THE GEOTHERMAL ENERGY CONTRIBUTION FOR HEATING SUPPLY IN CITY OF ORADEA

VASIU I.
Research Center „Management of Energy Processes”
Department of Energy Engineering, Faculty of Energy
Engineering and Industrial Management, University of Oradea
ioanvasiu03@yahoo.com

Abstract: Thermal energy demand for district heating in the city of Oradea is supplied at present, almost at whole, by the Cogeneration Thermal Power Plant, based on classical fuels, mainly consisting of low grade coal and natural gas, with partially contribution of the geothermal energy.

Geothermal resource at low enthalpy, located within the city area of Oradea, available at an estimated level of 250 GWh/year, exploited at present by 12 wells, can provide a share of 55 GWh/year for district heating, representing at present about 7 % from the overall thermal demand at the end users inlet.

Geothermal energy is delivered by means of 3 main thermal stations, in order to prepare, especially household warm water, but sometimes also secondary agent for space heating, using additionally heat, based on natural gas.

Even if the geothermal energy provides at present only a small part of the overall heating requirement at the city level, nevertheless by increased financial support, in the near future is expected its much more contribution, as an alternative to polluting energy of coal and natural gas.

Keywords: geothermal energy, low enthalpy, improved energy supply.

1. INTRODUCTION

Economic and social development of the human society requires much more and reliable energy supply. More energy used, means more health and culture, high technological achievements, increased labor productivity, safe water resources and enhanced comfort in everyday life around the world. Energetic services consisting of heating, lighting, food preparing and transporting are essential inside a modern society.

Thermal and electrical energy, representing the most used final energy forms, taking part on a large scale in almost all human activities, are generated at present at global level, as well in Romania, in a great share in the thermal power plants, based on fuels burning, derived from coal, crude oil and natural gas, named classical fuels. Besides the useable energy, these power plants generates a series of pollutant substances, more consistent at the coal burning, that affect the human health and the environment.

Romania has at its disposal varied classical primary energy resources, at present in lowered amounts, which in addition with a remarkable useable potential of renewable energies, contribute to the electricity and heat production of the power plants.

Due to the continuously decrease of the hydrocarbons production registered in Romania in the last years, at this moment the internal natural gas demand can be covered only by imports, at raised prices.

Under these circumstances, in order to improve its energy security, Romania have to promote especially the indigenous classical primary resources, knowing that only the coal is at whole at disposal, based on advanced energy generation technologies in the thermal power plants, defined by high energy and environmental efficiency, assuring on this way safe and cheap energy for the economic and social growth, that will contribute to an increased people's daily well-being, expected in the country.

At the same time, has become a requirement to extend in the near future the renewable energies usage, available on the national territory, such as biomass, hidro, wind, solar and geothermal energy, in order to raise their contribution to the overall energy supply at country level, as an alternative to polluting energy of classical fuels, [8].

Significant geothermal resources have been discovered in Romania, especially at low enthalpy, more of them located along the western border. In Oradea city, geothermal energy provide, at least partly, the district heating demand, thus displacing a share of the classical fuels requirement, in benefit of the environment quality.

At present, in the city of Oradea currently operates a large district heating system supplied, almost entirely, by the Cogeneration Power Plant, which provide thermal energy based on coal with oil-fuel support and natural gas, [7].

2. DISTRICT HEATING SYSTEM OPERATING IN ORADEA

Thermal energy required at decreased potential for district heating, can be generated, either separate in the heat-only boilers of the thermal stations or together with electricity in the power units of the cogeneration plants.

Thermal and electrical energy cogeneration based on a single combined thermodynamic cycle, developed simultaneously in the same power unit, using the same fuel source, is widely applied in the thermal power plants, as an advanced energy generation technology, compared with separate production of these two energy forms, in same size of values.

Fig.1. Cogeneration Thermal Power Plant of Oradea

In principle, cogeneration integrates the electricity production with a heat recovery process at decreased level, that become usable for district heating processes, thus resulting a considerable improvement from the viewpoint of energy and environmental efficiency, on the whole installation.

Cogeneration power plants offer a better option for covering heat and electricity demand in an economical manner due to the considerable amounts of fuels saved in the combined thermal cycle, simultaneously with decreased pollutant emissions released into the environment.

Combined heat and power plants (CHP) can be viewed primarily as a source of heat, with electricity production as a by-product. Thus, these thermal plants are currently designed to provide heat to the towns and communities or to the industry, rather than electricity, [6].

2.1. Cogeneration power plant and thermal network

The Cogeneration Thermal Power Plant of Oradea was built in the western side of the city between 1963-1976, when the social and economic development of the city has reached a higher level, in order to provide thermal energy for heating purposes required by the industry and dwellings achievements, (fig. 1).

Cogeneration Power Plant of Oradea generates both, heat and electricity, using a combined thermodynamic cycle. Thermal energy is generated at the level required by the district heat demand, while the electricity is received by the National Energy System. The main equipment s are 5 power units, having together an overall installed capacity sized now at 195 MW_e , supplied by 6 steam generators with natural circulation, at an overall installed capacity of 1,830 tonn steam/h, from which 3 units operate on natural gas and other 3 units on coal with oil-fuel support flame, connected to the stack nr.1 and respectively nr.2, (table 1). Steam generators operation is continuous, with a high level of activity during the cold season, when the thermal load of the district heating system has an important share.

The main fuel used at the Cogeneration Thermal Plant of Oradea, during the operation time, for electricity and heat production, was the low-rank coal, mainly Romanian lignite, with an appreciable humidity and uncombustible mineral matter content, burnt in powdered state, mostly brought from the area of Oltenia and Northern Ardeal coal mining basin (Voivozi and Sărmăşag mines) or sometimes imported in smaler amounts at reasonable distances from the country's western border (Hungary, Poland), [6], [7], [9].

After the year 2002, with the finishing of connecting the cogeneration plant to the main gas pipe line passing along the western border of Romania, together with the modernising of three steam generators, by changing the combustion from pulverised coal to natural gases, the share of gas fuel in the overall generated energy became significant, especially in summer time, needed only for the household warm water preparation. After a short period of 3-4 years, the coal return almost wholely in the plant operation, being used an average amount of 1,0-1,2 million tones/year, while the consumed natural gas was insignificant.

The flue gas cleaning equipment consists of electrostatic precipitators, 2 units for each steam generator operating on coal (nr. 4, 5 and 6), with a high efficiency of filtering, about 98% in optimal operating regime.

With a view of preparing warm water and secondary heating agent, the Cogeneration Power Plant delivers at its boundary through the primary thermal networks about 1,000 – 1,050 GWh, as a mean value over the past 5 years, from which only 730 GWh/year reaching the inlet of consumers, (fig. 2).

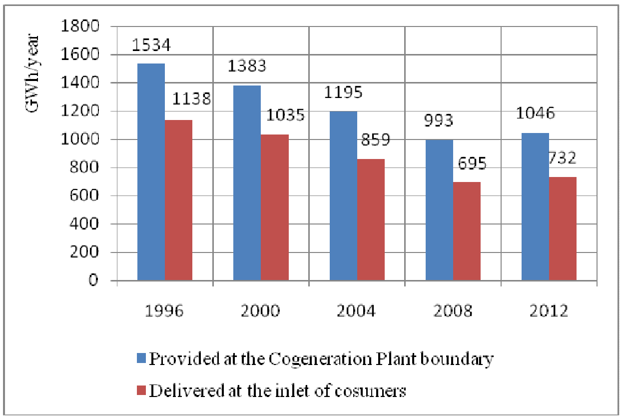

Fig. 2. Thermal energy production generated in recently years by the Cogeneration Plant of Oradea

Hot water at temperature of 120-130^{o}C is sent from the power plant, located in the western side of the city, to the heating stations by directly pumping through 6 primary main pipe-line and their connections, having nominal diameters between 50-900 mm, with a total length of 75 km double route-pipe, of which about two-thirdes are mounted underground, (fig. 3), [7], [9].

Thermal energy is transferred from the main pipe-lines to consumers by means of 146 heating stations having a designed installed thermal capacity sized between 1.2 – 10 MW_t/unit, in addition with 475 small heating units, places at the customers, directly connected to the primary network.

Heat distribution to the consumption site occurs through 155-160 km secondary network with diameters inside the range of 40-200 mm, consisting of 3 routh - pipe, of which two for heating agent and one for warm water, located almost entirely in closed thermal channels or in the basement of buildings.

Fig. 3. Primary main pipe-line system supplied by the Cogeneration Thermal Power Plant of Oradea

Until the year 1994, the Cogeneration Plant has supplied with hot water in heating purposes a significant green house located at about 4 km from the heat source.

Thermal energy is delivered as household warm water and secondary heating agent, to more than 60,000 dwellings, especially multi-flats blocks and private houses, to about 2,600 private and public companies, mainly consisting of buildings and small sized industrial spaces in field of trade, travel and industry, public or private buildings meaning for health, education, culture and administration, [7], [9].

Table 1. Main technical parameters of the power units installed at the Cogeneration Power Plant of Oradea

Power unit	Technical characteristics						Fuels used
	Electrical nominal power	Thermal nominal power	Nominal steam flow		Nominal superheated steam temperature	Nominal steam pressure	
	MWe	MWt	t/h	kg/s	°C	MPa	
I	25	127	165	45,8	540	13,6	Natural gases
II	25	127	165	45,8	540	13,6	Natural gases
III	45*	269	350	97,2	540	13,6	Natural gases and oil fuel
IV	50	307	400	111,1	540	13,6	Coal and oil fuel
V	50	307	400	111,1	540	13,6	Coal and oil fuel
Steam generator VI	-	269	350	97,2	540	13,6	Coal and oil fuel

2.2. District heating system performances

In present stage of thermal engineering in field of heating supply technologies, low energy efficiency can be obtained in thermal plants, mainly due to the great losses associated to thermal equipments, especially through combustion and heat transfer related to steam or hot water generators, as well as to transmission and distribution thermal networks.

Although the Thermal Power Plant of Oradea operates in cogeneration regime, generating thermal energy together with the electricity in a combined termodynamic cycle, that in principle is a performant technology by comparision with separate production of these two energy forms, even if over the operation time have been applied technical improvements inside installations, nevertheless the outlook on the power plants design since the 1960s, in addition with the present-day general technical wear-state of the thermal equipments, lead together at present to decreased energy efficiency and environmental performances.

In the last ten years, Cogeneration Power Plant operating in Oradea has achieved energy efficiency at mean values of 55-60%, more lowered compared with 75-85% currently registered by the updated cogeneration thermal plants using the same technology and termodynamic parameters, that show a reduced degree of the fuels usage. At the same time, transport and distribution heating system operates under considerable thermal losses, representing in the last years average values of 30-32 %, sometimes even 35 % from the overall thermal flow delivered at the plant boundary, by comparison with usually values of 15 %.

During the operation time, Cogeneration Thermal Plant has had a minimal impact about the environment in the city area of Oradea, but at present pollutant emissions released into atmosphere exceed the limits allowed by the european rules, especially at the coal burning.

With the view of improving Thermal Power Plant operation in the Oradea city, updated cogeneration technology have to be promoted, that in addition with extensively use of the geothermal resource available in area, will contribute to raised overall performances of the district system, finally providing safe and affordable energy, more friendly with the environment, [7], [9].

3. GEOTHERMAL RESOURCE IN THE CITY AREA OF ORADEA

Due to the limited amounts of classical and nuclear fuels, taking into account continuously rising of liquid and gaseous hydrocarbons, renewable primary energy is of present interest, through accessibility and abundance, but especially from the environmental protection point of view.

Geothermal energy, available in the city area of Oradea at an appreciable thermal potential, can provide partly, besides classical fuels, the district heating demand.

3.1. Heat from the Earth

Geothermal energy represents the natural heat of the Earth, continuously coming from its molten interior, together with that resulted from the radioactive materials decay contained inside the underground rocks. On average, the temperature of the Earth increases with depth, about 25–30˚C/km above the surface ambient temperature, named geothermal gradient, [10].

The heat is transferred mainly by conduction towards the earth surface as magma, that usually remains below the crust, heating nearby rocks and underground water. The thermal energy of the Earth is huge, but only a very small fraction could be utilized, in limited areas inside which geological conditions allow the meteoric water penetration along fractured and cracked rocks, into the hot zones, at depths until 4.0-4.5 km, thus accumulating the heat.

Depending on the temperature and pressure, underground hot waters can migrates upwards through fractures and cracks, reaching the surface as hot springs, as geothermal fluid, but most of it remains underground, stored in permeable and porous collecting rocks, at shallow to moderate depths, under a layer of impermeble rocks, forming the hidro-geothermal reservoirs, named thermal aquifers, [4].

Currently are exploited hidro-geothermal reservoirs, located until usually depths of 2.0-2.5 km, rarely below 3 km, easily accessible in favorable economical conditions, in present-day stage of drilling technology. A great part of hidro-geothermal resources comprise of low and medium enthalpy, below 50-160^{o}C, commonly in range of 50-110^{o}C delivered by wells having less than 3 km deep, useable for heating purposes, [4], [10].

Geothermal energy is considered a renewable resource because the heat emanating continuously from the Earth depth is limitless, ensuring an abundant, inexhaustible and clean energy supply.

3.2. Geothermal reservoir in Oradea area

Considerable hidro-geothermal resources have been discovered on the Romanian territory, mainly along the western border, generally at low enthalpy, inside the range temperature of 45–120^{o}C, suitable for direct heating purposes.

Geothermal energy represents a significant, abundant and clean primary energy source in the city of Oradea. Hidro-geothermal reservoir identified in the Oradea's city underground covers an area of 75 km^2, located in limestone and dolomite rocks of Triassic age, placed at variable depths inside of 2.2-3.2 km, with natural recharge from Borod-Aleşd zone, by gravitational penetration of meteoric water, [1], [2], [5], [8].

The exploitation of thermal reservoir in the area of Oradea is achieved using 12 active wells drilled in the city limits, from which 11 production wells and 1 reinjection well. Another 2 wells were drilled in recent years in the city area.

The pressure existing in aquifer allows the artesian operation of wells at a geothermal water flow between 5-25 l/s per well, depending on the geological structure of rocks in area, with possibility of increasing to about 20-50 l/s in underground pumping system. The overall flow rate of all wells reach about 65-75 l/s by comparison with a total potential evaluated at 140 l/s. Registered temperatures at the outlet of wells are in range of 72-74^{o}C in the eastern and 105-106^{o}C in the western side of city area. This change of temperatures over the thermal aquifer take place due to the progressive rise of geothermal gradient from 2.7 (3.5)^{o}C/100 m in est to 4.1 (4.3)^{o}C/100 m in west, at the average collector's depth of 2,400 m. The hidro-thermal collector allows reinjection of the used geothermal fluid at pressures below 10 bar and flow rate between 25-40 l/s, [1], [2], [5], [8].

Table 2. Main parameters of the hidro-geothermal system in the city area of Oradea

Area	Depth	Temperature at the well outlet	Geothermal gradient	Well flow artesian /pumping regime	Overall mineral salts content
[km^2]	[km]	[^{o}C]	[^{o}C/100 m]	[l/s]	[g/l]
75	2,2-3,2	70-105	2,7-4,1	4-30 /20-50	0,8-1,4

The main technical parameters of the Oradea hidro-geothermal system, are presented in table 2.

Geothermal waters contain a series of dissolved substances, taken over from the collector, mainly including carbonates and sulphate of calcium, magnesium and sodium, as a result of limestone and dolomite presence in aquifer. In a suitable range of temperatures, these dissolved components can be form deposits of scale (crust) on the inner space of thermal circuits, leading to decreased performances of thermal equipments and damages of installations.

Geothermal fluid exploited in city area of Oradea has an overall mineral salts content inside a range of 0.8-1.4 g/l, without major tendency of scaling on the inner surfaces of thermal equipments, reasonable for utilization by means of heat exchangers. Chemical analysis have established thermal water of calcium-sulphate-bicarbonate type, almost with absence of dissolved gas.

3.3. Direct use of geothermal energy in city of Oradea

Geothermal resource located inside the limit of Oradea city can contribute in a more raised measure to improve the district heating supply, by an intensive exploitation of existing available potential, providing a clean, safe and cheap energy, compared with that obtained by fuels burning.

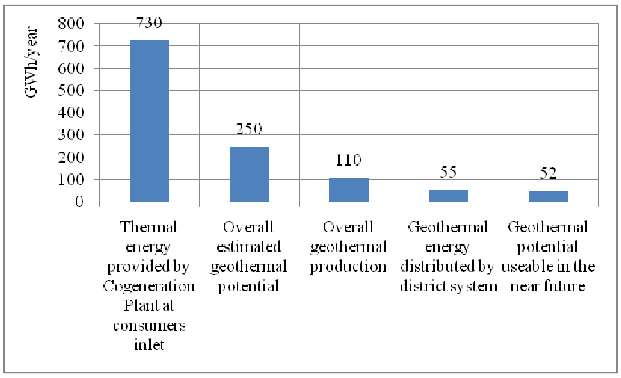

Fig. 4. Hidro-geothermal resource in city area of Oradea

Geothermal energy usage has been continuously developed in the city area of Oradea during the last years as an alternative heating source to the pollutant energy of coal and natural gas.

Nowadays, geothermal resource available in the city area of Oradea has a remarkable potential estimated at 250 GWh/year, that partly is harnessed by means of 12 active wells, delivering an overall yearly production of about 110 GWh, from which 55 GWh/year is distributed through the district heating system, covering partly the thermal demand in the wells area, (fig. 4), [7], [9].

Generally, geothermal energy at low enthalpy exploited in the city area of Oradea and in its neighborhood is used directly, in the most part for heating purposes, including dwellings and industrial spaces, warm water preparation, industrial processes, greenhouse heating, but also for balneology, bathing and swimming, fish farming and aquaculture.

The geothermal fluid coming from Oradea's aquifer allows only direct utilization through heat exchangers, because of its low parameters, being impossible to achieve a cogeneration process based on a thermodynamic cycle, in order to obtain simultaneously thermal and electrical energy. Thus, geothermal energy is only distributed through pipe network and therefore the term „cogeneration geothermal system" sometimes used, have to be replaced with „distribution geothermal system", [7].

The geothermal energy is distributed to the consumers from the wells area, in the most part, through the heating stations, built by Transgex Company, the most important of these operating in the Nufărul, Ioşia-Nord and Calea Aradului districts of the city.

Warm water and space heating supply, through the heat exchangers, are among the most important direct use of the low enthalpy geothermal resources.

The temperatures registered in range of 72-105°C at the geothermal wells head outlet, related to the thermal aquifer in city area of Oradea, allows the water heating until 55-58°C for household or industrial purposes. Preferred water delivery temperature of the geothermal fluid for space heating is in the range 60-90°C and commonly the return temperature is between 25-40°C. Often, geothermal installations prepare hot water in opened circuit, [7].

This available temperatures field at the wells head above showed, make possible the space heating delivery simultaneously with the warm water, if the flow rate of well allows, but an additionally thermal contribution is required for secondary agent preparation. The length and size of this supplementary heat depend on the geothermal fluid temperature available at well head and on the ambient temperature registered in the cold period of year. In this view, geothermal stations are equipped with hot water generators operating on natural gas, designed at an overall thermal power of at 3-5 MW_t, according to the size of geothermal installation.

The operation regime of geothermal stations, with a view of simultaneously providing of space heating and warm water, is established by technical and economical designs, this operation mode being profitably in a range of well head temperatures above 85°C, which can offer at least 58-60°C in the warm water circuit toward consumers, [7].

Geotherm Station built in the district of Ioşia-Nord, the most updated achievement in the city, (fig. 5), is equipped with 3 heat exchangers of plate type, harnessing the geothermal energy, in opened circuit,

Fig. 5. Geotherm Station in Ioşia-Nord district

between inlet and return temperatures of (104-105)°C and respectively (35-40)^{o}C. Distribution system is composed of 3 circuits, named geothermal (primary), intermediary and geotermic (secondary), which together transfer thermal energy to the consumers as warm water and secondary heating agent (dwellings in multi-flats buildings, individual dwellings, public spaces in field of education, health, culture).

Few tehnical parameters of the main geothermal station operating over the city area of Oradea, are shown in the table 3, [7].

aquifer in city area of Oradea, show a low enthalpy resource, proper for direct utilization. A significant part of the geothermal production at about 55 GWh is distributed yearly by 3 main thermal stations, in order to prepare warm water and to deliver space heating, covering partly the district thermal demand.

Additional heat production proposed to be achieved by the Transgex Company in the next few years in the city of Oradea, at level of 50-52 GWh/year, will increase the geothermal energy share at 7 % to slowly above 14 - 15 % from the overall thermal demand at the end users inlet, that will improve the district heating supply in the whole city area.

Table 2. Main characteristics of geothermal stations providing district heating in the city area of Oradea

Geothermal station	Parameters of geothermal wells		Geotherma fluid temperature at the outlet of installation	Thermal power capacity	Number of secondary thermal stations connected	Number of dwellings supplied with	
	Temperature at the well outlet	Flow rate				warm water	space heating
	[^{o}C]	[l/s]	[^{o}C]	[MWt]	-	-	-
Nufărul	74	45	32	6	7	6,000	-
Ioşia Nord	105	30	38	12	3	3,400	3,400
Calea Aradului	92	10	30	3	2	1200	-

Overall thermal capacity of Geoterm heating station, located in district of Ioşia-Nord, is at about 12 MW_t , composed of 7.0 MW_t coming from geothermal resource and 4.5 MW_t installed in 2 hot water boilers operating on natural gas. In this geothermal station, almost 4 MW_t have been added to the geothermal energy in order to cover the peak load in some of the most cold days registered in the last winters, (fig. 5).

At present, in the city area of Oradea, more than 7,000 dwellings are supplied by geothermal stations with warm water and in addition for about 3,400 dwellings is assured simultaneously warm water and space heating, [7].

Further development of the geothermal energy use is foreseen in Oradea city. In the next few years Transgex Company will extend the geothermal resource in the city area by drilling new wells, working in doublet production-reinjection system, which can provide in addition about 52 GWh, in the most part addressed for district heating.

6. CONCLUSIONS

Thermal energy demand for district heating in the city of Oradea is provided at present, almost at whole, through an extended district heating system, supplied by the Cogeneration Thermal Power Plant, based on classical fuels, especially consisting of low grade coal and natural gas, on the whole being registered o low energy efficiency.

Geothermal reservoir discovered on the city area of Oradea, available at estimated yearly potential of 250 GWh, can be an alternative to polluting energy of coal and natural gas, providing a clean and cheaper energy for the benefit of local community.

The temperatures registered in range of 72-105^{o}C at the geothermal wells head outlet, related to the thermal

REFERENCES

[1]. Antal, C., Setel, A., – Exploitability of Geothermal Resources in Pannonia Depression, Analele Universităţii din Oradea, Fascicula Energetică, vol. 15, 2009, pag. 154-157.
[2]. Bendea, C., Bendea, G., Roşca, M., Cucueteanu, D. – Current Status of Geothermal Energy Production and Utilization in Romania, Journal of Sustainable Energy, vol. 4, nr. 4, December, 2013.
[3]. Burchiu, N., Ghiţulescu, M. – Potenţialul geotermal în România. Stadiul actual şi perspectivele de dezvoltare a aplicaţiilor pentru valorificarea energetică, Energetica-40, nr. 6A/1992, pag. 252-262.
[4]. Dikson H. Mary, Fanelli Mario, – What is Geothermal Energy ?, Instituto di Geoscienze i Georisorse, CNR, Pisa, Italy, 2004 (www. geothermal – energy. org).
[5]. Rosca, M., Antal, C., C. Bendea – Geothermal Energy in Romania: Country Update 2005-2009, Proceeding World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010.
[6]. Vasiu, I. – Cogenerarea - soluţie tehnică eficientă de producere a energiei termice pentru consum urban în municipiul Oradea, Energetica-53, nr. 2/2005, pag. 63-67.
[7]. Vasiu, I. – Using Geothermal Energy for District Heating in the City of Oradea, Proceedings of Conference ”Modern Science and Energy”, SME – 2014, Technical University of Cluj-Napoca.
[8]. Veliciu, Ş. – Overview of the Geothermal Potential of Romania, Symposium DR-AHK, Geothermal Energy in Romania, Bucharest, november 2011, International Center For Green Energy Information ICGEI – Bucharest Scientific Bureau.
[9] *** Institutul de Studii şi Proiectări Energetice Bucureşti, Studiu de fundamentare privind strategia locală de alimentare cu energie termică a municipiului Oradea, 2007 şi 2008, (www. Oradea.ro).
[10] *** World Energy Council – World Energy Resources 2013, London, United Kingdom, 2013 (www. worldenergy.org)