the heat from the terrestrial crust, used for energy or as therapeutic mineral waters, with temperatures at the source higher than 20°C".

The National Agency for Environment Protection, established by the Governmental Decision no. 1625/23.12.2003, is the responsible authority under the Environment Protection Law. It has been intended to work so as to ensure a healthy environment, in line with Romania's economical development and its social progress. Its mission consists in ensuring a better environment for the present and future generations, through a continuous enhancement of air, soil and water quality.

The National Administration "Romanian Waters" is the competent authority under the Water Law. Its competence goes to surface waters of the public domain as regulated by the Law of Waters no. 107/1996, with their minor beds, shorelines and lake basins as well as their natural resources and energy potential, underground waters, sea-walls and beaches, dams, reservoirs and others.

The economic and technical operation and development of the energy sector (electric and thermal) is regulated, ruled, supervised and monitored by the National Agency for Energy Regulation (NAE)R, which was set up by an Emergency Ordinance in October 1998 as an independent and autonomous public institution. For electric energy, according to the current legislation, the National Power Transport Company (TRANSELECTRICA) has to purchase the entire available power produced from renewable resources at the price established by the NAER, based on the financial and economic assessment study. The competent authority for the Energy Efficiency Law was the National Agency for Energy Conservation (NAEC) which was included in NAER.

For thermal energy sold to a private commercial customer, the unit selling price is usually fixed by direct negotiation between the two parties. In case the customer is a public utility (e.g. district heating), the unit selling price has to be approved by the Local Council and also by the National Regulatory Agency for Local Administration.

There are two main companies in Romania currently exploiting geothermal resources, Transgex S.A. and Foradex S.A., which have the long term concession for practically all known geothermal reservoirs.

Transgex S.A. was established in 1970, having as main activities prospecting and geological exploration for mineral resources, by well drilling and mining works. Up to now, the company has drilled about 150 wells for geothermal water. The Transgex S.A. Company was privatised in 2000. At present, as basic activity, Transgex S.A. is developing the use of geothermal energy for district heating in the towns of

Oradea, Beius, Salonta, Marghita, as well as in the villages Livada, Sacuieni, Tasnad, Sinicolau de Munte, Santion. Geothermal energy is delivered in towns to block of flats, administrative institutions and economic agents, and in smaller communities to block of flats and administrative buildings, mainly in open loops.

Foradex S.A. is a large company privatised in 2008. The main part of its activity is drilling (in Romania and abroad). It has a Geothermal Department, has exploration or exploitation licences in the southern (North Bucharest, Olt Valley) and south-western part of Romania, but not much information is available regarding its activities.

Turism Felix S.A. is a tourist company owning most hotels in Felix Spa, near Oradea, as well as the geothermal wells and the exploitation licence. The geothermal water is only used for health and recreational bathing.

A few other (smaller) companies have exploration or exploitation licences for geothermal sources, the typical example being one low temperature well used for one or more swimming pools.

For shallow geothermal energy exploitation, by means of ground source heat pumps, there are many companies that install this kind of heating systems. A vast majority of these companies are affiliated to the Romanian Geoexchange Society.

The University of Oradea is a state university established under this name in 1990, based on different higher education institutions of which the first started its activity in 1780. Some of its faculties have geothermal related training and/or research among their activities, such as the Faculty of Energy Engineering and Industrial Management, the Faculty of Environment Protection, the Faculty of Electrical Engineering and Information Technology, and the Faculty of Medicine and Pharmacy. The Department of Energy Engineering currently offers B.Sc. training in Engineering of renewable energy systems and M.Sc. training in Renewable Energies.

The Romanian Geoexchange Society is a non-profit organization established in 2002, whose objectives are to promote the HVAC-GSHP systems, to create a national regulatory frame, to educate the users and to direct them to res, to represent the Romanian market abroad and to present its achievements, to train the Romanian specialists, to contribute at the European training and certification frame for the 22 specialties involved in the domain of heating and cooling with geothermal heat pump (according IGSHPA) and to bring the Romanian technical and managerial experience into the European projects.

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CONCLUSION

The geothermal energy has a great potential for development in Romania. This potential can be exploited only through a wise national strategy in investments and professional training.

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Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2015	0.05	0.4	7069	61931	0.000707	0.000645
Under construction end of 2015	0	0	--	--	--	--
Total projected by 2018	0	0	--	--	--	--

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name	Year commiss.	No of units	Status	Type	Total inst. Capacity (MW_e)	Total running cap. (MW_e)	2015 product. (GWh_e/y)
Oradea	CE Iosia Nord	nov.2012	1	O	B-ORC	0.05	0.05	0.4
Beius	Beius	2014	1	O	B-ORC	0.05	0.05	0.4
total			**1**			**0.05**	**0.05**	**0.4**

Key for status:		Key for type:			
O	Operating	D	Dry Steam	B-ORC	Binary (ORC)
N	Not operating (temporarily)	1F	Single Flash	B-Kal	Binary (Kalina)
R	Retired	2F	Double Flash	O	Other

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH Plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2015	158	300	8	50	10	12
Under construction end of 2015	2	5.2	--	--	--	--
Total projected by 2018	2	76.5	--	--	--	--

Table D: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commiss.	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	2015 geo-thermal heat prod. (GWh_{th}/y)	Geother. share in total prod. (%)
Oradea	Iosia Nord	2005	NO	NO	19	24.2	25	78.5
Oradea	Nufarul	1992	NO	NO	5	5	10	100
Oradea	Calea Aradului	2002	NO	NO	1.6	1.6	3.9	100
Beius	Beius	2001	NO	NO	21	21	25.6	100
Sannicolau	Sannicolau	1980's	NO	NO	2.7	2.7	3.3	100
Saravale	Saravale	1980's	NO	NO	1.34	1.34	2.21	100
Lovrin	Lovrin	1980's	NO	NO	1.44	1.44	2.16	100
Jimbolia	Jimbolia	1980's	NO	NO	1.44	1.44	2.85	100
Teremia	Teremia	1980's	NO	NO	1.88	1.88	3.45	100
Calimanesti	Calimanesti	1980's	NO	NO	10.73	10.73	18.7	100
Otopeni*	Otopeni	1980's	NO	NO	10.6	10.6	17.67	100
Moara Vlasiei	Moara Vlasiei	1980's	NO	NO	29.9	29.9	33.5	100
total					**106.63**	**111.83**	**148.34**	

Otopeni City has replaced its geothermal DH system by a gas-boilers based DH system!

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2015		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015	307*	19*	40*	40*	2*	N/A
Projected by 2018	600	40	100			

* - According to present data base. It is estimated that at least around other 300 systems are not documented at all.

Table F: Investment and Employment in geothermal energy

	in 2015		Expected in 2018	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	0.2	3		
Geothermal direct uses	0.5	6	8	7
Shallow geothermal	1.0*	20	5.0**	50**
total	**1.8**	**31**	**25.5**	**310**

* - Estimate

** - Without **ELI-NP** - Extreme Light Infrastructure - Nuclear Physics. Only ELI-NP will require minimum 250 specialized heat pump installers and geothermal ground heat exchanger installers.

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	National Research Plan II, by competition	National Research Plan II, by competition	National Research Plan II, by competition
Financial Incentives – Investment	N/A	Grants from Environment Fund	DIS - "Green House" Program (approx. 1350 Eur/application)
Financial Incentives – Operation/Production	Green Certificates (not operational, yet)	N/A	N/A
Information activities – promotion for the public	Media information (not on regular basis)	Media information (not on regular basis)	Regeocities training courses for local authorities
Information activities – geological information	No	No	No
Education/Training – Academic	YES, BSc, MSc and PhD in Renewable Energies at the University of Oradea	YES, BSc, MSc and PhD in Renewable Energies at the University of Oradea	Basics in all construction and polytechnic universities in the country. Doctoral studies in some of them (UPB, TUCEB and UOR).
Education/Training – Vocational	NO	NO	The 2 involved specialties (GSHP installers and GHE installers) are in course of official recognition and inclusion in National Occupations File (COR). The occupational standards are also in course of elaboration. The specialization courses are not recognized and endorsed by the Education Ministry if the respective specializations are not included in COR.

Key for financial incentives:

DIS	Direct investment support	RC	Risc coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota