# Re-introduction of the geothermal energy for the Otopeni district heating system

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## ABSTRACT

The paper presents a review of the past use of the geothermal energy in the Otopeni City, as well as a technical and economic analysis with regard to the re-introduction of this renewable energy for feeding the district heating system of the city.

## 1. INTRODUCTION

Romania is one of the countries having available geothermal resources, their existence being discovered after geological studies performed in the 1960's. [1]
In the 1980's the geothermal resources were used to provide energy for the geothermal district heating systems of some little towns, like Otopeni and Insuratei. [2]
Without a detailed explanation from behalf of the authorities, the operation of the geothermal district heating systems was halted before 1990.
After 1990, the municipality of Bucharest has ordered several feasibility studies in order to analyze the possibility to retrofit the conventional district heating system, based on fossil fuels, to a geothermal district heating system based on geothermal energy.
The feasibility study made in 1993 for Bucharest indicates that the cost of geothermal transformations of the conventional district heating system will be recovered in two years. [3]
In the last 25 years, the number of district heating systems in Romania has decreased continuously, in favor of local heating systems. At present, only 20% of the in 1989 existing district heating systems are currently in operation. [4]
Data presented in Table 1 shows the decreasing number of Romanian towns using district heating systems.
This tendency was followed by an increase of the total consumption of conventional fuels, and also by the damage of exterior architectural aspect of the buildings.
A good action at this time is to finish the thermal rehabilitation of buildings (blocks of flats mainly), action started since our accession to the UE. Most of these buildings are connected to DH systems. [5]
In Bucharest over 600,000 flats from the total of 3,000,000 are thermally rehabilitated. Unfortunately the number of flats using the Bucharest DH system is up to 570,000.

**Table 1. Evolution of the number of Romanian cities connected to DH systems [4]**

| Year | Cities existing at national level | Cities having DH systems | Cities renouncing at the DH systems |
|---|---|---|---|
| 1989 | 2583 | 315 | 0 |
| 2009 | 3180 | 121 | 194 |
| 2010 | 3180 | 116 | 5 |
| 2011 | 3180 | 110 | 6 |
| 2012 | 3180 | 86 | 24 |
| 2013 | 3180 | 78 | 8 |
| 2014 | 3180 | 70 | 8 |

## 2. PRESENT DAY SITUATION OF THE DH SYSTEM FROM OTOPENI CITY

The city has 106 blocks of flats with 1939 apartments. The apartment buildings are not rehabilitated - from the point of view of envelope and indoor HVAC systems. All these apartment buildings are connected to the recently rehabilitated district heating network (see Figure 1). [6]
Otopeni City is one of the few towns where the distribution network was totally rehabilitated. The rehabilitation project was performed by the company managing the district heating system of the city. The DH network uses pre-insulated flexible pipes. [7]

**Table 2. The situation of flats disconnected from the district heating system [7]**

| | | |
|---|---|---|
| 97 out of 106 blocks are connected to the DH system | 22 blocks | More than 50% of flats |
| | 28 blocks | 30…50% of flats |
| | 26 blocks | 15…30% of flats |
| | 21 blocks | Less than 15% of flats |

**Figure 1. Rehabilitation works of the Otopeni district heating pipeline network [7]**

The source providing heating to the DH system is represented by 7 heating plants running on natural gas, with great $CO_2$ emissions. The technical data regarding these thermal plants is presented in Table 3, and their location in Figure 2.

The city is thus highly dependent on the energy market prices, requesting subsidies from the state in order to make the real prices bearable for the consumers. [8]

**Table 3. Technical data on the Otopeni thermal plants [8]**

| | Nominal thermal power [MW] | Heat flow [Gcal/h] |
|---|---|---|
| TP 1 | 4,19 | 3,6 |
| TP 2 | 2,8 | 2,4 |
| TP 3 | 4,19 | 3,6 |
| TP 4 | 2,8 | 2,4 |
| TP 5 | 2,8 | 2,4 |
| TP 6 | 2,8 | 2,4 |
| TP 7 | 2,8 | 2,4 |
| TOTAL | 22,38 | 19,2 |


**Figure 2. The location of Otopeni gas heating plants [8]**

## 3. THE GEOTHERMAL RESOURCES OF THE OTOPENI CITY [9]

Geothermal research performed on Romania`s territory has shown the presence of numerous areas with geothermal high flux. In the presence of collector rocks for underground waters, positive geothermal anomalies lead to the formation of geothermal water deposits, accumulations that manifest themselves naturally at the surface in the form of natural thermal springs (in general in carbonated areas) or they are opened by drilling. According to statistics on the geothermal potential in Romania, the Otopeni basin presents the following characteristics:

- Surface: 300 km²
- Rock type: limestones and dolomite
- Depth: 2.000 – 3.200 m
- Nominal thermal power: 32 MW
- Daily supported consumption:310MWh/day
- Temperature: 58-84°C
- Chemistry: 1.5-2.2 g/l salinity
- Additional gases: 30 ppm H2S
- Flow rate: 60 L/s
- Minimum exploitation period: 20 years

On the territory of the Otopeni City there are 12 geothermal wells (located according to Figure 3), drilled in 1980's down to an average depth of 2000 m, which were not-used during the last more than 25 years. They can provide more than 65ºC hot water, at an average flow rate of 10l/s per well. [10]
In the '80s, the geothermal energy was used in the winter time for supplying heat to the district heating system of the Otopeni city – which was of the direct and open type.
The problem that appeared was the corrosion of steel elements – illustrated in Figure 4.
In the summer time the geothermal water fed a swimming hot water pool, used for recreation but also

for spa treatments. Both geothermal utilizations were stopped after 1990.

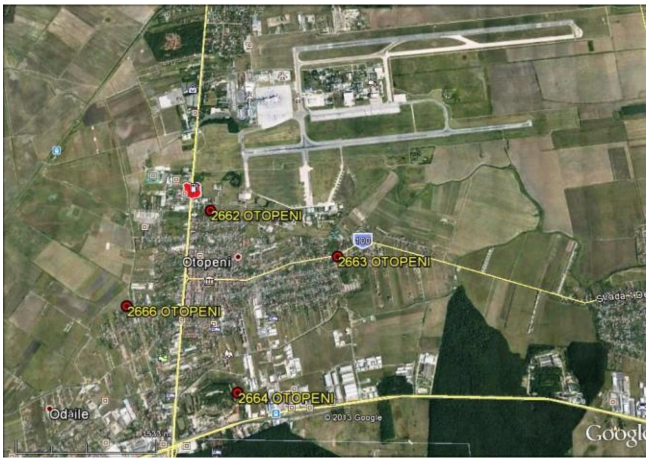


**Figure 3. The map of Otopeni geothermal wells. [10]**

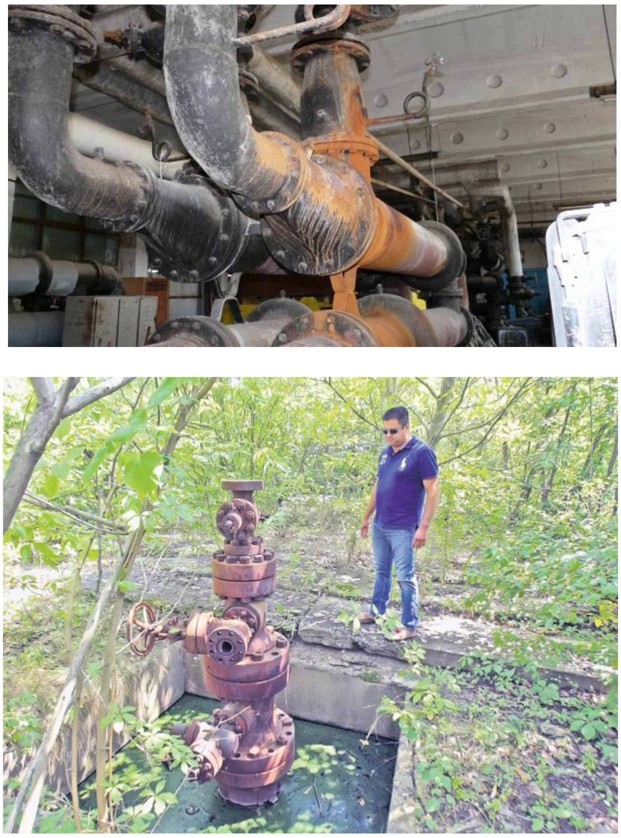

**Figure 4. Images from the Otopeni geothermal past exploitation [13]**

## 4. PROPOSED GEOTHERMAL ENERGY UTILIZATION

All this information makes Otopeni City a good place for starting the scientific research for the implementation of a geothermal district heating system. The complex study intends to analyze the possibility of combining the cogeneration systems based on fossil resources with a direct geothermal district heating – on the one hand, and also the possibility of tri-generation, by combining the cogeneration system with a geothermal district cooling system (based on the absorption technology). The use of a geothermal ORC cogeneration system will also be considered.

The first step of the complex study is a simplified model for a heating-only-system – which is analyzed in this paper, according to [11]. The conceptual schematic of the proposed geothermal project layout is presented in Figure 5.

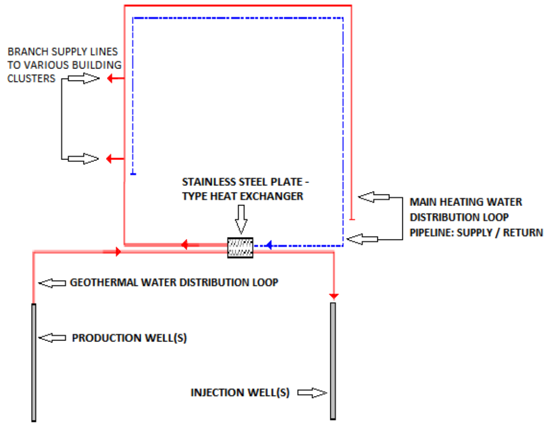


**Figure 5. Conceptual schematic of the proposed geothermal project layout for the Otopeni City district heating system [11]**

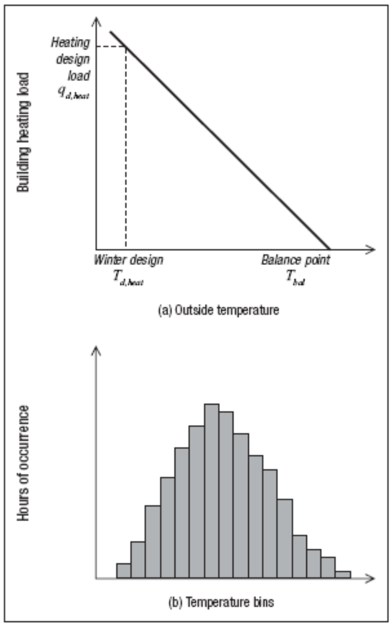


**Figure 6. Computation of the heating energy – the RETSCREEN / ASHRAE method [12]**

The computation of the heating energy is made according to the RETSCREEN/ASHRAE method – whose principle is presented in Figure 6.

The energy calculus for heating – for the overall district heating system of the Otopeni City - is presented in table 4.

**Table 4. Energy calculus for heating – for the overall district heating system of the Otopeni City [12][13]**

| Temperature bins for the heating season [°C] | Number of heating hours per year [h/year] | Heating power demand for the specific outdoor air temperature [kW] | Heating energy demand [kWh] |
|---|---|---|---|
| -15.0 | 28.30 | 22380 | 633439.16 |
| -12.5 | 29.54 | 20142 | 595064.88 |
| -10.0 | 81.08 | 17904 | 1451659.96 |
| -7.5 | 133.69 | 15666 | 2094412.99 |
| -5.0 | 339.58 | 13428 | 4559836.69 |
| -2.5 | 415.33 | 11190 | 4647556.47 |
| 0.0 | 840.67 | 8952 | 7525676.66 |
| 2.5 | 615.47 | 6714 | 4132285.43 |
| 5.0 | 721.30 | 4476 | 3228550.89 |
| 7.5 | 526.59 | 2238 | 1178502.95 |
| 10.0 | 704.63 | 0 | 0 |
| Total heating hours per year | 4436.19 | Total heating energy per year | 30046986.1 |

A spreadsheet analysis tool was developed to examine various scenarios of the proposed model.

The hypotheses of the proposed model are as follows:

***Technical hypotheses***

- The geothermal DH system is a heating-only-system, closed loop type;
- Out of the 12 existing geothermal wells, 6 will be used for extraction, and the other remaining 6 for re-injection;
- During summer time, the geothermal energy is used for domestic hot water production;
- At lower geothermal resource temperatures and/or flow rates, it was assumed that the heating water loop temperature would be boosted by a natural gas-fired boiler;
- The maximum installed capacity in the heating plants is 22,38 MW, and heating is stopped at outdoor temperatures above 10°C;
- The temperature bins considered for the calculus are those for the meteorological station from Baneasa, obtained by using the ASHRAE Weather Data Viewer software [13];
- The temperature bins corresponding to temperatures bellow -15°C were allocated to the -15°C temperature;
- The outdoor temperature starting from which geothermal can fully cover the heating loads is 4.4°C;

***Economic hypotheses***

- Well costs were not considered, as it is assumed they will be covered by a grant;
- Only the installation costs and the operation and maintenance costs for the geothermal heating plant were considered;
- Engineering design, and operation and maintenance costs are estimated as a percent of the costs of the geothermal heating plant.
- The overall investment costs were estimated at 100.000 euros for the 5 MW geothermal energy available, according to similar geothermal projects achieved in Romania (Beius)

The summary of the technical and economic analysis for the proposed geothermal district heating system – under the above mentioned hypotheses – is presented in Table 5.

**Table 5. - Summary of the technical and economic analysis for the proposed geothermal district heating system – base case (super optimistic)**

| **Parameter** | **Measuring unit** | **Value** |
|---|---|---|
| Geothermal water flowrate | [kg/s] | 60 |
| Geothermal water extraction temperature | [°C] | 70 |
| Geothermal water injection temperature | [°C] | 50 |
| Water supply temperature to the DH system | [°C] | 65 |
| Water return temperature from the DH system | [°C] | 45 |
| Water specific heat capacity | [kJ/kg * K] | 4.186 |
| Thermal power supplied by the geothermal water | [MW] | 5.0232 |
| Total investment | [RON] | **445000** |
| Investment needed for the wells - covered by grant | [RON] | 0 |
| Investment needed for the equipment in the geothermal station - covered by the project | [RON] | 445000 |
| Present day price for the delivered thermal energy | [RON/Gcal] | **112** |
| Proposed price for the delivered thermal energy | [RON/Gcal] | **80** |
| Annual energy savings for heating | [kWh/year] | 16880223 |
| Annual energy savings for DHW | [kWh/year] | 762557 |
| Annual total energy savings | [kWh/year] | 17642780 |
| Annual $CO_2$ savings | [t/year] | 87340.50 |
| Population financial annual savings | [RON/year] | **485442** |
| Simple payback period | [year] | **0.92** |
| Annual budget savings (elimination of subsidies) | [RON/year] | **40264505** |

The main factors affecting the simple payback of the district heating system are: geothermal resource flow rate, capital cost, and selling price of heating water. The geothermal resource flow rate dictates the thermal power that can be obtained from the geothermal source, and finally how many apartments can be heated and provided with DHW. The capital cost is an obvious factor affecting the payback period. If the cost for drilling new wells is taken into account and needs to be covered from the money of the investors, the payback period will increase accordingly – this is the reason why a grant for covering these costs is highly desirable. The selling price of the heating water was estimated at 80 RON/Gcal (same as for the Beius project).

It is very obvious that – besides the technical factors (flowrate and temperature of the geothermal water) - there are many economic factors that can drastically affect the super-optimistic case, such as: the costs for drilling new wells, the contract arrangement between the municipality and the company who runs and maintains the DH system in Otopeni with regard to the price needed to be payed by the population, share of the population connected to the DH system, the subsidies policy in Romania with regard to the DH systems, etc.

Various scenarios can be imagined, and they can be fed into the existing model, but the reliability of the input information may be questionable without proper geological data and without the involvement of the main actors interested in the implementation of such a possible project, namely the Otopeni Municipality and the private company responsible for the management of the DH system. This is the reason why the topic of the geothermal DH system in Otopeni is the subject of a grant proposal.

## 5. CONCLUDING REMARKS

The analysis presented in this paper has a great original component due to its contribution of finding the optimum design of a geothermal system from the economic and environmental point of view.

The introduction of the geothermal DH/DC system would improve the quality of life and the urban environment conditions and bring increased energy security to the area. The project could be multiplied at national level – where the "boundary conditions" would be favorable – with beneficial political results through the increase of the national energy independence and security.

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