# Thermal Energy Supply Strategy for the City of Oradea, Romania

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*Abstract:* - The City of Oradea has a population of about 230,000 inhabitants. At present, the main thermal energy supplier is a low grade coal fired co-generation power plant. A natural gas distribution network is also developing slowly. The city is fortunate to have a renewable energy source available, being located on a very good geothermal reservoir. The paper presents the situation of thermal energy supply about 10 years ago, the results of an energy strategy developed in the late '90s, the current situation, and the plans for near future.

*Key-words:* - Thermal energy strategy, District heating, Co-generation, Natural gas, Geothermal energy

## 1 Introduction

The City of Oradea is located in the western part of Romania, and 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 a low grade coal fired co-generation power plant. The oldest distribution networks and substations, as well as the power plant, are about 35 years old, needing renovation or even reconstruction.

An important renewable energy source is the geothermal reservoir located under the city, which is still not exploited at its maximum capacity. Another energy source, not used in Oradea before 2000, is natural gas, as a main transport pipeline is running close to the city.

Some possible scenarios have been envisaged in the late '90s to replace the low grade coal by natural gas and geothermal energy as alternative energy sources for Oradea. The proposed scenarios are compared with each other, as well as with the existing district heating system.

The strategy adopted by the Local Council to supply thermal energy to the City of Oradea changed a few times in the last 7 years, based on many arguments, not only economic or technical, but also social and political.

## 2 Initial 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). 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%.

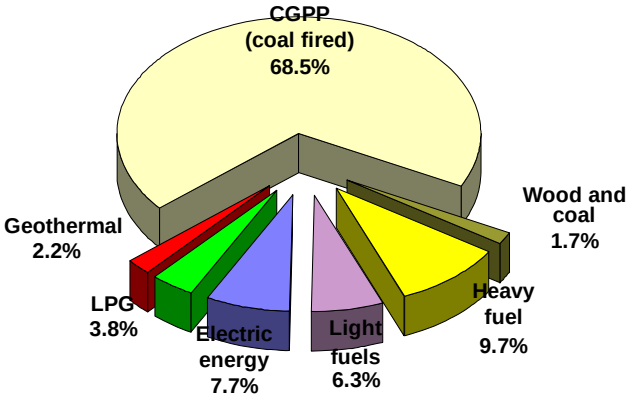


Fig. 1: Annual thermal energy consumption by primary energy sources in 1997

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 was supplied to the City of Oradea mainly by two low grade coal fired co-generation power plants (CGPP), belonging at that time to the National Power Company (CONEL).

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

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

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after two severe failures in the mid '90s, it is closed. After some unsuccessful attempts to sell it, it was decommissioned in 2005.

In 1997, 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 grid (0.59 $TWh_e$ by CGPP I and 0.47 $TWh_e$ by CGPP II), the difference being the own consumption. The total thermal energy delivered in 1997 was of 2.55 $TWh_t$, of which 1.04 $TWh_t$ as industrial steam, and 1.15 $MWh_t$ as hot water for heating (metered at the consumers). The heating agent is delivered to the substations through a 73.8 km long primary network, with diameters of 150÷800 mm. The consumption is metered at the consumers. The network of CGPP I 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.

The CGPP's were designed and built during a period when no importance at all was given to the identification, quantification, and reduction of the impacts produced on the environment by human activities. Therefore, in order to comply with the provisions of the Law on Environment Protection, the CGPPs probably need complete reconstruction, or at least very expensive retrofitting.

About 160,000 of the 230,000 inhabitants of the City of Oradea are connected to the district heating system which in 1997, was a branch of the municipal services company (APATERM).

The secondary network (about 545 km, of which 94% in concrete ducts, the other 6% in the building basements) owned by APATERM delivers the heating agent and sanitary hot water (s.h.w.) from 194 substations to end users.

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, with rock wool thermal insulation and tarred paper waterproof insulation. During the last 6÷7 years, about 15.4 km of heating agent and 4.5 km of s.h.w. pipes have been replaced by pre-insulated pipes.

The losses were estimated by APATERM at about 18% in the primary network and about 12% in the secondary distribution network.

Due to their age, and mainly due to an inadequate water insulation of the rock wool thermal insulation, outside corrosion of the secondary network steel pipes is almost general, and the inside corrosion caused by the dissolved oxygen (although all substations were designed with a chemical facility to remove oxygen, none has ever been built).

# 3 Alternative Energy Sources for the City of Oradea

## 3.1 Natural Gas

Natural gas was, in 1997, the least expensive energy source in Romania, and it was estimated at that time to remain so in the medium term future [2]. Natural gas could 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 Oradea was approved by the Government Decision. The distribution network could be supplied by the main gas pipeline running about 6 km west of the city. For the technical and economic assessment of the project, the Municipality of the Oradea City contracted, in 1998, 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 $350 \cdot 10^6$ $Nm^3$.

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

- **minimal:** the natural gas distribution network limited to areas not connected to the district heating system (300 $GWh_t$/yr.) and to certain industrial consumers 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:** extension of the minimal scenario by 200 $GWh_t$/yr. for space heating in 5 areas, 45 substations in which the geothermal energy would provide s.h.w., and by 500 $GWh_t$/yr. for industrial users supplied by the CGPP, totalling an average 1,450 $GWh_t$/yr., of which $150 \cdot 10^6$ $Nm^3$/yr. natural gas, with a capital investment of 48· million USD;
- **maximal:** supplying almost 98% of the 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· million USD.

## 3.2 Geothermal Energy

In 1998, the second cheapest energy source in the City of Oradea was the geothermal energy [2].

The geothermal reservoir comprises two specific aquifers, hydro-dynamically connected, the Triassic aquifer Oradea and the Cretaceous aquifer Felix Spa. The natural recharge rate was calculated at 300 l/s based on the only interference test by now, carried out in 1979 [5]. The hydro-geological [3], hydro-

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chemical [7], and geothermal [8] research proved that the reservoir is recharged via a deep pathway along an important structural line (oriented NE-SW), excluding the lateral recharge.

Out of the 9 geothermal wells drilled in Felix Spa, 50÷ 450 m deep, only 6 are currently in use. The oldest two wells in Romania were drilled in Felix Spa, the first in 1885 (which can still produce up to almost 200 l/s), and the second in 1887 (now closed). All wells are self flowing (artesian). The geothermal water has well head temperatures of 36÷48°C, and is used only for recreational and health bathing (Rosca & Farcas, 2001). Therefore, the geothermal water supply for Felix Spa is considered a priority. The total exploitable flow rate in Felix Spa was set by the National Agency for Mineral Resources (NAMR) to 210 l/s annual average, in order to prevent the reservoir pressure decline and to protect the natural reservation of *Nymphaea Lotus Thermalis*, a Tertiary remnant which grows naturally in geothermal ponds, a quite uncommon occurrence at this latitude (about 45ºN), and a tourist attraction.

The remaining 90 l/s annual average flow rate can be produced from the Oradea reservoir. A higher exploitation will only be approved by NAMR if at least the additional extracted flow rate is reinjected.

The Oradea aquifer is located in limestone and dolomites of Triassic age, 2,200÷3,400 m deep, on an area of about 113 km$^2$. 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. The main circulation is from north-east of the reservoir, along preferential pathways due to the boundary fault system (Fig. 2).

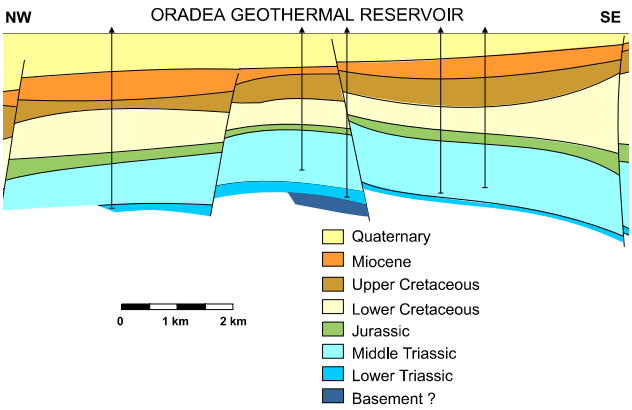


Fig. 2: Cross section through the Oradea reservoir

Between 1970 and 1980, 12 geothermal wells were drilled in the Oradea *"intra muros"*. The depth of these wells range between 2,500 and 3,400 m, with well head temperatures of 70÷105°C, and artesian flow rates of 5÷35 l/s. In 1997, all wells were in exploitation for direct uses: district heating, greenhouse heating, milk pasteurization, timber drying, bathing, etc. In the last 10 years, many of these operations stopped (greenhouse heating, timber drying, milk pasteurization), as companies closed.

The total installed capacity (with the drilled wells) is over 30 MW$_t$. Due to the artesian discharge and limited reinjection of the heat depleted geothermal fluid, in 1998 the annual geothermal energy utilization was only 65 GWh$_t$, far below the reservoir potential.

As showed by the numerical simulation of the Oradea geothermal reservoir [1], the reinjection of the heat depleted geothermal fluid in the aquifer will prevent the reservoir pressure decline, with no significant thermal brake-through over 30 years of production. The reinjection of a high percentage of the produced geothermal water, and a well designed utilisation scheme, could provide a fourfold increase of the production, from 65 GWh$_t$/yr. to 250 GWh$_t$/yr.

## 4 Thermal Energy Supply Strategy for the City of Oradea

In 1997, the State still subsidised certain types of energy for population, such as electric energy, heat from CGPPs, and natural gas. At that time, the least expensive thermal energy sources were, in this order: natural gas (5.3/7.9 USD/MWh$_t$ - with/without subsidies), subsidised thermal energy from CGPP (8.4 USD/MWh$_t$), and geothermal (6.7 USD/MWh$_t$). 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 was 16.25 USD/MWh$_t$ all over Romania. The USD was then about equal to euro.

The uncertainties concerning the future of the two CGPP from Oradea, caused by their old equipment, the decrease of the electric energy demand, the difficulties in lignite supply, the major difficulties in fulfilling the environment protection requirements, and mainly by the lack of financial resources for modernisation, demanded the consideration of other options for the medium and long term heat supply for the City of Oradea.

The Municipality could decide to keep the district heating system, to modernise and expand it to the not connected areas. Alternatively, the development of a natural gas distribution network, together with the development of the geothermal resource utilisation, could gradually take over from the CGPP the heat supply for the city (including the industry) and for the surrounding communities.

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The Energy Strategy study carried out in the late 90's proposed and analysed 5 options to offer the Municipality a background for making major decisions on the sustainable development of thermal energy supply to the City of Oradea. These options ranged from the perpetuation of *"Status quo ante"* to natural gas and geothermal as the main heat sources for the City of Oradea.

# 5 The Selected Option for Heat Supply for the City of Oradea

In accordance to the envisaged energy strategy, in 1999 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. Only two bidders submitted full proposals, with all required documents included, and the tender was won by a Consortium, with the proposed project described below.

The Municipality of Oradea City will create a company which will make the investment and will own the natural gas and heat distribution systems (hereafter named the Investing Company). The Consortium, together with the District Heating Section of 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).

The annual thermal energy demand, estimated again for 2005 at about 3 $TWh_t$ would have been supplied, 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)**: firewood, coal, liquid fuels, LPG, electricity.

The total capital investment for the Investing Co. was estimated at about 160 million euro. The total capital investment for the Operating Co. was estimated at about 6.8 million euro, of which 50% equity and 50% bank loan. The project life time for the economic assessment was set at 18 years, as the time to pay back the loans, including a 3 years grace period (estimated time to complete the project, including the design and tendering).

A discount rate of 8% was considered acceptable for both companies, and equal to the expected interest rate for the debt capital investment. The heat selling price to all consumers was calculated at 18.25 euro/$MWh_t$, which includes all running costs, loan pay-back, and a profit margin for both companies, with no subsidies. However, the heat consumption per user is supposed to decrease due to lower losses in the distribution system, as well as reliable metering and 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.

Table 1: Annual Pollutant Emissions with and without the Analysed Project (in t/yr.)

| | CGPP | wood +coal | Heavy fuel | Light fuel | 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** |

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 1, 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". 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 1. Other

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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.

At first, the Consortium was not interested at all in using any geothermal energy, in order to maximise the gas sales. Two key factors influenced the economic and financial feasibility of the project in a way that made geothermal energy very attractive, namely:

- as 12 wells were already drilled, the capital investment in geothermal development was relatively low;
- the geothermal energy source included in the project made more than 50% of the capital investment eligible for grant financing through the ISPA program.

## 6 The Actual Development since 2000

In 2000, TRANSGEX was privatised, closed or soled most other activities, and remained active in drilling, and mainly in exploration and exploitation of geothermal reservoirs. Since then, it developed continuously, operating now a number of geothermal systems in Oradea and the Bihor county, and planning faster development in the future.

In 2004, TRANSGEX formed an Association in Participations (similar to a joint venture company) with the Municipality of Oradea, in order to provide thermal energy to some substations. In 2005, the company delivered 86,000 $MWh_t$ in 11 geothermal operations in Oradea. In most cases, a heat plant supplies primary heating agent to the substations. The geothermal energy covers the heat load for s.h.w. all year round, and the base load for space heating. The peak loads are covered by natural gas fired boilers (not used during the last 3 winters).

The plan for later this year or early next year is to install a first power generation demonstration unit in the Iosia district of Oradea, in the vicinity of the most powerful geothermal well in Romania, delivering up to 60 l/s water with 105°C well head temperature. The power plant will work on the Rankine cycle, with the rated capacity of 200 $kW_e$.

In the fall of 2000, there were local and later on central elections in Romania. The Mayor and the Local Council of the City of Oradea changed, and the project proposed by the Consortium (although it won a tender organised by the Municipality) was no longer agreed and had to stop just before signing the contract. In 2001, the Municipality signed an agreement with a Romanian private company for natural gas distribution in Oradea. The company started to build the distribution network in 2004, first in the industrial area west of Oradea and in the residential area with family houses southwest of Oradea, where there is no district heating network. It continues to expand the distribution network in the southern part of Oradea, for some new housing developments. Although it is still less expensive than LPG, the selling price of natural gas is continuously growing. The import price from Russia increased from about 150 to 300 USD/1,000 $Nm^3$, and the price from domestic production from 90 to 150 USD/1,000 $Nm^3$.

In 2001, CONEL was split in smaller companies. In 2002, most of the CGPPs were transferred to the Municipalities of the towns near which they were built and which they supplied with thermal energy. In 2003, APATERM was split, and the District Heating Section merged with the CGPP in one company (public utility, owned by the Municipality). As the electric energy demand decreased drastically after 1990, and mainly after the first unit of the Cernavoda nuclear power plant was commissioned and connected to the grid, the CGPP is operated far from the design parameters. Having 5 units with a total installed capacity of 205 $MW_e$, it actually delivered to the grid about 590 $GWh_e$ in 1996, and about 350 $GWh_e$ in 2005, while the own consumption is about 300 $GWh_e$/yr. In 2005, the CGPP delivered a total of 1,870 $GWh_t$ thermal energy, which is its main product now. In 1998, the selling price of the heat delivered by the CGPP was 8.4 €/$MWh_t$ for population (subsidised) and 16.25 €/$MWh_t$ for legal persons (not subsidised). Since then, the coal price increased slightly, and the Environment Guard is fining the CGPP regularly when using low grade coal. In 2004, two boilers were modified to use natural gas. In 2005, about 60% of the energy was produced burning natural gas (in the very cold winter month, the gas pressure is too low, and usually coal is used). In 2006, one boiler was slightly modified to use biomass (corn). In a short time it was clear that this is technically possible, but the available quantity of corn at a reasonable price (including transportation by trucks) was insignificant. Another option was to use the residues from a large distillery in the county, but the distillery soon built its own co-generation power plant fired by this biomass.

Still, the production cost of thermal energy was, in 2005, about 31.8 €/$MWh_t$, of which the population paid 17.2 €/$MWh_t$, while 8.6 €/$MWh_t$ was subsidised from the local budget, and about 6 €/$MWh_t$ form the State Budget. The subsidy from the State Budget stopped from January 2006, and all subsidies will have to be completely cut by the end of next year.

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Furthermore, the CGPP has an authorisation to operate, from the National Agency for Environment Protection, until the end of 2010. This will not be extended unless all legal provisions on environment protection will be fully respected, which is, if not impossible, at least improbable, mainly due to technical and financial constraints.

## 7 Plans for the Near Future

In 2005, the Municipality of Oradea formed an association with the smaller communities around the city, called Oradea Metropolitan Area. Soon after that, the Municipality of Oradea, decided to find the best possible solution for the thermal and electric energy supply of the entire area, realizing that this is a key factor for the future development: to provide a safe and reliable energy at a reasonable cost.

After January 1st, 2007, when Romania became a full member of the European Union, important funds became available, through different programs.

In 2007, the Municipality of Oradea decided to open a tender for the elaboration of a Master Plan for the efficient thermal and electric energy production, distribution and consumption in the City of Oradea, as well as the elaboration of the technical documents and applications for financing, through grants from available sources, of the projects needed to carry out the proposed Master Plan.

As energy sources, of course fossil fuels will have to be considered, but the main target is to maximise the utilization of the renewable energy sources available in the area: geothermal, hydro, biomass,.

The proposed projects should also find solutions for optimizing the supply to all type of consumers in the City of Oradea, with possibilities to expand it to the entire Oradea Metropolitan Area, considering also the medium to long term development. It should also present solution for increasing the energy efficiency for all types of consumers.

## 8 Conclusions

The City of Oradea is a good example for the situation existing in many Romanian town, and probably in other East European countries too. The co-generation power plants are old, but are still the main heat source for the town, through district heating systems. The lack of funds (and maybe also interest and commitment) made the long needed changes in technology a very slow process. When fired by low grade coal, the environment impact is severe, and the technical solutions to prevent it, even if available, are prohibitively expensive. When firing hydrocarbons, the pollution is not so severe, but the oil and natural gas prices dramatically increased during the last years, and are not expected to decrease significantly in the near future.

Renewable energy sources (except hydro) have not been really encouraged in the past, but this did start to change a few years ago. At present, Romania has some incentives which already stimulated the development of renewable energy sources utilization.

Wherever a renewable energy source is available in the area, it is rather easy to include it in the energy mix of a large town with a district heating system, with a positive impact on the environment.

In the City of Oradea, the geothermal energy is used to supply the primary heating agent to existing substations of the old district heating system. Only minor modifications were required in the substations.

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