# INTEGRATION OF THE GEOTHERMAL RESOURCE INTO A LARGE DISTRICT HEATING SYSTEM

**by Marcel ROSCA**

## 1. INTRODUCTION

The City of Oradea, Romania, has a population of about 230,000 inhabitants. Almost 70% of the total heat demand, including industry, is supplied by a classical East European type district heating system. The heat is supplied by two low grade coal fired co-generation power plants. The oldest distribution networks and substations, as well as one power plant, are 35 years old and require renovation or even reconstruction. The geothermal reservoir located under the city supplies at present 2.2% of the total heat demand. By generalizing the reinjection, the production can be increased to supply about 8% of the total heat demand, without any significant reservoir pressure or temperature decline over 25 years. Another potential energy source is natural gas, a main transport pipeline running close to the city.

Two possible scenarios are envisaged to replace the low grade coal by natural gas and geothermal energy as heat sources for Oradea. In one scenario, the geothermal energy supplies the heat for tap water heating and the base load for space heating in a limited number of substations, with peak load being produced by natural gas fired boilers. In the other scenario, the geothermal energy is only used for tap water heating. In both scenarios, all substations are converted into heat plants, natural gas being the main energy source.

The technical, economic, and environmental assessment of the two proposed scenarios are compared with each other, as well as with the existing district heating system. Two other possible options, namely to renovate and convert the existing co-generation power plants to natural gas fired boilers or to gas turbines, are only briefly discussed, being considered unrealistic, at least for the short and medium term future.

## 2. CURRENT STATUS OF THE THERMAL ENERGY SUPPLY

The thermal energy used in 1997 in the City of Oradea for heating and industrial processes was about 3,000 $GWh_t$ ($2{,}58 \cdot 10^6$ Gcal) of which, by energy sources:

- CGPP: 2,040 $GWh_t$: 970 $GWh_t$ population, 150 $GWh_t$ tertiary sector, and 920 $GWh_t$ industry (of which 660 $GWh_t$ industrial steam), to which 150 $GWh_t$ are added as losses in the secondary network;
- wood + coal: 52 $GWh_t$ (for family houses), about 22,500 tons;
- heavy fuel: 290 $GWh_t$ (in industry, for own boilers), about 25,.000 tons;
- light fuels: 186 $GWh_t$ (118 $GWh_t$ population, 35 $GWh_t$ tertiary sector, 33 $GWh_t$ industry), total about 16.000 tons;
- electric energy: 230 $GWh_t$ (38 $GWh_t$ population, 92 $GWh_t$ tertiary sector, 100 $GWh_t$ industry);
- LPG: 113 $GWh_t$ (101 $GWh_t$ population and 12 $GWh_t$ tertiary sector);
- geothermal: 65 $GWh_t$ (30 $GWh_t$ population, 30 $GWh_t$ tertiary sector, and 5 $GWh_t$ industry).

As percentages, the CGPP provide 68.5% of the current thermal energy consumption of the city, followed by heavy fuel 9.7%, electric energy 7.7%, light fuels 6.3%, LPG 3.8%, geothermal 2.2%, and fire wood 1.7% (figure 1).

By user categories, the annual thermal energy consumption is distributed as follows: population 1,310 $GWh_t$ (44%), tertiary sector 320 $GWh_t$ (11%), and industry 1,350 $GWh_t$ (45%).

The thermal energy is supplied to the City of Oradea mainly by the two low grade coal fired co-generation power plants of the National Power Company (CONEL), Power plants Inc. branch.

CGPP I is located in the industrial area, West of the city. Its first group was set on line in 1965. The total installed capacity is 205 $MW_e$ and 310 $MW_t$, supplied by five generator groups, some with back-pressure and some with condensing turbines.

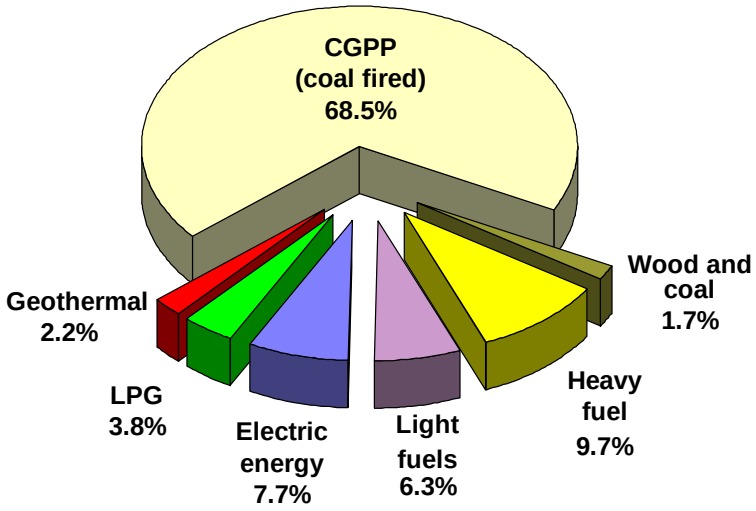


**Figure 1: Annual thermal energy consumption by primary energy sources in 1997**

CGPP II is located south-east of the city. Its first group was set on line in 1987. At present, it has three groups, all with back-pressure turbines, and the total installed capacity is 150 $MW_e$ and 170 $MW_t$.

In 1996, the two CGPP consumed 2.96 tons of lignite (with an average lower calorific value $H_i$=8,350 kJ/kg) and 33,500 tons of heavy fuel (of which 55% CGPP I), producing a total of 1.69 $TWh_e$ electric energy, of which 1.06 $TWh_e$ was delivered to the national grid (0.59 $TWh_e$ by CGPP I and 0.47 $TWh_e$ by CGPP II), the difference being the internal consumption. The total thermal energy delivered in 1996 was of 2.55 $TWh_t$ (see table 1), of which 1.04 $TWh_t$ as industrial steam for technologic processes, and 1.15 $MWh_t$ as hot water for heating (metered at the consumers). The fluid and heat losses in the primary network have been estimated by the **producer** as 0.23 $TWh_t$ (about 9%), but during the cold season only the fluid losses in the primary network reach up to 1,500 $m^3$/day.

The heating agent is delivered to the consumers through a primary network (owned by CONEL) which is 73.8 km long (of which 53.8 km in concrete lines) with diameters of 150÷800 mm, the metering being accomplished at the consumers' inlet. The network of CGPP (the only one operated before 1988), has three mains built in 1967÷1972, with a total length of 55 km. It has two junctions with the two mains of CGPP II built in 1988÷1989. Due to their age (which generates heat and fluid losses) the rehabilitation of the primary network is an imperative necessity, the cost of this operation being estimated at about 60 million USD.

**Table 1: Evolution of heat delivery from the two CGPP [in $GWh_t$]**

| | 1989 | 1991 | 1993 | 1996 | 1997 |
|---|---|---|---|---|---|
| Hot water: district heating | 854 | 1,031 | 1,175 | 1,300 | 1,340 |
| industrial | 475 | 324 | 273 | 215 | 250 |
| ***Total hot water*** | ***1,329*** | ***1,355*** | ***1,448*** | ***1,515*** | ***1,590*** |
| Industrial steam | 1,957 | 1,452 | 1,035 | 1,046 | 660 |
| **Total** | **3,286** | **2,807** | **2,483** | **2,561** | **2,250** |

At present, about 157,000 of the 228,000 inhabitants of the City of Oradea use hot tap water and space heating agent supplied by the district heating branch (APATERM) of the municipal services company.

The secondary network (about 550 km, of which 94% in concrete lines) owned by APATERM delivers the heating agent and sanitary hot water (s.h.w.) from heat substations to end users. The losses are estimated at about 18% in the primary network and about 12% in the secondary distribution network.

The whole production, transport and distribution infrastructure faces deficiencies in exploitation, due to moral worn out, high losses and lack of metering, caused by an acute lack of funds for maintenance and modernisation. The current status of the district heating in Oradea is depicted in table 2.

The secondary network of the Oradea City district heating system connects the 194 substations with the end users through local networks, supplied by circulation pumps existing in every substation. The cold water network is usually distinct, whether the heating agent pipes (supply and return) and the s.h.w. pipes are installed in concrete lines (about 94% of the total 545 km, the other 6% in the building basements).

The s.h.w. and heating agent pipes are 63% over 15 years old, 33% between 10 and 15 years, 3% between 5 and 10 years, and only 1% less than 5 years. Most secondary network is of steel pipe (zinc-plated for s.h.w.), with rock wool thermal insulation and tarred paper waterproof insulation. During the last 3÷4 years, about 15.4 km of heating agent and 4.5 km of s.h.w. pipes have been replaced by pre-insulated pipes (steel pipes with polyurethane foam thermal insulation and polyethylene or PVC outer coating.

The secondary network rehabilitation was limited by the modest amount of funds available up to present. Where the old secondary networks are replaced, they are usually set in new lines, so that each staircase in an apartment block has an individual connection, in order to facilitate metering at least at this level, for both space heating and s.h.w. According to the common design, all blockhouses have vertical supply pipes for cold and hot water in kitchens and bathrooms and 3÷4 double pipes (supply and return) for the space heating agent. Therefore, the water and heat metering at apartment level is rather improbable for the near future, the cost of the required meters being practically prohibitive at present.

**Table 2: General data on the Oradea district heating system (1997)**

- Total population ..... 228,500
- Total apartments and family houses ..... 80,000
- Total inhabitants supplied by the district heating system ..... 156,800
- Total apartments and family houses connected to the district heating system ..... 57,000
- Thermal energy delivered by CGPP's ..... 2,250,000 $MWh_t$
  - of which:
    - district heating ..... 1,190,000 $MWh_t$
    - industrial space heating ..... 260,000 $MWh_t$
    - industrial steam for technological processes ... 650,000 $MWh_t$
    - losses in the secondary network ..... 150,000 $MWh_t$
- Losses in the primary network ..... 350,000 $MWh_t$
- Total electric energy produced ..... 1,700,000 $MWh_e$
- Heat delivered to APATERM substations ..... 1,340,000 $MWh_t$
  - of which:
    - secondary network losses ..... 150,000 $MWh_t$
    - population ..... 970,000 $MWh_t$
    - companies and social cultural institutions ..... 220,000 $MWh_t$
- Geothermal energy annual supply is 65,000 $MWh_t$, of which 21,000 $MWh_t$ as s.h.w. (distributed through APATERM substations) and 44000 $MWh_t$ for space heating, s.h.w. and process heat (through local networks).
- Annual consumption of a standard apartment is 17 $MWh_t$, of which 10.5 $MWh_t$ for space heating, and 655 $MWh_t$ for s.h.w.
- Substations operated by APATERM ..... 194
  of which:
    - 105 with a thermal capacity of ..... 1.2÷3 $MW_t$
    - 36 with a thermal capacity of ..... 3÷4.5 $MW_t$
    - 53 with a thermal capacity of ..... 4.5÷10 $MW_t$
- 103 substations have pumping stations (with pressure vessels) to supply cold and hot water to the upper stories of the blockhouses.
- The installed electric capacity in substations is of 2,400 kW, and in pumping stations is of 3,600 kW
- All secondary network are in concrete lines, having a total length of 545 km, operation time has expired for 80% of the pipes, so that these require often repairing.

Due to their age, and mainly due to an inadequate waterproof insulation of the rock wool thermal insulation, outside corrosion of the secondary network steel pipes is almost general, as well as the inside corrosion caused by the oxygen dissolved in the water. In 1997, more than 2,000 repairing jobs were needed to stop leakage in the secondary network (10/day in average during the cold season!).

The rehabilitation of the secondary networks more than 15 years old (about 340 km) will take quite a few years, as the jobs will only be funded from the income of the APATERM company. For the development costs considered in this study, the rehabilitation of 65 km of old secondary networks at the operability limit was estimated at a total value of 8 million USD, meaning a unit cost of about 120 USD per meter of new network.

Other energy carriers are also present in the thermal energy balance of the City of Oradea, as follows (see also table 3):

- **Liquefied petroleum gas (LPG)**: 60.000 steel bottles (of 12.5 kg) per month average consumption, which means 9,000 t/yr., representing 113,000 $MWh_t$/yr.
- **Light liquid fuel (LLF):** total consumption 16,000 t/yr. (186,000 $MWh_t$), of which about 188,000 $MWh_t$ for population, 33,000 $MWh_t$ for industry, and 35,000 $MWh_t$ for the tertiary sector.
- **Wood and coal** for stove heating in districts not connected to the heating system: annual average consumption 22,500 t, representing 52,000 $MWh_t$.
- **Heavy fuel** used in industry for heating and industrial processes: annual consumption about 25,000 t (290,000 $MWh_t$).
- **Electric energy** used for heating and industrial processes: annual consumption estimated at about 55,000 $MWh_e$ for population and at about 130,000 $MWh_e$ for industry and tertiary sector, representing a total thermal energy contribution of about 230,000 $MWh_t$/yr.

Out of a total of almost 2,980 $GWh_t$/yr., the population used 44%, the tertiary sector 11% and the industry 45%.

**Table 3: Thermal energy consumption ($GWh_t$/yr.) by sectors and by primary energy sources in 1997**

| SECTOR / utilisation / SOURCE | DOMESTIC | | TERTIARY | | INDUSTRIAL | | TOTAL |
|---|---|---|---|---|---|---|---|
| | heating[2] + s.h.w.[3] | kitchens | heating[2] + s.h.w.[3] | kitchens | heating[2] + s.h.w.[3] | steam[4] heat[5] | |
| District heating[1] | 970 | | 150 | | 260 | 660 | 2,040 |
| Coal / Wood | 50 | 2 | | | | | 52 |
| Heavy fuel | | | | | | 290 | 290 |
| Light liquid fuel | 118 | | 15 | 20 | 33 | | 186 |
| Electric energy | 33 | 5 | 77 | 15 | | 100 | 230 |
| Liquefied petroleum gas | 5 | 96 | | 12 | | | 113 |
| Geothermal | 30 | | 30 | | | 5 | 65 |
| **TOTAL** | **1,206** | **103** | **272** | **47** | **293** | **1,055** | **2,976** |

[1] Coal fired CGPP
[2] space heating
[3] sanitary hot water
[4] industrial steam
[5] thermal energy for industrial processes

The annual thermal energy demand of the City of Oradea was estimated to be in 2005 of about 3,200 $GWh_t$ (11.5 PJ, that is 2,750,000 Gcal), of which:

- 1,400 $GWh_t$ population: 970 $GWh_t$ by the existing district heating system, 300 $GWh_t$ family houses, 130 $GWh_t$ new housing developments in satellite areas;
- 480 $GWh_t$ tertiary sector: 320 $GWh_t$ at present, 160 $GWh_t$ developments;
- 1,250 $GWh_t$ industry: 260 $GWh_t$ space heating, 500 $GWh_t$ industrial steam, 290 $GWh_t$ heavy fuel, 160 $GWh_t$ electric energy for heating, 40 $GWh_t$ LLF;
- 65 $GWh_t$ geothermal energy.

The estimation of the future heat demand was based on current consumption, forecast of the industrial consumers development, and forecast of the demand of new housing developments on the surrounding area.

## 3. ALTERNATIVE ENERGY SOURCES FOR THE CITY OF ORADEA

### *3.1 Natural Gas*

Natural gas is at present, and is estimated to remain in the medium term future, the least expensive energy source in Romania (Cohut, Antics and Rosca, 1998). Natural gas can supply the medium and log term thermal energy demand of the city and surrounding are, subject to the foundation of an entity able to provide financial backing for the development and operation of the distribution network.

The investment for the construction of a natural gas distribution network in the City of Oradea has been approved by the Government Decision (HG no. 746/1997). The distribution network will be connected to the main gas pipeline Satu-Mare - Arad (running about 6 km west of the city). For the technical and economic assessment of the project, the Municipality of the City of Oradea contracted a Feasibility study for an installed flow rate of 110,000 $Nm^3/h$, able to deliver an annual volume of natural gas of about $350 \cdot 10^6$ $Nm^3$).

The natural gas will mainly be used for:

- cooking;
- space and tap water heating in 23,600 buildings not connected to the district heating system (mainly family house with 1÷2 families);
- the existing district heating system by installing gas fired boilers in the substations or individual for large buildings. The boilers will provide the thermal energy for both space and tap water heating, or for space heating only in the substations where the s.h.w. will be heated with geothermal energy;
- industrial companies, for space and tap water heating, as well as for process heat.;
- district heating systems to be developed in satellite communities (Felix - 1 Mai Spas, Episcopia, Sanmartin);
- future housing and industrial developments in the City of Oradea.

Three possible scenarios have been considered for the natural gas utilisation in the City of Oradea, namely:

- **minimal:** the natural gas distribution network on the left bank of the Crisul Repede river, limited to areas not connected to the district heating system (300 $GWh_t/yr.$) and to certain industrial consumers currently using light fuel and electric energy (about 450 $GWh_t/yr.$), with an average consumption of $80 \cdot 10^6$ $Nm^3/yr.$, and a capital investment of almost 22 million USD;
- **medium:** an extension of the minimal scenario by 200 $GWh_t/yr.$ for space heating in 45 substations from 5 areas in which the geothermal energy will provide s.h.w., and by 500 $GWh_t/yr.$ for industrial users currently supplied by the CGPP, totalling an average consumption of 1,450 $GWh_t/yr.$, of which $150 \cdot 10^6$ $Nm^3/yr.$ natural gas, at an capital investment of $48 \cdot 10^6$ USD;
- **maximal:** supplying almost 98% total thermal energy demand in 2005, which was estimated at 2,850 $GWh_t/yr.$, representing $300 \cdot 10^6$ $Nm^3/yr.$ natural gas consumption, at a capital investment of $75 \cdot 10^6$ USD.

### *3.2 Geothermal Energy*

The second cheapest energy source in the City of Oradea is the geothermal energy (Cohut, Antics and Rosca, 1998). Between 1970 and 1980, 12 geothermal wells have been drilled inside the City of Oradea *"intra muros"*. The depth of these wells range between 2,500 and 3,400 m, with wellhead temperatures of 70÷105°C, and artesian flow rates of 5÷35 l/s. All wells are currently under commercial exploitation for direct uses: space heating, s.h.w., greenhouse heating, timber drying, milk pasteurisation, bathing, etc., the geothermal energy being delivered through local networks in the neighbouring area. Due to artesian discharge and limited reinjection of the heat depleted geothermal fluid, the annual geothermal energy consumption is only 65 $GWh_t$, far below the reservoir potential.

The Oradea aquifer is located in Triassic limestone and dolomites, at 2,200÷3,400 m depths, on an area of about 113 km$^2$, and is exploited by 12 wells, with a total artesian flow rate of 140 l/s and well head temperatures of 70÷105°C. The water is of calcium-sulfate-bicarbonate type, with no scaling or corrosion potential. There are no dissolved gases, and the TDS is lower than 0.9÷1.2 g/l. The reservoir is bounded by faults. There are also internal faults in the reservoir, dividing it into four blocks which do not cause discontinuities in the circulation of the water in the reservoir. The main circulation is from the north-east, along preferential pathways represented by the fault system at the boundary (Figure 2).

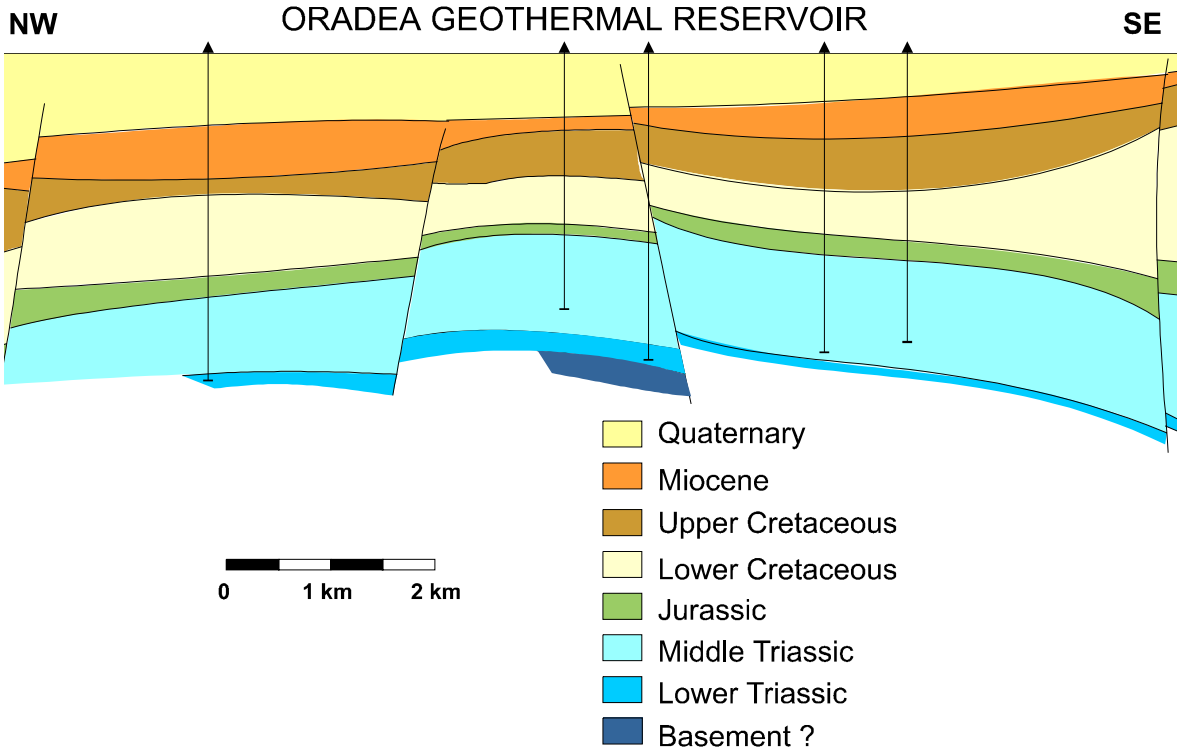


**Figure 2: Cross section through the Oradea reservoir**

The main target of the geothermal development program is the development of the existing production (wells) and distribution (district heating system, substations) infrastructure, by: (i) artificial production from the geothermal wells using deep well pumps; (ii) the conversion of the low productivity wells into injection wells, to maintain the reservoir pressure and dispose of the heat depleted fluid; (iii) connection of the 5 re-equipped geothermal doublets with the district heating system, to provide s.h.w. for up to one third of the Oradea City population.

The proposed system will provide a fourfold increase of the geothermal energy production, from 65 GWh$_t$/yr. to 250 GWh$_t$/yr., of which 205 GWh$_t$/yr. for s.h.w. only, securing therefore a constant delivery around the year, by 45 substations supplying about 80,000 people.

As showed by the numerical simulation of the Oradea geothermal reservoir, the injection of the heat depleted geothermal fluid in the tapped aquifer will prevent the reservoir pressure decline, with no significant thermal brake-through over 30 years of production.

The capital investment cost for the geothermal development has been estimated at about 9 million USD. The discounted cash flow analysis of the project shows attractive indices: discounted pay-back time 6.8 years and internal rate of return 20%, at a discounted unit price of 12.5 USD/MWh$_t$.

## 4. PROPOSED OPTIONS FOR SUSTAINABLE DEVELOPMENT OF THE THERMAL ENERGY SUPPLY FOR THE CITY OF ORADEA

The total thermal energy demand of the City of Oradea in 2005 was estimated at almost 3,200 GWh$_t$, with a slight decrease of the industrial heat demand, and an increase in the other sectors, resulting in the following distribution by sectors: population 45%, tertiary sector 15%, and industry 40%.

At present, the State subsidies for the population the energy from certain sources, as electric energy and heat from CGPP, and natural gas. In October 1998, the least expensive thermal energy sources were, in this order: natural gas (5.3/7.9 USD/$MWh_t$ - with/without subsidies), geothermal (6.7 USD/$MWh_t$), and the subsidised thermal energy from CGPP (8.4 USD/$MWh_t$); and the most expensive: LPG gas (26.7 USD/$MWh_t$), light liquid fuels (20 USD/$MWh_t$), and heavy fuel (18.8 USD/$MWh_t$). The unsubsidised price of the thermal energy delivered by CGPP to legal persons is 16.25 USD/$MWh_t$ all over Romania.

Nevertheless, according to the agreements of the Romanian Government with the World Bank (WB) and International Monetary Fund (IMF), the subsidies have to be eliminated by the end of year 2000. In this case, the least expensive energy sources will be: natural gas (8.6 USD/$MWh_t$) and geothermal (12 USD/$MWh_t$); and the most expensive are: liquefied petroleum gas (38 USD/$MWh_t$), light liquid fuel (25.8 USD/$MWh_t$), and heavy fuel (23.6 USD/$MWh_t$), the thermal energy from CGPP reaching a minimum of .17.2 USD/$MWh_t$.

**The uncertainties concerning the future of the two CGPP from Oradea** (generated by the condition of their equipment, the decrease of the electric energy demand, the difficulties in lignite and heavy fuel supply, the major difficulties in fulfilling the environment protection legal requirements, and mainly by the lack of financial resources for re-technologisation and modernisation), **demand the consideration of alternative options** for the medium and long term heat supply for the City of Oradea. The modernisation and re-technologisation of the CGPP, as well as the rehabilitation of the primary heating agent networks, will only be taken into consideration by CONEL if they will prove profitable, and if CONEL will find the needed financial resources. At present, as well as for the next 5÷10 years, these conditions have a high level of uncertainty, and therefore maximum responsibility is required for the analysis of the energy strategy of the City of Oradea.

The Municipality may decide to keep the district heating system, to modernise and expand it to the not connected areas, by developing a natural gas distribution network which, together with the geothermal resource, could gradually take over from the CGPP the heat supply for the city (including the industry) and for the surrounding communities (Episcopia, Sanmartin, Baile Felix - 1 Mai).

The analysis of the future possibilities to supply the necessary thermal energy to the City of Oradea was based on the following conditions:

- the Government approved the **natural gas** supply to the city, subject to urgent start of the activities related to this project;
- **the geothermal resources** can provide at least 8% of the total demand, or about 19% of the population demand for at least 30 years, at a competitive price, while also improving the environment protection;
- **CONEL** can not guaranty the medium and long term delivery of co-generated heat at an acceptable price, mainly when having to fulfil the legal regulations regarding environment protection;
- **district heating** is the most efficient method, both technical and economic, to provide space heating and sanitary hot water in urban communities;
- **the least expensive and least polluting** energy sources are natural gas and geothermal fluids.

The following options have been proposed and analysed to offer the Municipality a background for making major decisions regarding the sustainable development of thermal energy supply to the City of Oradea.

**Option 1 - Perpetuation of *"Status quo ante"***

This option has the **advantage** of relatively low costs for the re-technologisation of the substations and for the partial rehabilitation of the secondary network owned by APATERM, but has many **disadvantages**:

- low probability to find financing for the works required by CGPP (about 100 million USD), regardless of the final outcome of the restructuring of CONEL;
- long time for APATERM to finalise the necessary works;
- not solving the problems of heat supply to the areas not connected to the district heating system;

- not providing a reliable and inexpensive energy source to industry and therefore reducing its attractively for potential investors;
- not using the least expensive and least polluting energy sources: gas and geothermal;
- the heat selling price to the end users will continue to be a monopoly price and will continue to increase to provide funds for the rehabilitation and modernisation works of both the producer and the distributor.

**Option 2 - Keeping the current heating system, with the conversion of the CGPP to use natural gas**

As natural gas will continue to be (at least for the midterm future) the least expensive fossil fuel, the conversion of the CGPP to gas may be still considered, the co-generation having the highest technical efficiency for fossil fuel fired **power** generation. As compared to option 1, this option requires higher investments for the CGPP conversion, namely about 250 million USD to convert the boilers to natural gas instead of lignite, or about 700 million USD to fully replace the technology and use gas turbines, or combined gas-steam systems. The institutional and organisational structure capable of such an investment is to be decided in the future, according to expected modifications of the legal prescriptions.

The **advantage** of this option would be the **possibility** that the operator of the gas fired CGPP could reduce the thermal energy unit price. The major **disadvantage** of this option is the difficulty to create a financially viable entity in the legal conditions currently prevailing in Romania, and also considering the very high investment and an uncertain market for the main product - electric energy (a thermal power plant would ever compete with a nuclear power plant).

**Option 3 - Mainly CGPP, partially natural gas**

Relative to options 1 and 2, a natural gas distribution network will be built on the left bank of the Crisul Repede river, in the city areas not connected to the district heating system, from which certain industrial users will also be supplied (the minimal scenario for the natural gas distribution network). As compared to options 1 and 2, this option has the **advantage** of starting the use of the least expensive energy source (natural gas) to supply about 23% of the total thermal energy demand of the population, and therefore solving the heat supply problem for the city areas not connected to the district heating system.

Besides the **disadvantages** that remain from options 1 and 2, it should be mentioned that, also the capital investment for the gas distribution network is relatively low (22 million USD), the unit investment is rather high (29.6 USD/$MWh_t$) due to low gas sales. Under these circumstances, the investment is not economically viable (the net present value is negative), being obviously unattractive for any investor. In this case, the Municipality will have to make the whole investment, with the result of increasing the selling price of natural gas and heat.

**Option 4 - Partially CGPP, partially natural gas and geothermal energy**

This option considers the development of the geothermal energy utilisation to supply s.h.w. in 45 substations located in 5 city areas (supplying about 19% of the total heat demand of the population). Natural gas will supply thermal energy for space heating in the 5 areas where geothermal energy provides s.h.w., and will also take over the entire heat demand of the industrial users(the medium scenario for the natural gas distribution network). The other substations will continue to be supplied by the CGPP, as in options 1, 2, and 3.

The main **advantages** of this option (compared to option 3) are:

- increased use of the least expensive and polluting energy sources (52% of total);
- the possibility to built the system in stages, without badly affecting the CGPP;
- the development of a free competition energy market;
- provides a reliable and inexpensive energy source for the industrial users, most of them already disconnected from CGPP or intending to do so.

The main **disadvantages** of this option are:

- higher investment cost (48 million USD), but a lower unit investment cost (28.2 as compared to 29.6 USD/$MWh_t$), and a better economic efficiency (net present value 4.9 million USD, internal rate of return 16%, and discounted pay-back time 8.8 yr.), more attractive for potential investors;

- continued dependence on the CGPP for 48% of the total thermal energy demand, exclusively for the population and the tertiary sector, with the respective level of uncertainty (as regarding the future evolution of the CGPP and their possibility to offer unit prices fair for both the producer and the users).

**Option 5 - Natural gas and geothermal energy only**

About 98% of the thermal energy demand of the Oradea City and of the surrounding communities (Felix - 1 Mai Spas, Episcopia, and Sanmartin), can be supplied by natural gas (the maximal scenario) and geothermal energy. The substations will be converted into local heat plants, the secondary network will be rehabilitated, the metering will be generalised, and the geothermal energy utilisation will be developed up to the reservoir potential in 5 doublets.

**Advantages:**

- allows the enforcement of energy efficiency increase methods;
- generalises the use of the least expensive and least polluting energy sources;
- provides a safe, reliable and high quality service by the construction of the natural gas distribution network in the entire city and surrounding communities;
- provides the possibility to purchase natural gas either from the domestic or international market, at the lowest possible price, based on long term contracts;
- the availability of a reliable and inexpensive energy source will be a major advantage in attracting investors able to revive the industrial potential of the Oradea City;
- best economic efficiency of all options (net present value 12.9 million USD, internal rate of return 19%, and discounted pay-back time 6.9 years), for the highest capital investment 875 million USD), but the lowest unit investment (23.6 USD/$MWh_t$).

**Disadvantage:**

- the Municipality will face difficulties in financing the investment;
- the social impact of the two CGPP activity reduction.

To **insure the sustainable development of the thermal energy supply** of the City of Oradea and to **increase** both the **heating services quality** and the **environment protection** it is necessary to **establish an institutional structure** capable to provide the technical and financial management of the heat and natural gas production and distribution. The first and most difficult task of this new structure will be to find financing for the development projects, by association with private investors, association with a strategic investor, public subscription, or from the capital market (domestic or international).

The basic criteria for a sustainable development of the thermal energy supply for the City of Oradea should be: services quality, technical efficiency, responsibility for the environment; economic viability; financial autonomy; and social acceptability.

The corollary of the entire energy related activity should be the increase of the energy efficiency (by energy savings and better management) in all sectors: production, transportation, distribution, and utilisation. In a modern society, **energy saving** is the cheapest, safest, cleanest, and easiest available energy resource.

## 5. THE SELECTED OPTION FOR HEAT SUPPLY FOR THE CITY OF ORADEA

In accordance with the envisaged energy strategy, the Municipality of Oradea City organized a tender for the association with a reliable commercial company experienced and able to invest in the development and operation of the natural gas distribution network, to develop and operate the district heating system, and to develop the utilization of the geothermal resource. The Municipality of Oradea will create a company which will make the investment and will own the gas and heat distribution systems (hereafter named the Investing Company). The major investor or consortium, together with the District Heating Section of Municipal Water and Heat Company (APATERM) and minor private share holders, will create a company which will operate and maintain the gas and heat distribution systems (hereafter named the Operating Company). Also, the Municipality of Oradea will be awarded, by the National Agency for Mineral Resources, according to the provisions of the new Mining Law, the License of Exploitation for the Oradea geothermal reservoir. This way, the operation cost for the geothermal production will only comprise the cost of the electric energy used by pumps and the royalties for the extracted fluid.

The total annual thermal energy demand estimated for 2005 at about 3,055 $GWh_t$ will be supplied, in the envisaged strategy, from the following energy sources:

- **natural gas 2,723 $GWh_t$ (89,1%)**, which will replace 854,758 t lignite and 9,884 t heavy fuel in the two CGPP, 12,850 t fire wood and coal, 26,730 t heavy fuel in industrial heat plants, 15,907 t light liquid fuel, and 3,109,000 $Nm^3$ LPG;
- **geothermal energy 250 $GWh_t$ (8,2%)**, which will replace 75,186 t lignite and 870 t heavy fuel in the two CGPP;
- **other sources (2.7% in total)**, namely firewood, coal, liquid fuels, LPG, electricity.

The total capital investment for the Investing Co. was estimated at about 160 million EURO, of which about 86.7 million (54%) is expected as ISPA grant, 30% loan from the EBRD (with local guaranty), and the rest (16%) loan from the EIB (with Governmental guaranty). The total capital investment for the Operating Co. was estimated at about 6.8 million EURO, of which 50% equity and 50% commercial bank loan. The project life time for the economic assessment was set at 18 years, the time to pay back the loans, including a 3 years grace period. A discount rate of 8% was considered acceptable for both companies, and equal to the expected interest rate on the bank loan for the debt capital investment. The thermal energy selling price was calculated at 18.25 EURO/$MWh_t$, which includes all running costs, loan pay-back, and a profit margin for both companies. However, the heat consumption per user is supposed to decrease due to lower losses in the distribution system and reliable regulation at the end user.

Under the above mentioned conditions, the Net Present Value (NPV) of the entire project will be of about 26 million EURO for the Investing Co. and about 2.8 million EURO for the Operating Co., and the Internal Rate of Return (IRR) of 14.66% and 28.42% for the two companies respectively.

The replacement of heat produced from other fuels, and mainly by the two CGPP, by natural gas and geothermal energy will have a significant positive impact on the environment in the Oradea area, as it is obvious from the figures in Table 4, which presents the quantities of the main air polluters which would be emitted by the replaced fuels, by the natural gas in the proposed scheme (geothermal water does not emit any air polluters), and the difference between the two cases, therefore the “pollution savings”.

**Table 4: Annual Pollutant Emissions with and without the Analysed Project (in t/yr.)**

| | CGPP | wood +coal | Heavy fuel oil | Light fuel oil | GPL | Total | Natural gas | **Difference** |
|---|---|---|---|---|---|---|---|---|
| CO | 43,911 | 14 | 121 | 17 | 3 | 44,066 | 88 | **43,978** |
| $CO_2$ | 660,400 | 9,426 | 82,304 | 49,210 | 18,928 | 820,268 | 518,800 | **301,468** |
| $SO_2$ | 29,714 | 23 | 1,764 | 636 | - | 32,137 | 69 | **32,068** |
| $NO_x$ | 1,351 | 58 | 130 | 29 | 14 | 1,582 | 164 | **1,418** |
| particles | 2,493 | 18 | 29 | 18 | 3 | 2,561 | 83 | **2,478** |
| ash | 189.022 | 175 | 104 | 14 | - | 189.315 | - | **189.315** |

In much smaller quantities, the flue gases also contain toxic vapours (HCl, $NH_3$, $N_2H_4$, etc.) and aerosols (NaOH, $Ca(OH)_2$, NaCl, etc.) which are not quantified in Table 4. Other pollution sources, mainly at the two CGPP, will also be reduced, such as ash and slag dumps, coal dust from the coal storage yards, accidental spills of hydrocarbons, infested water, chemicals, etc.

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