Low Enthalpy Geothermal Power Generation in Romania

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ABSTRACT

Exploration for geothermal resources began in Romania in the early 1960's. Over 250 wells, drilled to depths between 800 and 3,500 m, showed the presence of low enthalpy geothermal resources (40-120°C).

The main direct uses of the geothermal energy are: district heating and bathing (health and recreational); greenhouse heating; industrial process heat; and fish farming decreased in the 1990's, but currently increasing slowly again.

20 years ago, the University of Oradea had a research program for power generation from low enthalpy geothermal water, with a couple of demonstration units working for short tests. Since then, no other geothermal power development took place, resulting in zero geothermal power generation to be present in Romania today.

However, the authors expect this to change, as new legislation was issued recently, which is much more favorable for power generation from all renewable energy sources, and mainly from geothermal energy.

In 2005, the European Commission approved for financing under the 6th Framework Program the project "Efficient Low Temperature Geothermal Binary Power" (acronym LOW-BIN), co-ordinated by the Centre for Renewable Energy Sources (CRES), Athens, Greece, with the University of Oradea as a partner in the project consortium. The main objective of the LOW-BIN project was to build two demonstration pilot units for power generation from low enthalpy geothermal sources, one to be located in Simbach, Germany, and one in Oradea, Romania. For a number of reasons, only the Simbach unit was constructed.

1. INTRODUCTION

Completion and experimental exploitation of over 100 wells during the past 25 years has enabled evaluation of the exploitable available heat from geothermal resources in Romania. Proven geothermal reserves are currently about 200,000 TJ for 20 years. Romanian geothermal resources are found in porous and permeable sandstones and siltstones or in fractured carbonate formations. The total thermal capacity of the existing wells is about 480 MWt (for a reference temperature of 25°C). Of this total, only 145 MWt are currently used, from 96 wells (of which 35 wells are used for health and recreational bathing only).

Geothermal development has been considerably hindered by the inevitable difficulties occurred during transition from a centrally planned to a free market economy. Moreover, inadequate knowledge of, and difficult access to the latest technology developments, as well as lack of know-how to identify and prepare relatively complex projects has further inhibited geothermal development, despite the substantial proven resources and benefits deriving from their use.

As a result, current geothermal production falls far behind the country's considerable demonstrated potential. Some systems, on a limited basis though, are or were applying the doublet concept of heat mining (Oradea, Bors and until 1994, Otopeni – all fissured carbonate reservoirs).

The current Romanian legislation relevant to geothermal development is harmonized with European Union principles and supports renewable energies, among which geothermal is specifically mentioned. The mineral resources (including geothermal) are owned by the State, their exploration and exploitation being regulated by the Mining Law issued in 2003. The National Agency for Mineral Resources is the Governmental institution in charge of issuing exploration and exploitation permits (long term concession).

In 2003, the Romanian Government approved the "Strategy for the development of renewable energy sources", which sets short and medium term targets in accordance with the EU principles and directives. 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 new Energy Strategy for the 2007-2020 periods.

At present, except for small hydro, all other renewable energy sources have minor contributions to the Romanian energy mix, and there is no geothermal power generation. The main energy sources are still fossil fuels.

2. MAIN GEOTHERMAL ACTORS

There are two main companies in Romania currently exploiting most of the geothermal resources, Transgex S.A. and Foradex S.A., which have the long term concessions for almost all known geothermal reservoirs. Other organizations involved in activities related to geothermal energy in Romania are Turism Felix S.A. and the University of Oradea.

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 5 towns and 5 villages. Geothermal energy is delivered in towns to blocks of flats, administrative institutions and economic agents, and in smaller communities to blocks of flats and administrative buildings.

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, and has the exploration and exploitation licences for the geothermal resources in the southern part of Romania.

Turism Felix S.A. is a tourist company owning almost all hotels in Felix Spa (the largest spa in Romania), near the City of Oradea, as well as the geothermal wells and the exploitation licence. The geothermal water is only used for health and recreational bathing.

The University of Oradea is a state university established under this name in 1990, based on different higher education institutions, the first of which 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, the Faculty of Environment Protection, the Faculty of Electrical Engineering and Information Technology, the Faculty of Sciences, and the Faculty of Medicine and Pharmacy. The Faculty of Energy Engineering currently offers a B.Sc. program in Thermal energy engineering (strongly oriented to renewable energy sources) and a M.Sc. program in Renewable energies. Five members of its current academic staff followed the six months UNU Geothermal Training Programme in Iceland.

Furthermore, 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.

3. GEOTHERMAL RESOURCES

The search for geothermal resources to be used for energy purposes began in the early 60's based on the geological program for hydrocarbon resources. There are over 250 wells drilled with depths down to 3,500 m, that shows the presence of low enthalpy geothermal resources (40-120°C). The proven reserves, with the already drilled wells, are estimated at about 200 PJ. Considering 20 years as life span of the corresponding investments, the total installed capacity of the existing wells is estimated at about 480 MW_t (for a reference temperature of 25°C). Of this total, only about 150 MW_t are currently used, from about 100 wells (of which more than one third are only used for health and recreational bathing) that are producing hot water in temperature range of 40-115°C. For 2009, the annual energy utilisation from these wells has been estimated at about 3 PJ (of which almost 1 PJ for health and recreational bathing), with an average capacity factor of about 0.6.

Figure 1: Location of Romanian geothermal reservoirs

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. The main geothermal reservoirs in Romania are located in Oradea, Bors, Beius, Western Plain, Olt Valley and Otopeni, their location being presented in Figure 1 (Rosca et al., 2005).

The Pannonian geothermal aquifer (Western Plain) is multilayered, confined 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 Timisoara and Jimbolia in the South. The aquifer is situated at a depth of 800 to about 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 from 50 to 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. The wells are produced mainly artesian, but also with downhole pumps in a few cases.

The main geothermal areas are - from North to South - Satu Mare, Tasnad, Acas, Marghita, Sacueni, Salonta, Curtici-Macea-Dorobanti, Nadlac, Lovrin, Tomnatic, Sannicolau Mare, Jimbolia and Timisoara. The main uses in these locations are: greenhouse heating; district hating; industrial uses (crop drying, hemp processing, ceramics drying, timber drying), and health and recreational bathing (Bendea and Rosca, 1999).

The Oradea 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 13 wells, of which one is used for reinjection. Well head temperatures range from 70 to 105°C. There are no dissolved gases, and the mineralisation is lower than 0.9-1.2 g/l. The water is of calcium-sulphate-bicarbonate type. 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. The natural recharge rate was calculated at 300 l/s based on the only interference test by now, carried out in 1979 (Paal, 1979). The Oradea aquifer (Triassic) is hydrodynamically connected to the Cretaceous aquifer Felix Spa (shallower and colder), and are part of the active natural flow of water.

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. 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. In the past, three wells were used to produce a total flow rate of 50 l/s, and two other wells are used for reinjection, at a pressure that did not exceed 6 bars. The geothermal water was used for heating 12 ha greenhouses. The dissolved gasses were partially separated at 7 bars, which was the operating pressure, and then the fluid passed through heat exchangers before being reinjected.

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 84°C wellhead temperature. A second well has been drilled in early 2004, and a line shaft pump has been installed soon after completion. The geothermal water has a low mineralization (462 mg/l TDS), and 22.13 mg/l NCG, mainly CO_2 (0.01 mg/l of H_2S). At present, the geothermal water from the first well is used to supply district heating to part of the town of Beius.

The Ciumeghiu geothermal reservoir is also located in the Western Plain, 50 km south of Oradea. The geothermal water is produced in artesian discharge, having 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 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 Cozia-Calimanesti geothermal reservoir (Olt Valley) is located in fissured Senonian siltstones 2,700-3,250 m deep. There are 4 wells drilled in the area, with artesian flow rates of 8.5-22 l/s and well head temperatures of 70-95°C. The TDS is 15.7 g/l, and there is no major scaling. 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 existing wells is about 18 MW_t (of which 3.5 MW_t from combustible gases), but only 7 MW_t is used at present (at peak load). The utilisation is mainly for district heating, but also for health and recreational bathing.

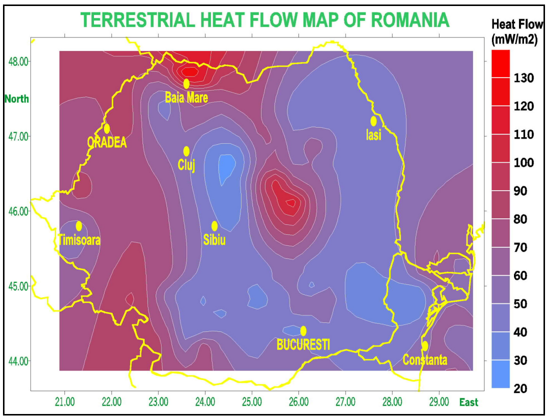

Figure 2: Terrestrial heat flow map of Romania

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 limestone and dolomites. The aquifer, situated at a depth of 2,000-3,200 m, belongs to the Moessic Platform. The geothermal water has wellhead temperatures of 58-84 °C, and 1.5-2.2 g/l TDS, with a high content of H_2S (up to 30 ppm). Therefore, reinjection is compulsory for environment protection purposes. The production was carried out using downhole pumps, because the water level in the wells is at 80 m below surface. The flow rate was 22-28 l/s per well. At present, only one well is used almost all year round, for health and recreational bathing. It is to be mentioned that, at present, potential users are available.

The terrestrial heat flow map (Figure 2) shows a potential for enhanced geothermal systems in the North (Baia Mare area), and in the central part of Romania (Veliciu, 2001).

4. GEOTHERMAL BINARY PLANTS

Geothermal energy use today mainly concerns hydrothermal systems, and water bearing formations at elevated temperatures of depths down to 3-4 km. Applications include direct heat uses, usually at lower temperatures up to 100-110°C and electricity generation for higher temperatures. When the temperature exceeds 180°C, the most common geothermal power generation technology used is flash plants, with the geothermal fluid flashing at 180°C or more and the separated steam driving a wet steam turbine in order to generate electricity.

At lower temperatures, the preferred geothermal power generation technology is binary power plants of Rankine or Kalina cycles. In these plants, the geothermal fluid transfers its heat to a closed loop of a working fluid, which can be either an organic fluid, usually a hydrocarbon (usually isobutane or isopentane) or a (hydro) fluorocarbon (Organic Rankine Cycle – ORC), or ammonia (Kalina cycle), which flashes and its vapor drives a turbine for electricity generation. The working fluid condenses within a second heat exchanger cooled either by water (directly or through a cooling/evaporation tower) or by air. Then the liquid fluid is pumped through the geothermal heat exchanger and the cycle continues. This process has conversion efficiency (ratio of electricity generated over geothermal heat input) between 7% and 15% depending on the source temperature and the load. The bulk of energy losses occur at the cooling heat exchanger.

By selecting the working fluid, designing and optimizing the machine, binary cycle units can operate with geothermal fluid temperatures as low as 70°C. Although they have higher costs per kW of installed power than geothermal flash power plants, in many cases they are the most suitable option for geothermal power generation.

The first operational geothermal power system in Australia, and the lowest temperature geothermal binary plant in commercial operation in the world at that time, was the Mulka plant. It comprised a 15 kW ORC engine, built in 1984-1985 in Adelaide and commissioned in 1986, funded by the government of South Australia, coupled to a 1,300 m deep well drilled in 1904, and refurbished by the South Australian Department of Mines and Energy in 1985, supplying 86ºC water at 5 bar wellhead pressure. The plant run virtually non stop for three and a half years, showing frequency stability and response to load changes comparable to diesel engines of similar hydraulic governing systems.

In 1981, the National Geothermal Research Institute of the University of Oradea, Romania, designed and developed a pilot binary power plant using carbon dioxide (CO_2) as working fluid. The first installation used a piston engine for the working fluid expansion and produced 1 MW electric power. In 1996 a new pilot plant was designed, the piston engine being replaced by a turbine. The plant utilized 85ºC geothermal water. Both plants were experimental.

The first European 1,300 kW Rankine Cycle unit was designed and constructed by Italian Companies SOWIT and TURBODEN, with the support of the EU THERMIE program GE/00210/88/IT. Its operation started in July 1992, near an ENEL geothermal power plant at Castelnuovo V.C. near Larderello. It was tested with hot water supply of temperature in the range 90-115ºC and generated 800-1,300 kW of electricity.

Present geothermal binary plants can accommodate heat supply usually at the 90-180ºC range, handling both base and peek loads, as well as variable loads including low instantaneous load of 0-25% of the installed capacity. They have a high degree of computerized automation, including self starting and are capable of 100% unattended operation, with remote monitoring and control through a telephone or satellite link. Alternatively they can be operated by semi skilled labor on part time basis.

5. THE LOW-BIN PROJECT

In 2005, the Geothermal Energy Department of the Centre for Renewable Energy Sources from Athens, Greece, leading a consortium of 9 European organizations (CRES, TURBODEN, GFZ-Potsdam, Geoteam, University of Oradea, Technical University of Setubal, Polytechnic of Milano, BRGM and ISOR), submitted the proposal for the project "Efficient Low Temperature Geothermal Binary Power" (acronym LOW-BIN) to be financed under the 6th Framework Program of the European Commission. The proposal has been evaluated and approved for financial support, and the project actually started in 2006. More details for the Low-Bin project are available at the web site: http://www.lowbin.eu/.

The objectives of the LOW-BIN project were to design, manufacture and monitor the operation of the following ORC prototype machines: a first one for 65-90ºC low enthalpy geothermal resources; and a second one for heat and power cogeneration by heat recovery from the cooling water circuit from 120-150ºC geothermal resources, with overall energy efficiency of 98-99%. TURBODEN also manufactures similar machines for biomass operating at ~300ºC, where the cooling water supplies a district heating system at 60/80 ºC.

The first prototype was installed in Simbach, Germany, and the second prototype was planned to be installed in Bors or Oradea, Romania.

The first type of unit can be used where or when there are no consumers for the geothermal heat, or if the financial incentives make the geothermal power generation more profitable than the potential direct uses. A good example is the LOW-BIN prototype in Simbach, Germany, where the geothermal water is also used for a district heating system. In summer, when the heat demand is low, the ORC unit operates in parallel to the district heating. The 80°C geothermal water is cooled in the ORC unit evaporator to 60°C, which quite enough for heating the domestic hot water delivered to the consumers connected to the district heating system. The cooling water for the condenser of the ORC unit is cooled in an evaporative condenser. In this way, the ORC unit provides an additional income from the green electricity produced, and increases the utilization factor of the geothermal energy available from the existing well.

The first prototype developed for the LOW-BIN project is tailor-made for low temperature geothermal environment, which allowed the selection of lower cost materials, and hence considerable costs reduction. The whole machine was reengineered in order to identify recoverable energy losses and improve overall conversion efficiency. This included reengineering the turbine design, as well as selecting R134a as working fluid that gives an excellent thermodynamic match to the available geothermal water supply temperature (80ºC).

In order to reduce capital costs, geothermal direct heat applications are attached to binary units, either in parallel, or in cascade (series) to the power plant geothermal outlet line. Examples of such cases are the geothermal fields of Svartsengi and Husavic in Iceland, Neustadt Glewe in Germany, Altheim and Bad Blumau in Austria and others. The parallel systems provide limited cost or energy efficiency benefits to the binary plant. The cascade systems, although resulting in significant reduction in energy production costs, still have large amounts of wasted energy released to the environment through the cooling fluid circuit (Figure 3).

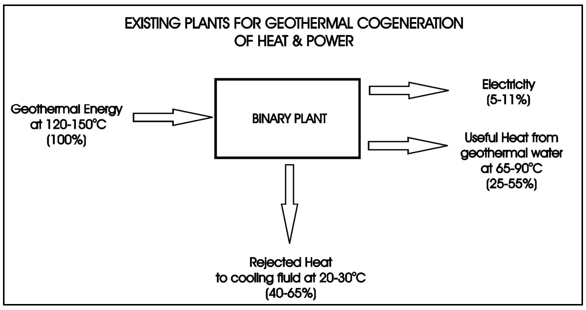

Figure 3: Energy flow chart of existing geothermal binary plants for heat and power cogeneration.

The second type of LOW-BIN ORC unit can be used where the available geothermal water temperature exceeds 120°C, or where it contains a significant concentration of dissolved combustible gasses which can be separated and used in a boiler to increase the well head temperature. In these cases, the ORC unit can be used in series with direct utilization systems, typically as a district heating system. A part of the return water from the district heating system is heated up 80°C in the condenser of the ORC unit, and the other part in a heat exchanger using the geothermal water outlet from the ORC unit evaporator (Figure 4).

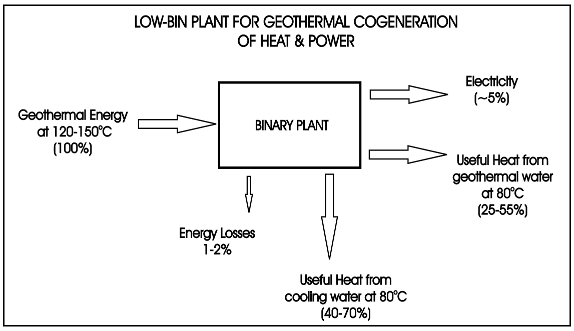

Figure 4: Energy flow chart of geothermal binary plant for heat and power cogeneration proposed in the LOW-BIN project.

The overall efficiency of a cogeneration system of this type can reach 98-99%, as the total energy losses can be reduced to a minimum (1-2%) by improving the ORC unit design and by reducing the heat losses of all components (pipes, valves, heat exchangers, etc.).

Using the conversion efficiency according to the technology developed during the LOW-BIN project, the total potential for geothermal power generation in Romania from the identified reserves, is estimated at about 800 MW from the wells with 65-90ºC, and about 80 MW from the wells with 90-120ºC wellhead temperatures.

6. THE ORADEA LOW-BIN PROTOTYPE

The Bors geothermal reservoir has been the first choice for the location of the ORC unit manufactured by TURBODEN in the LOW-BIN project for cogeneration (Prototype 2).

As the geothermal water has a high scaling potential, a sub-contract has been awarded to Geoproduction Consultants Instrumentation & Projects (GPC I&P) company of Paris, France. After sampling geothermal fluid from all the wells drilled in the Bors geothermal reservoir, GPC I&P carried out the chemical analysis, defined the chemical inhibitor, and determined the required concentration and the depth at which it should be injected in the production wells.

The plan was to install a line shaft pump in one of the five wells to increase production to 30 l/s. The ORC unit was designed to generate 220 kW_{el} from this flow rate, for vaporizer inlet and outlet geothermal water temperatures of 120 and 85°C respectively. The condenser was designed for 20 and 50°C inlet and outlet temperatures respectively, to be used for sanitary hot water supply, floor heating or greenhouse heating.

Unfortunately, the greenhouse company located between Bors and Oradea went broke and closed. The Municipality of Oradea planned to develop an industrial park in the area, as it is close to Oradea and to the Hungarian border. After a short while, the planned location of the industrial park was changed (close to the University), but it is still in the planning phase. The two villages located near the geothermal wells, Bors and Santion, are rather small, with small houses spread over a large area, therefore with a very load head demand density, making a district heating system too expensive to be economic at a reasonable heat selling price. There are some factories in the area, some cargo truck terminals and logistics companies, and a hotel, but the total heat demand is rater low and all had other heat sources (mainly natural gas, at a reasonable price at that time).

The TRANSGEX Company owns the wells and has the exploitation license for the Bors geothermal reservoir, the situation being the same in Oradea, where it also has a type of joint venture (GEOTERM) with the Municipality for heat supply. The main heat producer for the Oradea district heating system is the co-generation power plant located between Bors and the City of Oradea, organized as a commercial company owned by the Municipality of Oradea. The cogeneration power plant mainly uses low grade coal and heavy fuel oil (to maintain the flame). Two boilers have been modified to use natural gas, but when the price increased very much these were not used any more.

The power plant and the district heating system are very old (more than 40 years), and in very bad shape, with high heat and water losses. The make up water in the primary network only is about 30 l/s during summer and up to about 100 l/s during winter.

As the co-generation power plant is only about 3-4 km from Bors, TRANSGEX discussed with it management and with the Municipality of Oradea to use the available heat from the LOW-BIN ORC unit to pre-heat the make up water for the district heating primary network. Considering energy efficiency and operation of the LOW-BIN demo unit, this would have been a very good solution, as the make up water is rather cold (10-20°C).

This solution was considered temporary, until the Municipality of Oradea would access the funds to build a new co-generation power plant and to retrofit the district heating system. By that time, it was reasonable to assume that the area between Oradea and the Hungarian border would develop, providing new heat consumers. However, despite that all parties were interested in reaching an agreement, no contract has been signed yet.

As the Bors reservoir is closed and rather small, all the produced geothermal water has to be reinjected. When the production was of about 50 l/s during the greenhouse heating season, TRANSGEX also injected into the reservoir colder water from a shallower aquifer, to maintain reservoir pressure for artesian production. The cold water was injected only between the heating seasons. An evaluation of the Bors reservoir behavior, based on the available data and previous exploitation experience, showed that the well head temperature might decrease to about 105°C after about 10 years of continuous exploitation (with reinjection and cold water injection).

For all the above mentioned reasons, it was decided to install the LOW-BIN ORC unit in the City of Oradea, in the Iosia district, near a well that produces 35 l/s geothermal water with a well head temperature of 105°C. The well is located inside an outdoor swimming pool complex, near the Crisul Repede River. It supplies the primary fluid to three substations of the Oradea district heating system. The geothermal heat plant is located near the production well, and part of the heat depleted geothermal water is used in the swimming pools.

Although the temperature is lower than in Bors, the location was considered more suitable for the LOW-BIN demo unit, for a number of reasons:

- the geothermal water from the Oradea reservoir has a low mineralization, almost no dissolved gasses, and no scaling, nor corrosion potential, and the well head temperature is not expected to decrease significantly in time due to the high natural recharge rate;
- the existence of a geothermal district heating system;
- the existence of the swimming pools near by, which could be the consumer for the heat available from the ORC unit condenser;
- the existing geothermal heat plant has two natural gas fired peak load boilers, which could be used to increase the condenser inlet temperature up to 118°C during relatively short periods of time, in order to test the ORC unit at different operating parameters;
- the plans of the Municipality of Oradea to renovate and extend the swimming pool complex on the empty available land to the river bank, so that it would comply to all requirements of the national and European Union regulations;
- the presence of nearby Crisul Repede River at less than 100 m distance, which could provide additional cooling water for the ORC unit condenser until the completion of the new swimming pool complex.

7. FEASIBILITY CONSIDERATIONS

TURBODEN designed a new unit, optimized to work under the conditions of the new demonstration site in the Iosia district of Oradea all year round (summer and winter), with the operational conditions presented in Table 1.

Table 1: Operational conditions for the LOW-BIN unit designed for the demo site in Iosia, Oradea

Parameter	Unit	Summer	Winter
Hot source mass flow rate	kg/s	29	29
Vaporizer inlet temperature	°C	105	105
Vaporizer outlet temperature	°C	70.39	72.38
Cold source mass flow rate	kg/s	95.0	90.3
Condenser inlet temperature	°C	25	35
Condenser outlet temperature	°C	35	45
Expected gross power output	kW	200	140

Due to the utilization of the geothermal fluid for district heating as well, the power consumed by the line shaft pump installed in the production well and the circulation pump for the condenser cooling water, totaling about 140-150 kW, can not be all considered a consumption (parasitic loss) of the ORC unit. After installing the line shaft pump (close to the lower, smaller diameter casing), the production well is no longer self flowing, although during the summer the only demand is for hot tap water at a lower flow rate, and a lower pumping power.

According to the Romanian legislation, the National Power Transport Company (TRANSELECTRICA) has to buy all power produced from renewable energy sources (the "green power") at the "Price for the Next Day". This price is of course fluctuating, but increasing steadily. The average price was 40.13 €/MWh in November 2007, 60.53 €/MWh in November 2008, and usually lower during summers.

According to the Law on green energy in force in 2007, for every MWh green power the producer received one green certificate. Companies producing power form other energy sources had to have a certain quota of green certificates per year, the quota increasing every year. These companies can obtain the required green certificates by producing green power, or by buying them either on the Green Certificates Exchange, or directly form the green power producers (at a negotiated price), otherwise they have to pay a high fine for the missing green certificates. On the Green Certificates Exchange the minimum and the maximum prices, fixed by the same Law, were 22 € and 42 € respectively. As the supply is still much lower than the demand, all green certificates are sold on the Exchange at the maximum legally allowed price. After the end of each year, part of the money obtained from fines are distributed to green power producers proportional to the amount of green certificates sold on the Exchange. For 2007, this "bonus" was almost twice as much as the money received for selling the green certificates on the Exchange, and slightly less for 2008, but this situation will not last very long, as some large wind power projects are in the construction phase, and some more in the design stage, with licenses for green power production already approved.

Therefore, the total average income from selling the green power and the green certificates was about 70 €/MWh in 2007, and about 100 €/MWh in 2008 (without considering the "bonus").

A company like GEOTERM could also produce green power for own use. In this case, all the green power from the generator of the ORC unit is delivered to the national power grid. The company also consumes power from the grid, for operating its equipment. At the end of the year, the company only pays the difference between the consumed electric energy and the produced green energy. The purchase price for electric energy is about 110 €/MWh. Therefore, the total gain of the company would have been about 140 €/MWh in 2007, and about 160 €/MWh in 2008, real income from the green certificates, and savings from the energy produced and not paid for (without considering the "bonus").

The cost of the ORC unit, as a prototype, was rather high. The EC contribution to the LOW-BIN project was needed to cover part of the research cost, part of the difference in cost between a prototype and commercial product, as well as part of the other costs related to the demo site (permits, design, civil works, piping, electric equipment including grid connection, etc.). Even so, and even with relatively low operation and maintenance costs, considering the most favorable scenario as economic gains for the company (i.e. production for own use), the pay back time was estimated between 10 and 20 years, depending on the estimated "bonus" (which is actually quite difficult to estimate for such a long period of time). The economic and financial feasibility of such a small scale project should anyhow be expected to be marginal.

8. AFTERMATH

Although the profitability of the project was marginal, as at least it was not losing money, by late 2007 TRANSGEX, the majority partner of GEOTERM, finally decided to go ahead, mainly because it was an EC funded project.

After negotiating and signing an agreement, TURBODEN supplied to TRANSGEX the conceptual design and all the required specifications for the demonstration site. After that, TRANSGEX had to:

- get the concession for GEOTERM of about 500 m^2 of land near the geothermal heat plant in Iosia, need for the demonstration site, the land being the property of the Municipality of Oradea;
- sign a contract with an authorised company for the project and application needed to obtain the permit from the National Authority "Romanian Waters" to use water from the Crisul Repede river for cooling, when needed;
- sign a contract with an authorised company for the project and construction of the connection to the national power grid;
- sign a partnership contract with the LOW-BIN partner University of Oradea, based on which the university could use the budgeted EC contribution to cover part of the demo site and demo unit costs;
- register GEOTERM as a power producer and obtain the licence for green power generation;
- design and build the demonstration site according to the specifications provided by TURBODEN.

In spring 2008, one year after becoming a member of the European Union, Romania had the first elections for the European Parliament. The Mayor of Oradea was elected, and one of the two Vice-Mayors was then elected by the Local Council as Interim Mayor, as local elections were scheduled for summer 2008 when a new Local Council and, as expected, a new Mayor was elected, a member of the party that formed the Government (and in minority in the Romanian Parliament). After the Parliament election in winter 2008, that party still has a minority, but a coalition of two other parties forms the Government.

Unfortunately, in Romania the authorities are not taking any decision, if it has a potential importance, some months before the elections (expecting a change in power, and not being certain of the new policies), and some months after the elections (administration structures are reorganized, many persons, mainly in high level positions, are changed on political reasons). As a result, by the end of 2008 it was impossible for TRANSGEX not only to obtain the permit for using the river water for cooling, but even to obtain the concession for the need land for the demonstration site, although the Municipality is a partner in GEOTERM.

Upon an application by the LOW-BIN project coordinator, the European Commission approved a 6 month extension of the contract (and project time). Even with this extension, by the end of 2008 it was too late for TURBODEN to start manufacturing the prototype unit for the Oradea demo site. Therefore, this part of the LOW-BIN project was stopped, only the prototype unit for Simbach, Germany, being finally completed and tested.

According to a new Law (No.221) on energy from renewable sources, of November 2008, for 1 MWh electric energy produced form geothermal resources and associated combustible gasses, the producer receives three green certificates (instead of one, in the old law). For thermal energy from geothermal resources and associated gasses, the producers receive one green certificate for 1 MWh. The maximum price for one green certificate was also increased from 42 to 55 €. At present, the economic feasibility of geothermal projects is much better, both for electric and thermal energy production, even for small scale projects.

9. CONCLUSION

Romania is rich in low enthalpy geothermal resources suitable for direct heat uses and power generation through binary plants. At present, although a considerable part of these resources is utilized for direct heat applications, a lot more further development is possible, especially for geothermal power, which is facilitated by the new technology developed for the LOW-BIN project. The recent alignment of Romanian legislation on renewable energy to the European directives, and especially the new incentives provided to geothermal power plants in terms of green certificates, form the necessary environment for a new future to geothermal power generation in Romania.

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