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GEOTHERMAL DEVELOPMENT OPPORTUNITIES IN ORADEA

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ABSTRACT

Located in an area of sedimentary basins with low-enthalpy geothermal resources, Oradea city in Romania has a tradition of geothermal research and exploitation. Considering the objectives of the local public administration to develop further the utilization of geothermal resources, the report presents potential geothermal development opportunities in the area.

The necessity of a more efficient use of the existing resources and infrastructure is underlined, plus the need for a strategic orientation towards the increase in geothermal exploitation opportunities. Optimization with sustainability as a key goal in the utilization of the geothermal resource in Oradea is of importance, as well as improving air quality by reducing burning of fossil fuels, lowering the heating cost for the population and improving energy safety by increasing usage of a local energy source. This can help Romania to fulfil the 20-20-20 goal of the EU, which can improve the local development of the area. The report presents a proposal of a geothermal road map to 2030, with 3 phases of development at metropolitan level.

1. INTRODUCTION

The main topic of the report relates to geothermal development opportunities, as it considers the geothermal resource being one of the most important future inputs for energetic mix independence in the Oradea region. This implies also actions towards a more extensive use of geothermal energy.

The general literature review about the benefits of geothermal power and energy shows, that geothermal resources are a cheap form of renewable energy, with many advantages proven over time. No energy storage is necessary and it is reliable as it is season and weather independent. It is green energy and can be utilized in a sustainable way, with natural recharge or maintained through injection.

The utilization forms of geothermal resources with temperatures over 150°C include electricity production as the most important utilization form, while the medium- to low-temperature resources (<150°C) are suited for many different types of applications for heating, industry, agriculture, aquaculture, spas etc. (Lindal, 1973). For an improved utilization of geothermal resources, the Lindal diagram shows the cascading utilization and combined uses as an instrument for improved feasibility of geothermal projects. Although the temperature factor can limit some options, other applications can be developed (Gudmundsson, 1988).

The paper will review the existing geothermal characteristics and infrastructure, as a starting point to identify steps for improved efficiency and development opportunities of the geothermal resource in the area, and its impact in the local community.

1.1 Oradea metropolitan area

The city of Oradea is located in the western part of Romania, close to the Hungarian border (Figure 1). Capital city of Bihor County, Oradea is also the leading local economy driver of the county, with a population of approx. 200,000 inhabitants. The surrounding metropolitan area further develops an urban pole of around 250,000 inhabitants (Table 1 and Figure 2).

FIGURE 1: Romania, location of Oradea (modified from Infoturism.ro, 2016)

TABLE 1: Oradea statistical data: population and surface (INS, 2016)

Statistical data	Population	Surface (km^2)
Romania	20,121,000	238,391
Bihor county	600,223	7,544
Oradea metropolitan area	251,000	792
Oradea city	201,000	116

The most significant economic activities in Oradea are related to trade, manufacturing industry, transport and storage, construction, and professional, scientific and technical activities.

In 2007, the Municipality of Oradea created the Oradea metropolitan area, an association of Oradea city and the surrounding communities for common joint approach for more efficient development. The main

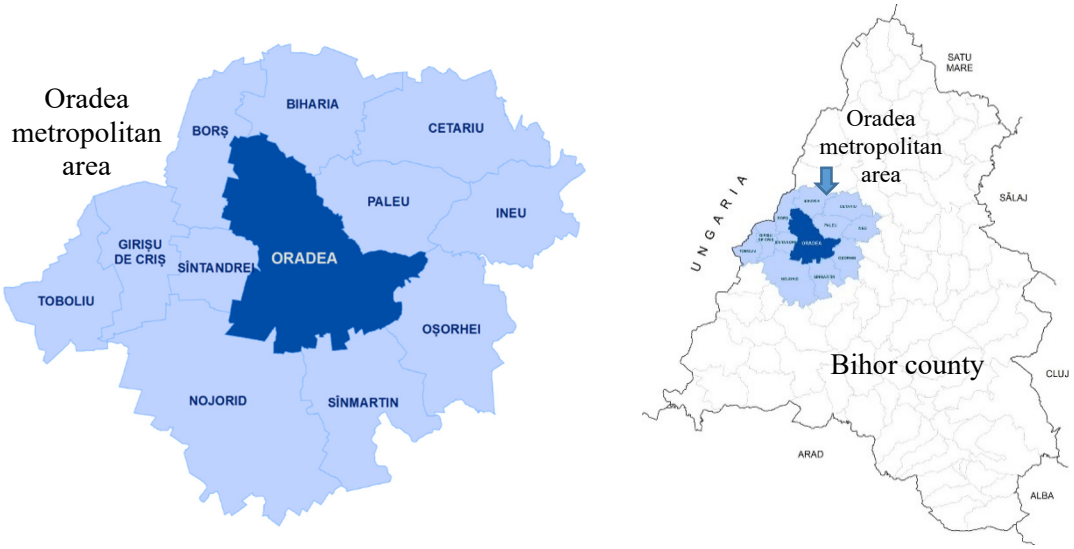

FIGURE 2: Bihor county and the location of the Oradea metropolitan area (Oradea, 2016)

objective was to share the resources and the efforts for a common development of the urban pole of Oradea. This association is generating specific common approaches for coherent planning and also projects for the geothermal development in the metropolitan area.

Regarding the weather in Oradea, the annual average air temperature is 10.6ºC, with the highest value recorded in 2014, 12.8ºC, and the lowest value in 1985, 9.0ºC, which gives a thermal amplitude of 3.8ºC. The monthly minimum is recorded in January, with an average of -0.7ºC, and the maximum in July, when it reaches 21.3ºC (Pereş and Köteles, 2015).

1.2 National Agency for Mineral Resources (NAMR)

According to the official website of NAMR (2016) and according to the law *Decision no. 1419 / 18.11.2009, amended by GD no.550 / 2013* regarding the organization and functions of NAMR, its main tasks are as follows:

General provisions of NAMR:

- It is organized and operates as a specialized body of the central public administration, with legal personality, subordinated to the Government and coordinated Prime Minister by a state councillor;
- It is governed by a president with the rank of Secretary of State;
- The funding comes from the General Secretariat of the Government, through a tertiary credit;
- It is the competent authority empowered to apply the provisions of the Mining Law no. 85/2003, as amended and supplemented, and the Petroleum Law no. 238/2004 modified and supplemented.

Main duties of NAMR:

- Manages resources of hydrocarbons (oil and gas) and mineral resources as public property, defined by Law no. 85/2003, as amended and supplemented, and Law no. 238/2004, modified and supplemented;
- Organizes the National Geological Fund – the resources / reserves, confirms, verifies, records and draws movement resources or reserves;
- Does concede with other state authorities, negotiate and conclude agreements on behalf of the state oil mining concession licenses and operating permits;
- Issues regulatory acts, rules, instructions, orders and regulations;
- Checks on holders of petroleum agreements and provisions of licenses or permits;

- Manages the national pipeline transport of oil and gas and regulates its operating activities through the system concession agreements concluded with domestic commercial companies nominated by the Government;
- Cancels acts of concession / administration; fees, taxes and tariffs;
- Establishes, under the law, the reference price for oil extracted in Romania to establish appropriate fee;
- Establishes national tariffs to exploit oil transport system;
- Sets tariffs for documents issued in the exercise of this or consultation and for use of documents and information concerning mineral resources;
- Follows the production of hydrocarbons and mineral resources in order to determine and correct receipt of the fee, opinions and other:
- Approves documentation on execution of prospecting, exploration or exploitation, mining and oil and documentation terminating the operations of oil and mining activities;
- Approves the annual exploitation;
- Develops and approves regulations and specific technical prescriptions;
- Follows established environmental protection measures during and after the oil and mining operations;
- Sets the safety parameters for hydrothermal mineral deposits, sludge and peat therapeutic and approves the establishment of sanitary protection perimeters;
- Develops and keeps oil books, books on mining and mining regulations;
- Collaborates with the regional authorities of water management, environmental protection and labour protection in the exercise of inspection;
- Certifies professional competence of individuals and businesses who undertake work and documentation;
- Guards and punishes offenders to the Petroleum Law and the Mining Law;
- Other duties established by law.

1.3 The Oradea geothermal system

The Oradea geothermal system is found within a fractured carbonated formation (Figures 3 and 4). According to Antics and Rosca (2003), the reservoir is located in Triassic limestone and dolomites at depths of 2,200-3,200 m in an area of about 75 km^2 mostly within the Oradea City limits. The water is about 20,000 years old, of calcium sulphate-bicarbonate type, with no dissolved gases, and mineralisation lower than 0.9-1.2 g/l. The reservoir is part of an active natural flow with the recharge

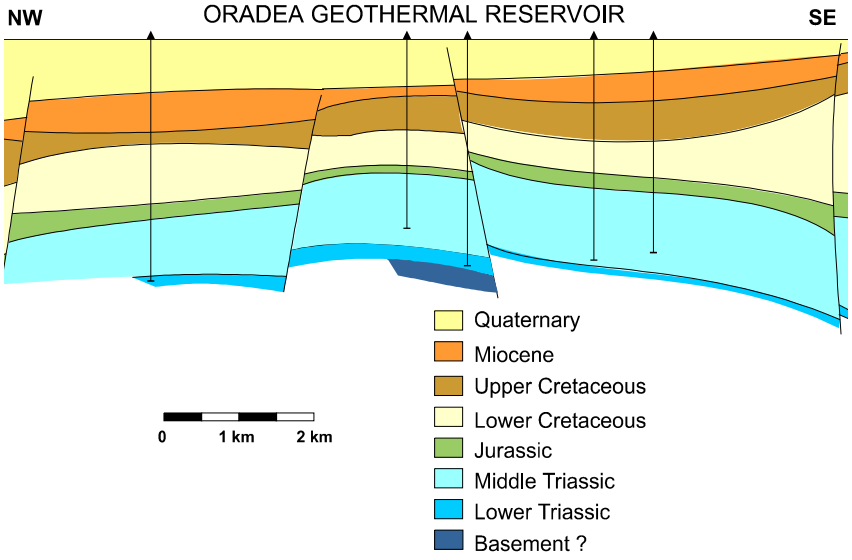

FIGURE 3: Cross-section through the Oradea reservoir (Rosca et al., 2016)

coming from the northern edge of the Padurea Craiului Mountains and the Borod Basin (Antics and Rosca, 2003). Studies indicate that exploitation in excess of an average annual total flow rate of about 300 l/s generates excessive pressure draw down in the system, thus exceeding the natural recharge. The current utilization permit, issued by NAMR, states that the maximum annual average utilization flow rate must not exceed 90 l/s without re-injection.

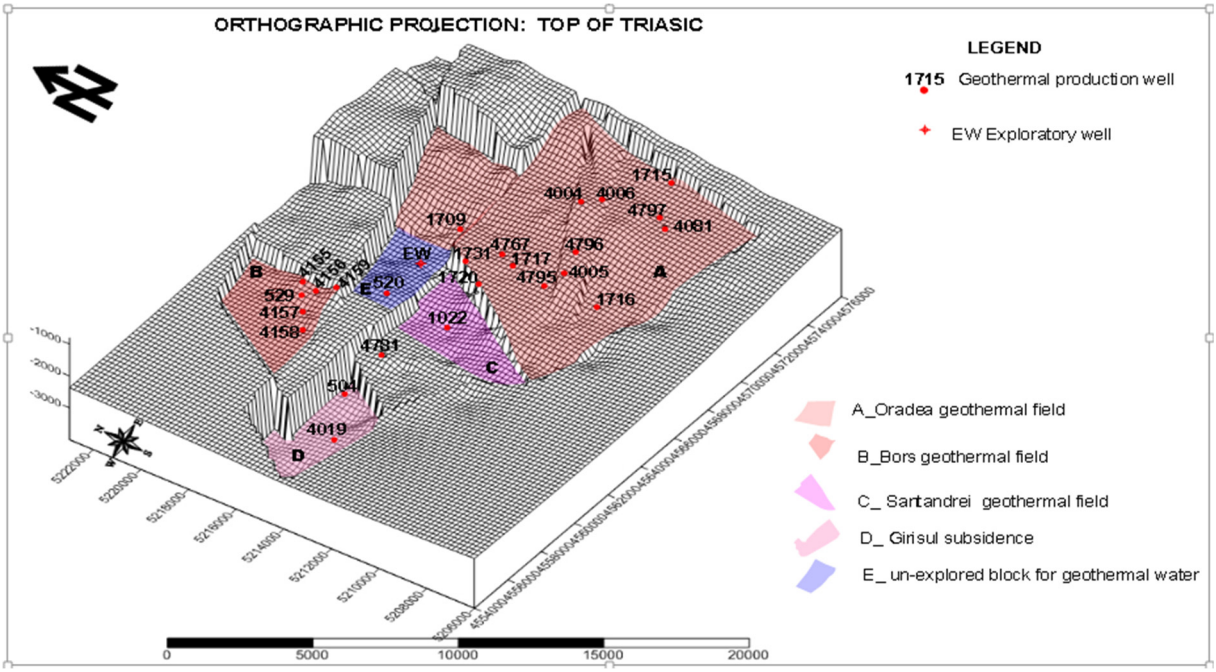

FIGURE 4: Top of the Triassic formation in Oradea and surrounding perimeters (Transgex, 2016)

1.4 Geothermal utilization in Oradea perimeter

The low-enthalpy geothermal energy is used mostly for heating purposes (including residential areas and industrial spaces), warm water preparation for the centralised district heating, industrial processes, greenhouse heating, but also for balneology, pools and spas, fish farming and aquaculture.

In the Oradea perimeter, there are currently 14 wells, 12 of which are production wells and 2 re-injection wells. Current annual average flow rate is about 60 l/s. The total installed capacity is about 21.5 MWth for the approved flow rate of 90 l/s. The current annual heat production is about 430 TJ/year with an average capacity factor of 63% (Rosca et al., 2013).

The estimated exploitation potential of the reservoir is around 250 GWh/year, but only 44% are utilised at present, giving a geothermal production in Oradea around 110 GWh/year. The development throughout the last 15 years of utilization shows no major changes. Table 2 shows geothermal utilization in Oradea.

TABLE 2: Utilization of the Oradea geothermal resource in 2013 (Vasiu, 2014)

	GWh/year
Thermal energy provided by the cogeneration plant	730
Geothermal potential	250
Geothermal production	110
Geothermal district heating production	55
Expected future potential of geothermal	52

In 2013, the geothermal resource in Oradea provided 55 GWh/year for district heating, about 7% of the overall thermal demand by the end users. Due to the relatively low geothermal temperature, the main utilization is supplying heat energy for the central district heating system. The geothermal energy is included in the energy mix for the district heating system, supplying the primary heating agent to some existing and updated substations of the old district heating system (Bendea at al., 2015). Geothermal heating energy is delivered to the district heating system by Transgex, from the 12 existing wells. Three main geothermal stations are used, mainly for preparing hot household water (HTW - hot tap water) as secondary agent for space heating, using additional heat, based on natural gas (Table 3).

TABLE 3: Characteristics of geothermal stations providing district heating in Oradea (Vasiu, 2014)

Oradea Geothermal Stations in 2013	**Well parameters**		**Geothermal fluid temp. at the outlet of the installation**	**Thermal power capacity**	**Secondary thermal stations connected**	**Number of dwellings supplied**	
	Temperature at the well outlet	**Flow rate**				**Hot water**	**Space heating**
	(°C)	**(l/s)**	**(°C)**	**(MW_{th})**	**-**	**-**	**-**
Nufarul	74	45	32	6	7	6,000	-
Iosia Nord	105	30	38	12	3	3,400	3,400
Calea Aradului	92	10	30	3	2	1,200	-
Total		85		21	12	10,600	

According to current data (Termoficare, 2016) the energy mix for the district heating system is mostly covered by SC Termoficare Oradea SA (publicly owned) that operates the cogeneration fossil fuel plant, plus the geothermal energy provided by the 3 geothermal plants owned and operated by the Transgex company, the local geothermal power private producer. The district heating system of Oradea uses 50% (around 55 GWh/year) of the total geothermal energy production, which makes it the main consumer of geothermal energy in the area. Reported to national level, this consumption corresponds to almost 35% of the total geothermal heat produced in Romania (Rosca et al., 2016). The following lists some short facts on the geothermal utilization in Oradea:

Tradition

- Spas attested during the Roman Empire times;
- First well drilled in 1885 in Felix Spa (depth 51 m, flow rate 195 l/s, temp. 49ºC) – still in use.

Exploitation

- 14 wells in Oradea + 20 wells in the metropolitan area (30 km radius);
- District heating covering 70% of population;
- The district heating system of Oradea currently uses 6% geothermal input, which means around 35% of the total geothermal heat produced in Romania.

Research

- National Centre for Geothermal Research (1992) – Oradea State University;
- Romanian Association of Geothermal (1994);
- First geothermal power generation unit in Romania (2012);
- Study case for a hybrid project: electric energy production plant using geothermal + photovoltaic panels (2014);
- Pilot centre for studying geothermal exploitation (2014);
- First reinjection well in the last 20 years drilled in Romania (2016).

2. FURTHER OPPORTUNITIES FOR GEOTHERMAL DEVELOPMENT IN ORADEA

In the context of increased natural gas prices, the renewable geothermal energy is the solution for sustainable development. A more intensive exploitation of the potential geothermal resources in Oradea and its metropolitan area, can provide a clean, safe and cheap energy. Considering the existing situation regarding the geothermal resources and exploitation in the Oradea area, this research project is divided into two parts:

a) Considerations regarding an improved efficiency utilization of the existing geothermal resources and infrastructure in Oradea;
b) Identifying development opportunities for geothermal exploitation and utilization in Oradea and metropolitan area.

The geothermal development opportunities will link development tools over different potential utilization forms of geothermal resources in Oradea area, related to the specific conditions of the national and regional level (geothermal reservoir and exploitation capacity, electricity and thermal energy market, specific development of the area and available resources, business opportunities and sources of funding, etc.). Figure 5 shows a version of the Lindal diagram with potential utilization of geothermal energy in the agriculture and agro-industry sectors.

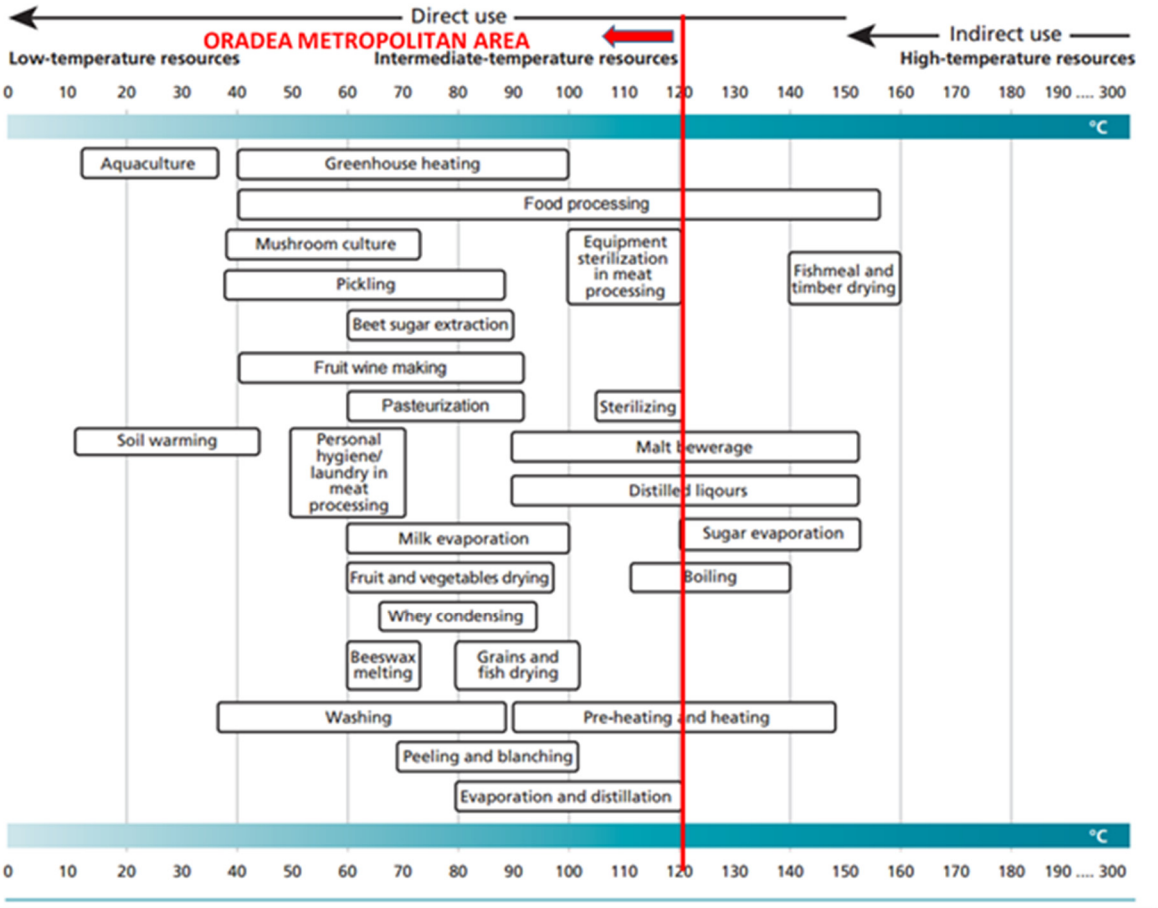

FIGURE 5: Lindal diagram for potential uses of geothermal energy in the agriculture and agro-industry sectors (modified from Van Nguyen et al., 2015)

2.1. Utilization of the existing geothermal resources and infrastructure in Oradea

It is necessary to create a large scale, commercially viable system for Oradea, which will optimise the value stream of lower temperature resources through systems based on cascaded use of geothermal. In

addition to electricity generation this could include direct heating and cooling, industrial and commercial applications, and agricultural uses. This way, the geothermal resources can be utilized for our own advantage and benefit of the environment.

Currently, the low-enthalpy geothermal energy exploited in the Oradea area is used directly, mainly for heating, industrial processes, greenhouses, balneology, spas, fish farming and aquaculture. The target is to develop the Oradea geothermal reservoir, so that it can be utilized up to its maximum potential. Research needs to identify the optimal conditions of efficient and profitable geothermal exploitation (gas fuelled plant vs. geothermal plants), energy mix etc. A cascaded system is a good example for increasing the energy utilization factor from the available flow rate of the geothermal water. The objective is to use the waste thermal water from the district heating system and create added value by more forms of utilization. A good example is the model from the Iosia geothermal plant where the waste geothermal water from the district heating is used for swimming pools in the area. The proposed model (Figure 6) can include: Power plant - 100°C, district heating & greenhouse - 50°C, spas, swimming pools and fish farms - 20°C, and return water going to water company.

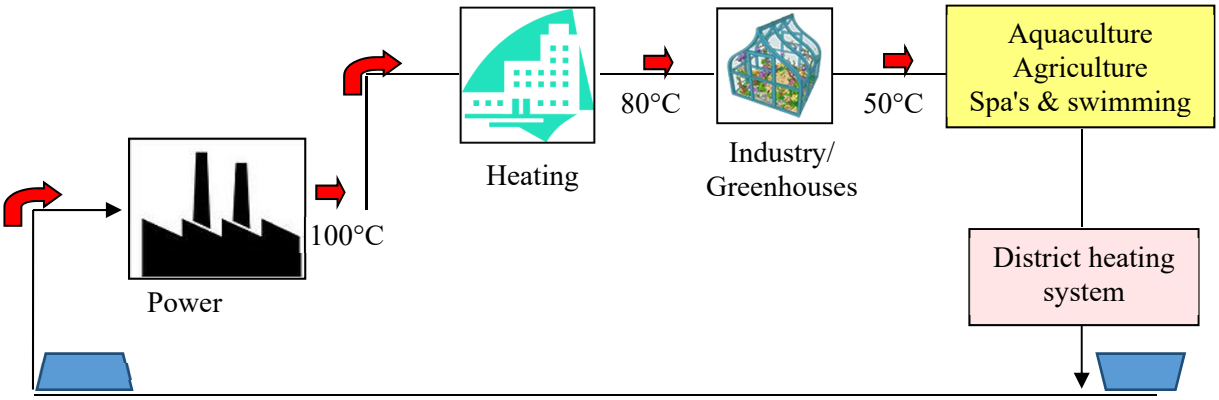

FIGURE 6: Geothermal cascaded utilization model for Oradea

2.1.1 Geothermal power production – Transgex Iosia geothermal plant

The public company Termoficare is producing electricity from the fossil-fuelled fired cogeneration plant. Until 2016 it coal was used as heating media. In April 2016 a new 50 MW gas cogeneration plant replaced it, producing now 43 MWe. The gas-generated electricity is sold on the national grid, with additional incomes available due to the special royalties offered by the Romanian government as a bonus for the high efficiency cogeneration electricity generated by the gas turbine, and green certificates (GC) for low impact on the environment. For the Oradea public cogeneration electricity producer, the Regulatory Authority for Energy (ANRE) in Romania stipulates, in the ANRE decision no. 2810 from 17.12.2014, that for the year 2015, the royalties shown in Table 4 are applicable (ANRE, 2016).

TABLE 4: Royalties for high efficiency cogenerated electricity (gas)

	Euro/MWh
Bonus for high efficiency electricity produced in cogeneration	37.35
Cogenerated electricity sold from the grid (no VAT)	32.74
Heating	21.63
Hot water	22.43

The system is fragile and political changes can affect the economic viability of the new cogeneration gas plant, such as through law changes, which can cancel the royalties and subsidies, low price of electricity in the national grid, increasing price of gas from the market, etc. Appendix I shows the monthly consumption of thermal energy (Gcal) in the Oradea DH system in 2015.

Termoficare does not use geothermal energy for the production of electricity. On the other hand, the private company Transgex is operating a 50 kW model of geothermal power unit in Iosia geothermal station, with the comment that it is not economically viable in the existing context. According to the existing legislation for electricity produced from geothermal energy there are no state subsidies or special royalties, not even green certificates. This is due to an unclear legislation that is not mentioning geothermal as a protected and supported resource by the state for power generation. The lack of special royalties, state subsidies or green certificates in the Romanian market, plus the low price for electricity in the national grid, was decisive in the geothermal power generation module from Oradea not being considered an economically viable project.

Due to the low enthalpy of the fluids in the sedimentary basin, geothermal fluid is not considered suitable for a cogeneration process based on a thermodynamic cycle, for simultaneously obtaining thermal and electrical energy (Vasiu, 2014). A financial analysis from the functioning period and considering the consumption of heat to produce electrical energy and revenues generated by this, showed that currently it is preferable for Transgex to concentrate on thermal energy district heating at the Iosia geothermal plant (personal communication with Transgex staff members), as seen by the following:

Revenues from 1 Gcal/h thermal energy = 8 MWe/h electricity

Further development regarding geothermal power production has to be correlated with an initiative for legislation change in order to promote geothermal resources as a state-supported option for the energy grid mix in Romania.

2.1.2 Geothermal energy - Oradea district heating system

The main consumer of geothermal resources from the Oradea perimeter is the district heating system (Figure 7). In order to increase the efficient utilization of the geothermal resources, it is necessary to analyse and improve the functioning model of the district heating system and the geothermal exploitation rate. As mentioned above, for the reference period of the year 2015, the main heat source was the

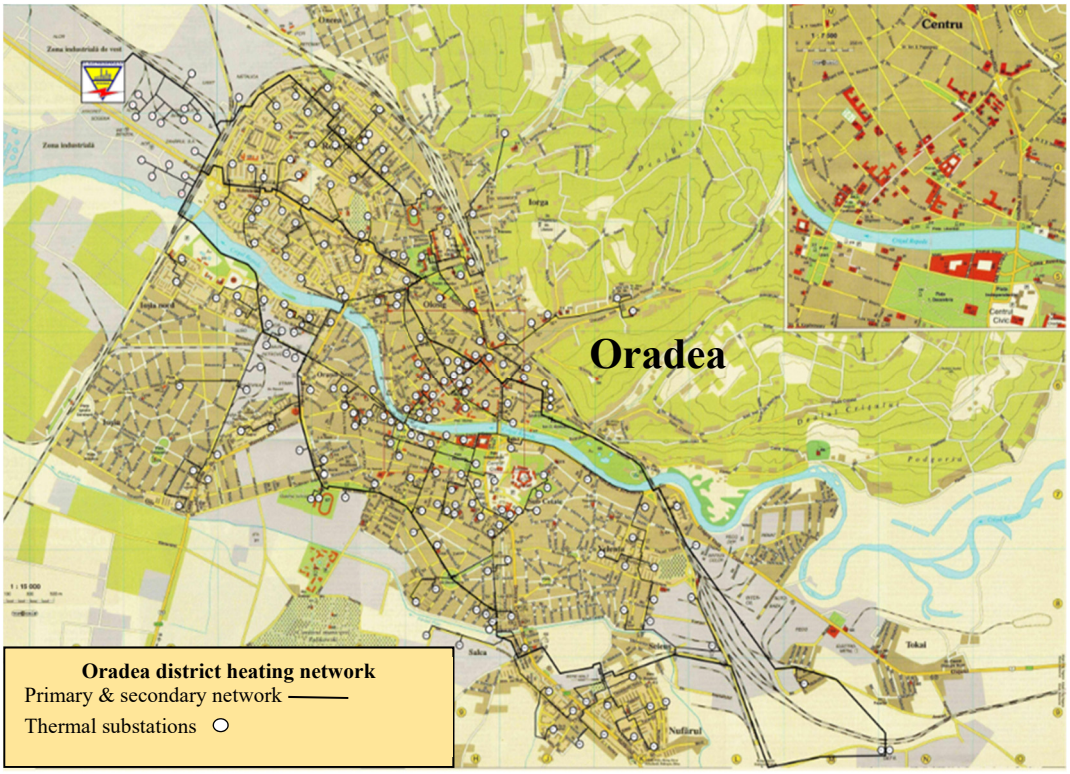

FIGURE 7: Oradea district heating system network (SC Termoficare SA, 2016)

cogeneration coal based plant, but today the Oradea district heating system main heat source is the 50 MW gas fuelled cogeneration plant, commissioned in 2016 by the local administration. The local transport network and district heating in Oradea is operated by SC Termoficare Oradea S.A. which manages a thermal network 219.5 km long (77 km primary and 142.5 km secondary and a total of 149 substations). It serves approximately 61,344 flats, 226 public institutions (schools, colleges, kindergartens and municipality) and a total of 1937 economic entities (banks, manufacturing facilities, etc.).

The water, which goes through the heat exchangers, is heated up to 90-110°C and returned at 35-40°C. The temperature of the geothermal water from the wells is suitable for hot tap water or industrial processes. An increasing or surplus of demand of space heating is provided through combined us of natural gas and heat pumps (Vasiu, 2014). According to the data (Termoficare, 2016; Vasiu, 2014) on the share of the geothermal resources vs. the fossil fuels used in the Oradea district heating thermal energy mix, the situation is as shown in Figure 8.

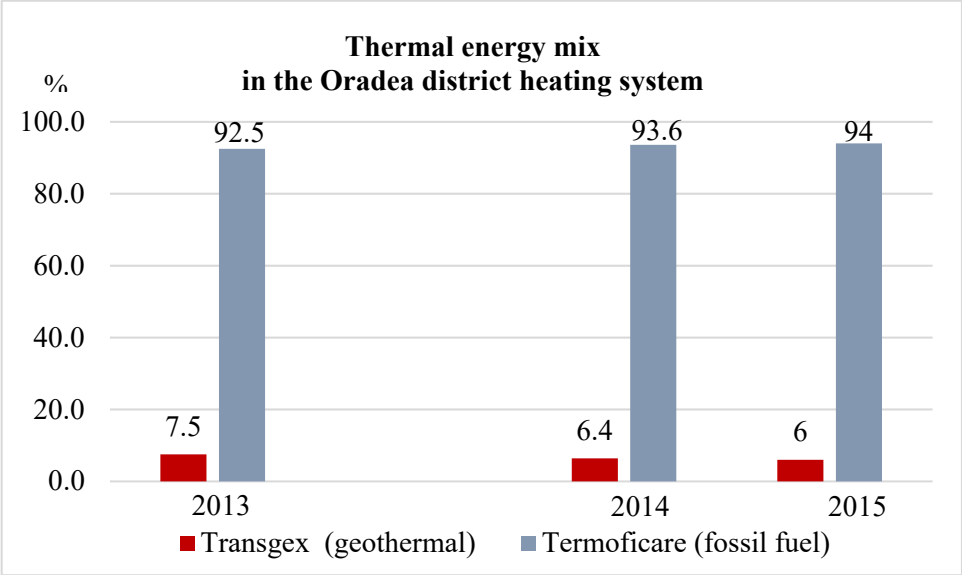

FIGURE 8: Thermal energy production analysis from the last 3 years in Oradea (comparison is made with the old cogeneration plant based on coal)

In order to identify the opportunities for potential development for the existing infrastructure, it is necessary to analyse the district heating efficiency in terms of production, sales and pricing policy for the end users (population and private companies). The year 2015 is the reference period for the analysis (Table 5). The potential exploitation level of the existing 11 production wells operated by Transgex in the Oradea perimeter is around 200,000 Gcal/year at approx. 25 Gcal/h (personal communication with Transgex staff members), which includes the rising level of injection as well. The hypothesis is that the share of geothermal energy in the total energy mix can be increased from the existing infrastructure (wells and geothermal stations), and that it can generate important savings for the local heating company (reducing the costs of thermal energy vs. fossil fuel) and for the local administration (reducing the subsidies per Gcal unit for population). Appendix II shows data on import prices for natural gas for EU.

TABLE 5: Total thermal energy production and sales in Oradea district heating (Termoficare, 2016)

Year	Production (Gcal/year)			Sales (Gcal/year)			Losses/ year
	Total	Fossil fuel	Geothermal	Total	Fossil fuel	Geothermal	
2014	823,705	790,053	33,652	482,637	451,809	30,828	41%
2015	892,635	853,613	39,022	558,772	525,027	33,745	37%

The average heat losses for EU district heating systems are around 10% (Nussbaumer and Verenum, 2014). In 2015, the production increased 8.4% from the previous year, while the sales increased with 15.8%. The reason was that the winter in 2015 had lower temperatures and the cold season was fully present from October to April. If the characteristics of last year (2015) for district heating are analysed, the situation is as shown in Table 6 and summarized in Figure 9.

TABLE 6: Total sales of Gcal/h units in the Oradea district heating system in 2015 (space heating + hot water)

2015 (Gcal/ h)	Total sales	%	Fossil fuel	%	Geothermal	%
Space heating	450,390	80.6%	432,630	96.1%	17,760	3.9%
Hot tap water	108,382	19.4%	92,397	85.3%	15,985	14.7%
Total	558,772	100	525,027	94.0%	33,745	6.0%

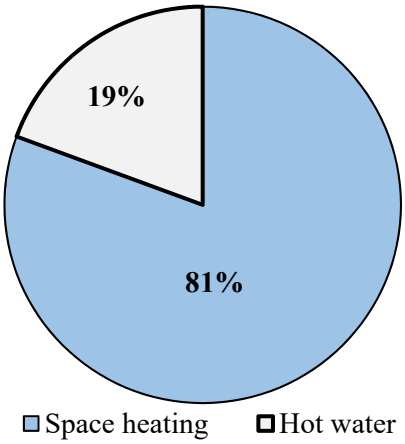

FIGURE 9 : Proportion of thermal energy consumption in Oradea in 2015

The data in Table 6 were processed from the information obtained from Termoficare in September 2016. It shows that main part of thermal energy for users is needed for space heating, which is operated an average period of 6 months, between the months of October-April. As expected, the geothermal input is mainly used for the hot water production (14.7% of the total Gcal units produced are used for hot water production) (see Figure 10). Based on this, a proposed option is, that during the summer period (May-

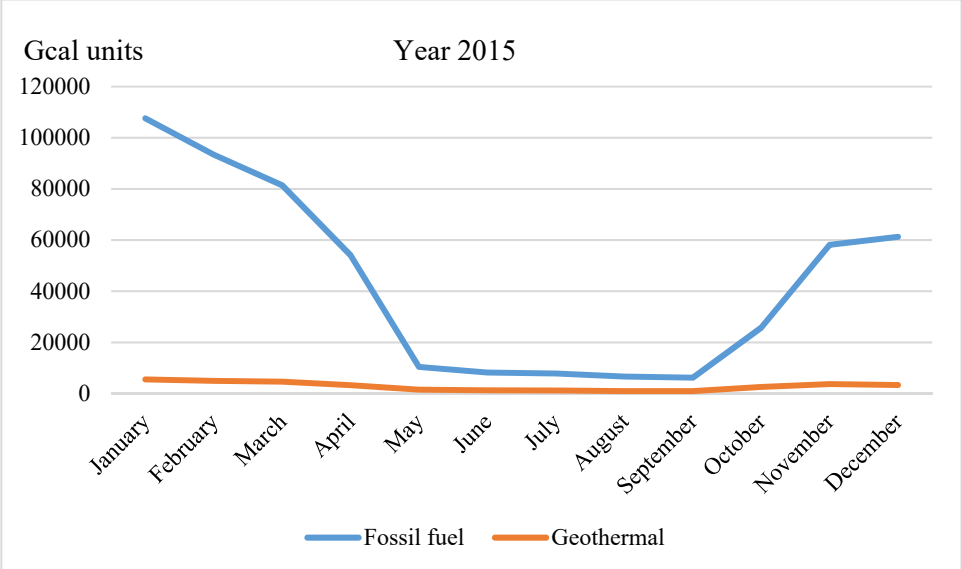

FIGURE 10: Monthly thermal energy sales in ORADEA district heating system

September), geothermal input in Oradea is increased to fully cover the needs of the system for hot water production, as there is a potential to increase the exploitation to 200,000 Gcal/year (personal communication with Transgex staff members). This means a considerably increased share of the geothermal energy in the total thermal energy mix.

In 2015, the data analysis on the monthly thermal energy consumption in the Oradea district heating (Appendix 1 – table with Gcal units consumption), reveals the heavy consumption due to the cold winter experienced (October-April). Figure 11 shows the consumption and the sources of thermal energy during the cold year of 2015 for the Oradea district heating system.

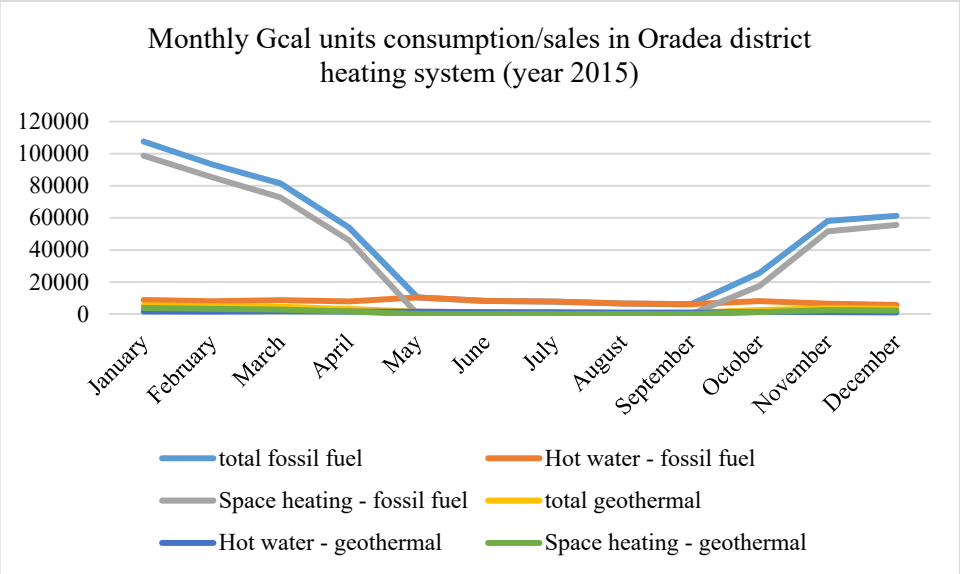

FIGURE 11: Consumption and sources for the thermal energy use in the Oradea district heating system during the year of 2015

A further review, reveals the high space heating demand, especially during the critical 3 months of January, February and March, covered by the cogeneration plant from fossil fuel. The geothermal energy is mainly providing for the hot water part, maintaining a stable delivery system for the district heating.

When discussing the thermal energy price policy in Oradea, it must be considered that Termoficare Company is producing the fossil fuel energy, but purchases the produced geothermal energy from Transgex, an independent private operator under state control. The total thermal energy is sold to the local district heating market at a weighted average price (final unique selling price on the market) of 260.7 RON/Gcal (Termoficare, 2015), which is converted to 57.9 €/Gcal (24% VAT included), at the currency rate of the Romanian National Bank for September 2016 (1 Euro = 4.45 RON). The continued calculations are based on this currency conversion, showing the market price and sales of thermal energy in Oradea. Table 7 shows the total Gcal thermal energy sales registered by Termoficare during 2015. It underlines the pricing policy and the total sales.

TABLE 7: Market prices and sales of Gcal units in Oradea in 2015

Year 2015	**Price Euro/Gcal (VAT included)**	**% of total price**	**Sales (Gcal)**	**Sales (Mil. Euro)**
Thermal energy sale price / Gcal	58.6	100	558,772	32.7
Local price billing/ Gcal	53.9	92.1%	-	30.1
Local subsidy / unit	4.7	7.9%	-	2.6

The final local thermal energy market price/Gcal is benefiting from the local subsidy policy (7.9%) from the Oradea municipality, in order to reduce the heat cost for the citizens. This local subsidy is not granted for business entities; they have to pay the full price of 58.6 €/Gcal (VAT included).

The registered losses from the thermal energy distribution and transportation network (Termoficare, 2016) reveal an annual loss of approx. 37.6% from the total Gcal production (approx. 1.5 M€). The huge losses put a constant pressure on the Gcal/unit cost on the local thermal energy market. This underlines the urgent need for the district heating distribution and transport network rehabilitation, revealing the urgency and importance for solving this problem. Even if these losses were not sold on the market, based on a stable demand on thermal energy, the production could slow down and reduce the costs for the extra production, distribution and transportation.

Losses from the system represent opportunity costs. In the near future, correlated to the declared rate of losses in the system of 34% for the year 2016, the production will lower as it does not have to cover so many losses, and can better adapt to the local economy trend regarding the thermal energy demand for district heating. The impact of low price geothermal in Gcal/unit on the thermal energy market is given in Table 8.

TABLE 8: Price analysis of Gcal thermal units (fossil fuel vs. geothermal):

Year 2015	**Euro/ Gcal**	**% of total price**
Geothermal Gcal price sold to DH	19.18	33.1%
DH Gcal price – mostly gas based	57.9	-
Final consumer price / Weighted average price	57.9	-

The data from the table underlines the fact that the selling price of geothermal energy/Gcal from Transgex towards Termoficare, is 3 times lower than the thermal energy/Gcal produced by fossil fuels. It is though important to note that for the final market price for of Gcal towards the end users, this comparison does not include the additional cost of distribution and transportation of the geothermal Gcal to the end user. A more detailed analysis to this aspect will be further developed in the next calculations, considering the production price as the reference point for an appropriate comparison between fossil fuel vs. geothermal feasibility analysis.

After processing the financial report of the public companies managing the district heating (Termoficare, 2015) the correlated data reveals the price structure, according to the Romanian legislation. The structure of the price and percentages of the total price were calculated (Tables 9 and 10).

TABLE 9: Thermal energy market price structure analysis – year 2015

	Fossil fuel		**Geothermal**
Euro/Gcal	**Electrocentrale**	**Termoficare**	**Transgex**
Production price	26.4	0	14.6
Transport tariff	0	8.2	4.6
Distribution tariff	0	14.1	0
Weighted average price = final price local market	58.6		19.2
Legal framework	ANRSC decision no. 3514/27.11.2013	ANRSC approval no. 114434/02.10.2013	ANRSC approval no. 215075/16.07.2014

TABLE 10: Gcal production prices - structure and sources analysis – year 2015

Gcal production prices in 2015 – structure & sources			
Thermal energy resource	**Customers**	**Price Euro/Gcal**	**% of consumer Gcal price**
Fossil fuel	Population Economic entities	26.4 27.4	45.0% 46.7%
Geothermal	Population Economic entities	14.6	24.8%

The analysis of the thermal energy production prices from the fossil fuel vs. geothermal resources, considers that the distribution and transport tariff for the primary and secondary distribution and transportation network of the district heating will also have to be added, no matter what the energy source is. It could be added as an extra cost only for the geothermal fluid transport cost to the thermal stations. The geothermal Gcal distribution price is 75.9% of the total selling price of geothermal Gcal towards the district heating system (Table 11 and Figure 12). Reported as the weighted average price of Gcal on the local market, the production price is 24.8% of the final price.

TABLE 11: Average price break down structure in the local DH thermal energy mix in Oradea – 2015

Price structure	Euro/Gcal	% of final price
Production	26.4	45.0%
Distribution	14.1	24.1%
Transport	8.2	14.0%
Others	9.9	16.9%
Total	58.6	100

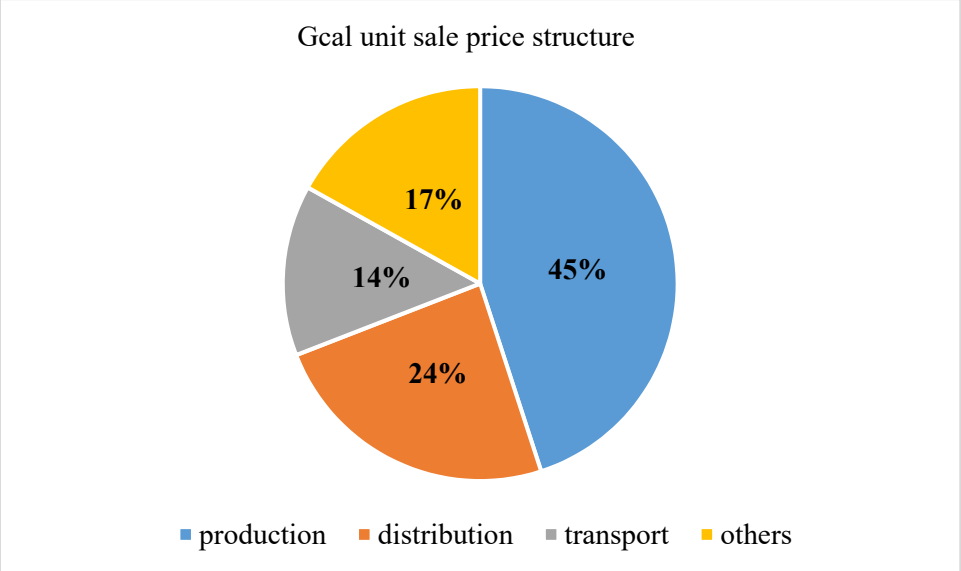

FIGURE 12: Average price structure in the local thermal energy mix

It is clear that the production price is the most important component of the final Gcal price on the market for a gas-based operation. For a clear comparison between the final thermal energy selling price of the fossil fuel Gcal vs. the geothermal Gcal, one has to consider that for the geothermal Gcal, the selling price is actually the selling cost towards the district company, without the extra costs for the distribution and transportation in the district heating network to the final users. For a clearer and close to reality comparison, it is better to compare the production prices of both (Table 12).

TABLE 12: Unit production prices (Euro/Gcal) – fossil fuel vs. geothermal – year 2015

Production price	**Fossil fuel**	**Geothermal**
	26.4	14.6

In terms of production prices of thermal energy in the Oradea district heating system, the geothermal Gcal unit feed-in price is 1.8 times less than the fossil fuel production Gcal unit:

1 Gcal geothermal production price = 0,56 x Gcal fossil fuel production price

As a main result regarding the 2015 geothermal energy production and sale analysis, related to the existing situation of geothermal utilization in the Oradea district heating and the comparison vs. the fossil fuelled thermal energy, the important data is emphasized in Table 13.

TABLE 13: Geothermal energy input and results in the thermal energy mix of 2015

Geothermal Gcal units production sales	**% from total thermal energy mix sales**	**Savings (%)**	**Savings (Euro)**
33,745	6%	4.5%	242,964

2.2 Intermediary conclusions

In order to improve the utilization efficiency of the geothermal resources based on the existing infrastructure and context in Oradea, the following conclusions have to be considered:

- The current exploitation rate of the Oradea geothermal reservoir is around 44%, with an average production of 60,000 Gcal/year, most of which is used for supplying approx. 6% of the total energy mix of the Oradea district heating system. The rest is sold by Transgex on the local energy market (to users which are not connected to the district heating system).
- The geothermal energy production from the Oradea perimeter can be improved with the existing infrastructure up to a production of 200,000 Gcal/year.
- Geothermal power production is not considered by the local geothermal operator (Transgex) as a viable approach for exploitation, due to low temperature of the Oradea geothermal reservoir. Its most efficient usage is producing thermal energy (due to malfunctioning legislation, low electricity price on the market, no state subsidies or green certificates).
- Geothermal energy in Oradea is mainly used for the district heating purposes, as it provides thermal energy for 70% from the population:
    - Geothermal energy mainly serves the market demand for hot tap water (14.7% of total mixed production of Gcal units)
    - Increasing the geothermal resource input in the thermal energy mix of the district heating to the full potential of the existing wells and geothermal stations (around 200,000 Gcal/year which would generate 35.8% in the total yearly thermal energy mix) will generate 8.3% savings related to the production prices of approx. 1.2 M€/year.
    - This will also reduce the DH energy costs (the production price of 1 unit geothermal Gcal is 1.8 times cheaper than the fossil fuelled Gcal/unit) for the population and economic entities. It will also reduce the local subsidy offered by the local municipality to support the population.
    - Actions are needed to reduce the losses of the district heating distribution and transportation network (approx. 1.5 M€/year) for a more feasible economic model of the district heating.
    - Improvements and extensions in infrastructure are needed for increased access and utilization of the geothermal fluid in the district heating system.
    - Furthermore, maintaining and boosting of the thermal energy market demand are needed in the area by supporting dedicated areas for district heating consumers and preparing new

development areas (Industrial Parks, Sport Centre, Ceyrat residential area, total geothermal coverage in Sinmartin area).

- Other utilization forms of geothermal energy in Oradea are limited and at a very low rate. The existing infrastructure and location of the geothermal source do not encourage reuse of the geothermal spent water for other utilization forms due to lack of infrastructure (except in the area of the Iosia geothermal plant, with cascaded utilization in the outdoor swimming pools nearby).

The above-mentioned points have to be included in the local and metropolitan development strategy, for a more efficient and sustainable approach. An improved policy for geothermal energy efficiency utilization must be based on the following main principles:

- Increase in heat exchanger efficiency in DH substations;
- Use of geothermal heat mainly for hot tap water production;
- Increased use of geothermal energy in the local DH thermal energy mix;
- Reducing the losses from the district heating distribution and transportation network.

3. FURTHER DEVELOPMENT OPPORTUNITIES FOR GEOTHERMAL EXPLOITATION AND UTILIZATION IN ORADEA AND THE METROPOLITAN AREA

3.1 Short facts on the geothermal development opportunities in Oradea

The potential

- 56% reservoir capacity exploitation is still available in the Oradea perimeter;
- There are 14 existing wells 3 and geothermal stations plus additional wells from the metropolitan area (existing wells and potential projects for drilling of new wells in Oradea, Bors, Girisu de Cris, Toboliu);
- Increased heat demand request has been identified for the district heating (Oradea, Sanmartin) which can be covered by the existing infrastructure up to the full potential capacity of the Oradea reservoir and the wells from Bors and Santandrei.

Opportunities

- Local and national economy trends require renewable and cheaper energy;
- EU funding sources are available for geothermal development investments or related activities in the cascaded utilization line (PNDR, POIM, ROHU, EEA Grants, etc.);
- *Oradea Geothermal City* – in April 2016, the local administration management publicly accepted the idea of obtaining the license for exploration and drilling for geothermal resources – this is included in the Local Development Strategy of Oradea 2014-2025;
- *Oradea Geothermal Cluster* – based on the existing geothermal traditions and infrastructure in Oradea, a regional association platform should be created to lobby, promote and support legislation change in favour of geothermal development in Romania. This includes financing, state subsidies, green certificates, changing of the Mine law and reconsidering geothermal as a renewable energy as well as putting it under a different legislation – water, energy. Separate law is needed for geothermal resources.

Challenges

- National legislation (geothermal = renewable resource, green certificates, state support etc.);
- Coherent development strategy (national, regional and at local level);
- Funding (EU grants eligibility, World Bank, European Bank of Investments, public and private partnerships, etc.);

3.2 Energy price levels

Analysing the European Union natural gas import price historical data (YCHARTS, 2016 – Appendix II), it is clear that the actual price is at an historical lower level (Figure 13). The utilization of the geothermal energy resources has been delayed due to the high investment costs and the very low price of the hydrocarbons. However, with the current international market prices of fossil fuels, and the dramatic decrease of the domestic oil and gas production, the geothermal development has favourable conditions.

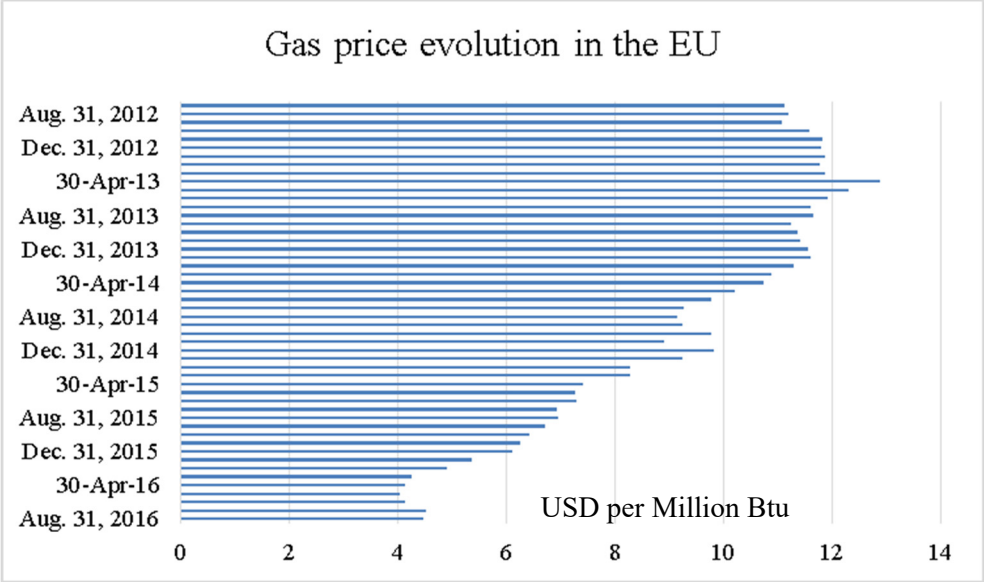

FIGURE 13: Natural gas price history (YCHARTS, 2016)

The risk analysis related to the increasing price of the natural gas on the international market, will directly determine the increasing final price of the Gcal unit in the Oradea district heating system. The sensitivity and risk analysis data regarding the natural gas price evolution underlines the disaster that can happen, and the need to further develop the geothermal system as an alternative in Oradea thermal energy market. Projections related to the year 2015 indicators (production, price, sales) are set as a reference point in order to generate different scenarios for development of the geothermal input and can divided into 3 phases. The timeline of implementation of these development phases also takes into consideration the 5-year sustainability period of the EU funded gas cogeneration plant, after which it is possible to propose a major change in the local thermal energy mix in favour of the geothermal resources.

3.3 Oradea geothermal supply and demand market – further development plans

A short analysis of the existing infrastructure in Oradea (Figure 14) and the geothermal development opportunities from the technical side emphasizes some specific potentials (Transgex, 2016; Termoficare, 2016; personal communication with staff members) highlights the following:

- *Ioşia geothermal station* is connected to the M2 primary network, including the heat stations PT 510 and PT 511. Well 1731 was connected to the Iosia geothermal power plant to provide the thermal energy for the *Andrei Saguna* and *Traian Vuia* high schools. Deep well line shaft pump was installed in well 1717 and connected to Ioşia geothermal station to provide geothermal heat to sub-stations PT 510 and PT 511.
- A new updated project for a geothermal plant in Nufarul for harnessing geothermal energy in combination with heat pumps and natural gas to produce thermal energy for heating and hot water

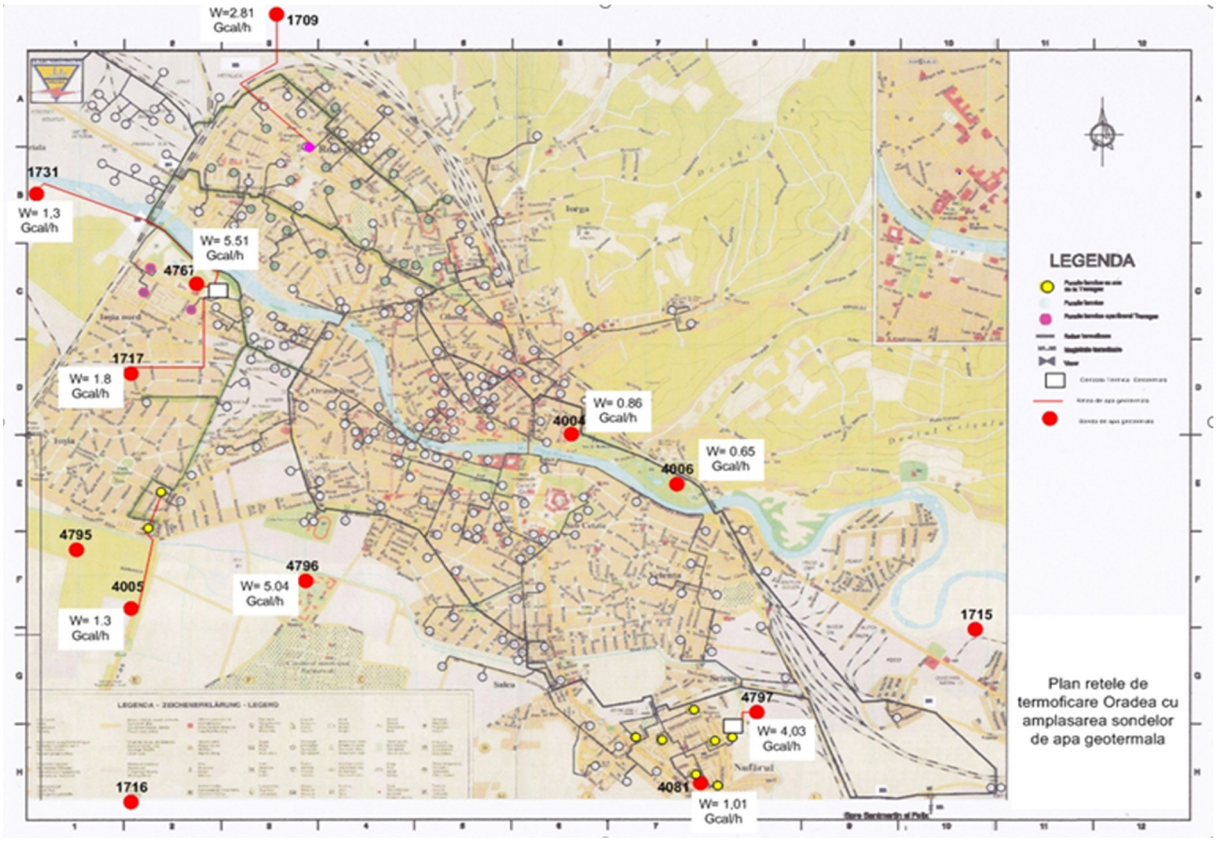

FIGURE 14: Heating networks in Oradea with the wells location and geothermal energy potential (Transgex 2016)

consumption to consumers in Oradea I Nufarul district.

- *Geothermal system for the Felix + Sinmartin areas*, either from existing sources or by updating the Nufarul 1 project with a new geothermal plan that can cover this special area (geothermal for Sinmartin / Felix). This project involves rethinking and updating the technical documentation for the Nufarul 1 geothermal plant, by converting the plant and replacing the heat pumps with pumps that provide geothermal energy (for hot water and space heating) towards Felix-Sanmartin area for the summer.
- Connection of new consumers to the geothermal pipeline from well 4796 to thermal unit PT 902 with new heat exchangers. The flow rate of well 4796 is high enough to allow for new consumers, which could include: Bihor County Library, building of Cadastral Office, Economy High School, the new Sports Centre, etc.
- Connection of well 1715 in Velenţa district to thermal unit PT 836, including thermal units from Dragos Voda district, and/or PT 864 with the block flats from the Moreni street, Ioan Slavici School and other economic entities.
- A new residential geothermal plant for customers in the Ceyrat residential area and the Polivalenta Hall, through thermal units PT 850 and PT 834.
- The main strategy for the district heating should be to assure hot water production from geothermal sources. The geothermal water will be transported from the wells located in the southwest section of the city, towards the DH plant where the hot water / primary heating energy is produced. In this option, Termoficare public company remains the official producer of domestic hot water, only changing from gas to geothermal fluid for the production of hot water for consumption. Transgex Company will remain the provider of the geothermal water.

Figure 15 shows the various types of utilization of geothermal energy in the Oradea metropolitan area. Appendix III lists geothermal projects that are believed to be in the pipelines in the Oradea area.

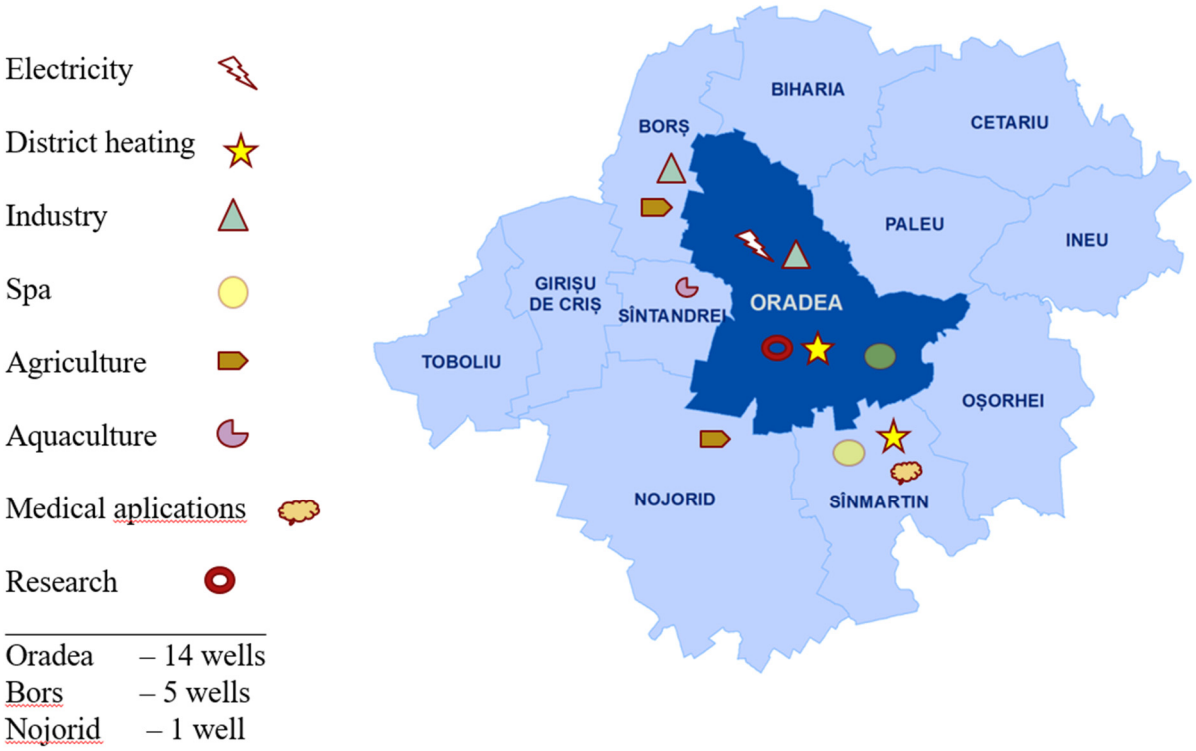

FIGURE 15: Various types of utilization of geothermal energy in the Oradea metropolitan area

3.4 Geothermal Road Map 2030 for the Oradea metropolitan area

For further geothermal development in Oradea metropolitan area, a *Road Map 2030* scenario is presented as a guideline model for planning the extended use of geothermal energy and to increase its efficiency. Starting point of the model is the need of a more efficient approach regarding the existing infrastructure, increasing the geothermal input into the district heating thermal energy mix and also extending it to the surrounding communities where existing wells can be used and directed towards the main consumers in Oradea. Based on the existing geothermal project pipeline, drilling of new wells is proposed in Oradea (3 wells), and more in Girisu de Cris, Toboliu.

The roadmap includes 3 phases aimed at increasing exploitation to 90% through reinjection, up to 500,000 geothermal Gcal units; and drilling of 3 new wells in Oradea and 2 new wells at Girisu de Cris and Toboliu. The areas (Figure 16) to be developed and the timeline are the following:

Area 1 – Oradea (2017): Electricity, district heating, industry, thermal bathing, research, medical.

Area 2 – Oradea, Bors, Sinmartin, Santandrei (2020): Electricity, district heating, industry, thermal bathing, agriculture, aquaculture, research, medical.

Area 3 – Girisu de Cris, Toboliu, Nojorid (2030): 1 + 2 + Electricity, agriculture, aquaculture.

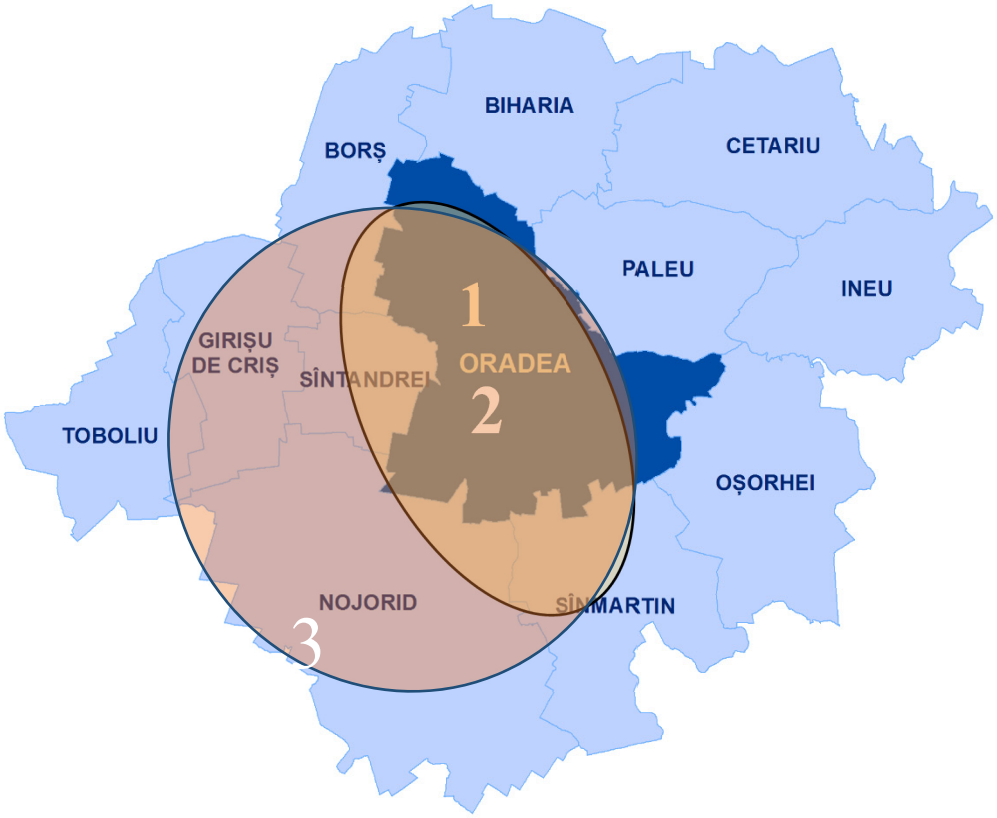

FIGURE 16: The 3-phase geothermal development model for Oradea

3.4.1 Phase 1 – current maximum geothermal production exploitation from the Oradea reservoir

The first phase is based on a more efficient model for the current utilization of the existing geothermal resources, and includes the following (see also Table 14 and Figure 17):

- Timeline: 2016/2017.
- Total production: 200,000 Gcal/year from the Oradea perimeter.
- Geothermal input in the thermal energy mix: 35.8 %.
- Necessary investments in the access infrastructure of the district heating system for the geothermal fluid.
- Geothermal energy used mainly for hot water production in the district heating system.

TABLE 14: Gcal unit sales projections in the Oradea district heating for the period 2016/2017 using the maximum geothermal input (200,000 Gcal/year) in the total thermal energy mix:

Thermal energy sales projection (Gcal/year) Comparison 2015 – future projection with 200,000 Gcal geothermal input			
Year	**Total**	**Fossil fuel**	**Geothermal**
Reference period – production 2015 (Gcal) % input in total thermal energy mix	558,772	525,027 94.0%	33,745 6.0%
Scenario 2016/2017 (Gcal/year) % input in total thermal energy mix	558,772	358,772 64.2%	200,000 35.8%
Market production price (Euro/Gcal) Production price sales 2015 (Euro) Production price sales estimates 2016/2017 (Euro)	 14,508,617 13,311,581	26.4 13,860,713 9,471,581	19.2 647,904 3,840,000
Savings/year for 2016/2017 (Euro) Savings/year for 2016/2017 (%)	**1,197,036 8.3%**	**4,389,132**	**-3,192,096**

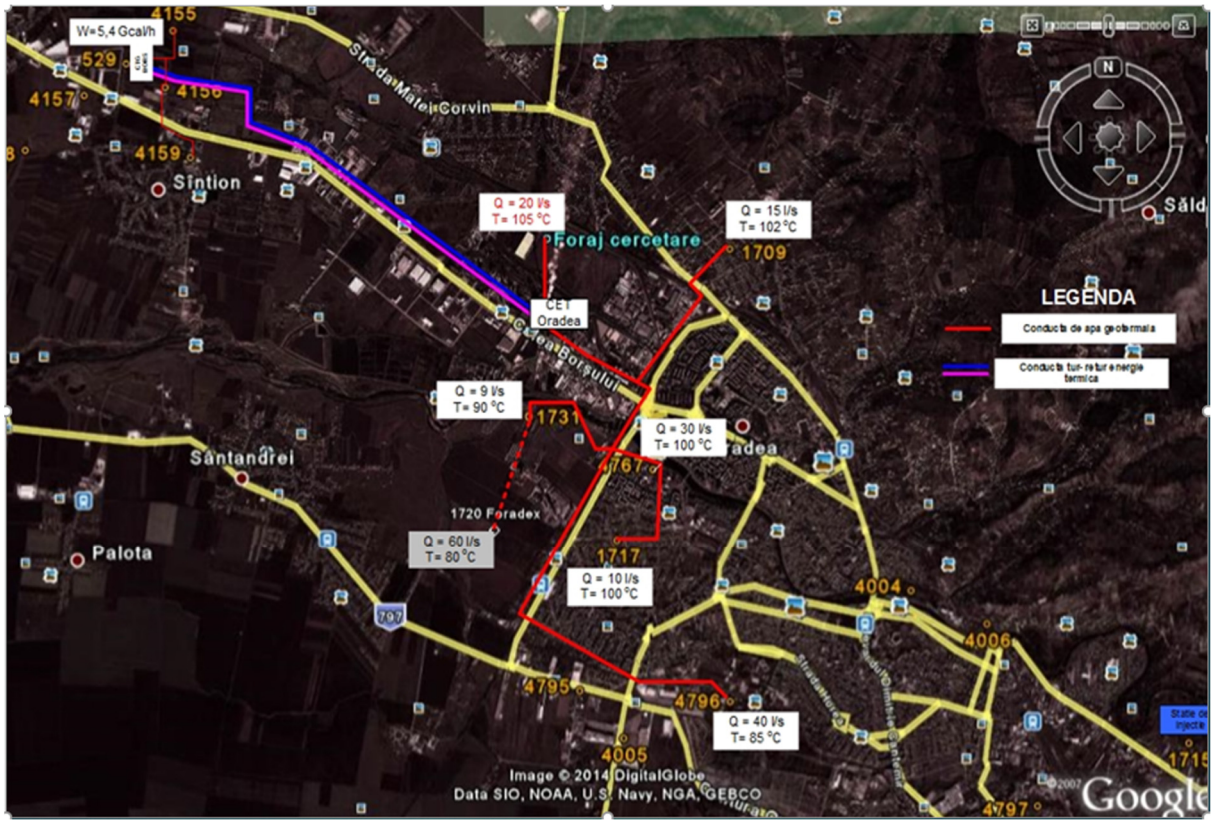

FIGURE 17: Geothermal wells that will be in service for CET Oradea (Transgex, 2016)

The projection model starts with the 200,000 Gcal units input in the total thermal energy mix as the maximum limit of geothermal exploitation results input from the Oradea reservoir (Transgex staff members, personal communication), in terms of infrastructure capacity (wells, temperature and pressure, geothermal stations etc.). The projection is based on a future period of 2016/2017 taking the data values from the year 2015 as a reference point for the total production of Gcal sold on the market. This generates a change in the thermal energy mix of the Oradea district heating system, as the geothermal resource input is up to 35.8% in the total yearly thermal energy mix, generating 8.3% savings related to the production prices of approx. 1,2 million Euro's/year. The values were compared in terms of production price sales (the only common dimension for comparison available at this point).

It is important to mention that for this goal, some investment is necessary for the improved access and more efficient utilization of geothermal energy in the Oradea district heating systems (equipment's, connections, system modifications and adaptations, geothermal substations, etc.). But this investment can be recovered in medium term from the generated savings based on the production price reduction. The injection rate has to increase as well, considering the legal binding level of 90 l/s natural recharge rate. This adds extra costs for the increased geothermal input in the total thermal energy mix of the district heating.

There is an element, which can affect this comparison. Fossil fuel thermal energy benefits from the cogeneration bonus and state subsidy, which is an extra advantage. But due to the fact that this aid scheme is only going to going to run for the next 5 years, the projections did not take it into consideration in the long run.

Presently, 50% from the total geothermal energy produced by Transgex goes to the Oradea district heating, while the rest has been sold to private and economic beneficiaries in Oradea. For the scenario presented above, it is assumed that all the geothermal energy is going straight to the district heating system. This would mean that former separate clients of Transgex need to move to the centralised system of the municipality.

3.4.2. Phase 2 = Phase 1 + new geothermal energy input from Oradea, Bors and Santandrei

The second phase is based on extended metropolitan model of usage of the existing geothermal resources (Figure 18 and Table 15):

- It considers Phase 1 as implemented, and continues the trend of increased geothermal input in the thermal energy mix of the Oradea district heating.
- Timeline: 2017/2020.
- Metropolitan approach (surrounding wells used for the district heating system).
- Total production: 360,000 Gcal/year = 200,000 Gcal/year from the Oradea perimeter + 100,000 Gcal/year from the Bors wells and 60,000 Gcal/year from the Santandrei well 1720.
- Geothermal input in the thermal energy mix: 36 %.
- The main consumption will go to the Oradea district heating system, plus the cascaded utilization model proposed in Santandrei (heating, hospital, aquaculture, greenhouse, bathing).
- Investments are necessary in the access infrastructure of the district heating system for the geothermal fluid from Bors and Santandrei to the Oradea thermal units and distribution and transportation network.
- Geothermal energy is mainly utilized for hot water production in the district heating system.

FIGURE 18: Phase 2 = Oradea + Bors + Santandrei (2020)

Bors geothermal reservoir is located in Triassic limestone and dolomite, at depths of 2,000-3,000 m, with an area of approximately 12 km^2, about 6 km northwest of Oradea. It is a closed reservoir with no natural recharge. The wellhead temperatures are about 120°C. Mineralization is 13 g/l with scaling prevented by downhole chemical inhibition and keeping CO_2 in solution (Transgex, 2016, staff members, personal communication).

Five geothermal wells have already been drilled, out of which 3 wells can produce up to 50 l/s (artesian) and 2 wells are used for reinjection. The cold water from shallow wells is injected into all 5 wells during the summer to build up reservoir pressure. The transport of thermal energy from the Bors perimeter to the cogeneration plant in Oradea to be used for preheating its make-up water. The main beneficiary of the potential thermal energy from Bors perimeter will be the cogeneration plant run by SC Termoficare S.A. The expected production potential of geothermal energy from Bors area is around 100,000 Gcal/year.

The Santandrei well 1720: According to data provided by the private owner company (Foradex, 2016), it has to artesian flow rate of 50 l/s with a temperature of 80°C. The plans are to increase the utilization of geothermal heat in the Oradea district heating system (space heating and hot preparation) for connected buildings in the Iosia district, and for future projects in the area (hospital, greenhouse, swimming pool/spas). For this purpose, it is expected to install a shaft pump into the well with the capacity of 60 l/s. The expected production of geothermal Gcal units from the area is around 60,000 Gcal/year. Also investment is necessary in the access infrastructure of the district heating system for the geothermal fluid.

Bors and Santandrei are considered input geothermal energy sources for the Oradea district heating system. Hence, the total expected production will be 360,000 Gcal/year, from which a total of 200,000 Gcal/year comes from the Oradea perimeter, 100,000 Gcal/year from the Bors wells and 60,000 Gcal/year from the Santandrei well 1720.

TABLE 15: District heating energy production projections in Oradea for the period 2020 using 360,000 Gcal/year geothermal input in the total thermal energy mix:

Thermal energy sales projection (Gcal/year) Comparison 2020 / future projection with 360,000 Gcal/year geothermal input			
Year	Total	**Fossil fuel**	**Geothermal**
Annual production, ref. 2015 (Gcal/yr) 2015 % input of energy source	558,772	525,027 94%	33,745 6%
Scenario 2020 (Gcal/yr) 2020 % input of energy source	558,772	198,772 35%	360,000 64%
Production prices (Euro/Gcal) Annual production cost 2015 (Euro/yr) Annual production cost estimate 2020 (Euro/yr)	 14,508,617 12,159,581	26.4 13,860,713 5,247,581	19.2 647,904 6,912,000
Savings/year for 2020 (Euro) Savings/year for 2020 (%)	**2,349,036 16.2%**	**8,613,132**	**-6,264,096**

The projection model starts with the 360,000 Gcal units input in the total thermal energy mix, considering that Phase 1 is already implemented, and other opportunities are still exploited. The projection is for the future period of 2016/2017 assuming the consumption of district heating energy in Oradea has not changed from the values of the year 2015. This is most likely an over estimate since by 2020 the enormous heat and water losses in the old distribution system, see chapter 2.1.2, will have been reduced to a normal rate through the annual ongoing rehabilitation projects.

This generates a change in the thermal energy production mix of the Oradea district heating system as the geothermal resource share is up from 6 to 36%. This leads to 16.2% savings in production cost for the Oradea district heating company (DH), or approx. 2.3 million Euro/year. It is important to be aware of that for this scenario, considerable investment is necessary for the improved access and more efficient utilization of the geothermal energy in the DH (new wells, down hole pumps, inter-connections and heat exchangers, etc., heat substations etc.). For simplicity and due to lack of detailed data, this calculation assumes that the feed-in price for the geothermal heat energy can be maintained at the same level as current price. It also assumes that the production cost of heat energy from the gas fired co-generation plant has not changed.

3.4.3 Phase 3 = Phase 1 + Phase 2 + new drilling projects for geothermal energy input from new wells in Oradea, Bors, Girisu de Cris and Toboliu

The third phase is based on an extended metropolitan model for utilization of the existing geothermal resources (Figure 19 and Table 16):

- Considers phase 2 as already implemented, and continues the trend of increased geothermal input in the thermal energy mix of the Oradea district heating.
- New wells are scheduled to be drilled and exploited in Oradea (3), Bors (1) and for other forms of cascaded utilization in Girisu de Cris (1) and Toboliu (1).
- Timeline: 2020/2030.
- Total production: 360,000 Gcal/year from the Oradea perimeter.
- Geothermal input in the thermal energy mix: 64 %.
- Necessary investments in the access infrastructure of the district heating system for the geothermal fluid.

FIGURE 19: Phase 3 Oradea Metropolitan Area (2030)

The projection model starts with the 500,000 Gcal units input in the total thermal energy mix, considering that phase 2 is already implemented, but other opportunities are still unused. The projection is based on a future period of 2030 taking the data values from the year 2015 as a reference point for the total production of Gcal sold on the market. This generates a change in the thermal energy mix of the Oradea district heating system, as the geothermal resource input is up to 64% from total yearly thermal energy mix, generating 16.2% savings related to the production prices of approx. 3,3 million Euro's/year. The values where compared in terms of production price sales (the only common dimension for comparison available at this point).

It is important to mention that for this goal, considerable investment is necessary for the improved access and more efficient utilization of geothermal energy in the Oradea district heating systems (equipment's connections, system modifications and adaptations, geothermal substations, etc.). However, this

investment can be recovered in medium term from the generated savings based on the production price reduction.

Phase 3 contains the investment project for drilling of 3 new wells and exploitation equipment in Oradea DH, at Oradea Fortress, Industrial Park, Tancodrom, at Termoficare, close to the cogeneration plant. It also includes investment for other applications in the surrounding area as Girisu de Cris, Toboliu, Bors (heating, industry, medical, aquaculture, agriculture, spas):

- Drilling of a new well in Girisu de Cris is proposed for geothermal power production, heating and 20 ha greenhouses.
- Drilling of the new well in Toboliu is proposed mainly for agriculture (greenhouses) and aquaculture.
- The 3 new wells proposed for drilling in Oradea for the district heating are at the following points: Oradea Fortress, Industrial Park – Tancodrom, and at Termoficare, close to the cogeneration plant.

TABLE 16: Gcal unit sales projections in the Oradea district heating for the period 2030 using the maximum geothermal input (500,000 Gcal/year) in the total thermal energy mix

Thermal energy sales projection (Gcal/year) Comparison 2030 /future projection with 500,000 geothermal input			
Year	**Total**	**Fossil fuel**	**Geothermal**
Reference period production 2015 (Gcal) % input in total thermal energy mix	558,772	525,027 94.0%	33,745 6.0%
Scenario 2030 (Gcal/year) % input in total thermal energy mix	558,772	58,772 10%	500,000 90%
Market production price (Euro/Gcal) Production price sales 2015 (Euro) Production price sales estimation 2030 (Euro)	 14,508,617 11,151,581	26.4 13,860,713 1,551,581	19.2 647,904 9,600,000
Savings/year for 2030 (Euro) Savings/year for 2030 (%)	**3,357,036 30%**	**12,309,132**	**-8,952,096**

3.4.4 Results

The main target of this project is to maximise the utilization of the geothermal energy sources available in the Oradea metropolitan area. The proposed projects should also find solutions for optimizing the supply to all types of consumers in the City of Oradea, with possibilities to expand it to the entire Oradea Metropolitan Area, considering also medium to long-term strategic development. It should also present solutions for increasing the energy efficiency for all types of consumers.

The model generated with this stepwise increase in the geothermal production, also enlarges the thermal energy production source. Adding the district heating distribution and transportation costs, it creates the scenario presented in Table 17.

Starting from the 2015 reference point (production prices, energy produced, quantities/sales, prices), the projection model for the 2017-2030 shows that if implemented, the third Phase strategy model can generate savings in production sales prices of the Gcal unit used in the Oradea district heating as follows:

- 2015-2017: The geothermal input of 6% in the thermal energy mix generates savings of approx. 486 k€;
- 2017-2020: A geothermal input of 36% in the thermal energy mix will generate savings of approx. 3.6 m€;
- 2020-2030: A geothermal input of 90% in the thermal energy mix will generate savings of approx. 23.5 m€.

TABLE 17: Conclusions regarding projections of *input* (geothermal Gcal) and *results* for Oradea district heating system

Geothermal energy input & results projections in the thermal energy mix 3-PHASE strategy – main dashboard				
	Estimated geothermal Gcal units production sales/year	**%/year from total thermal energy mix sales**	**Estimated savings/year %**	**Estimated savings/year Euro**
2015	33,745	6%	4.5%	242,964
Phase 1 - 2016/2017	200,000	36%	8.3%	1,197,036
Phase 2 – 2020	360,000	64%	16.%	2,349,036
Phase 3 – 2030	500,000	90%	30%	3,357,036

In the case of implementing Phase 3, geothermal strategy scenario for the Oradea district heating system, the model estimates a generation of total savings in the Gcal unit production price of approx. 27.6 m€ until year 2019. Onward from 2020 it is recommended to move to the expanded approach of 90% geothermal utilization, that will generate an extra 3.4 m€/year. It is assumed that changes in the market will mean that proportions of structure will be kept.

4. CONCLUSIONS

The EU's Renewable Energy Directive sets a binding target of 20% final energy consumption from renewable sources by 2020. Renewables will continue to play a key role in helping the EU meet its energy needs beyond 2020. EU countries have already agreed on a new renewable energy target of at least 27% of final energy consumption in the EU as a whole by 2030. This target is part of the EU's energy and climate goals for 2030. The National Renewable Energy Action Plan (NREAP) in Romania assumed this targets for Romania also.

In this context, for Romania in general and Oradea metropolitan area in particular, there is an urgent need for an updated geothermal strategy development. This can be done immediately by starting the initial steps:

a) Improve and optimize the existing geothermal utilization;
b) Separate geothermal resources from the Mining law;
c) Gathering and evaluation of existing data about geothermal (update, process and correlation);
d) Assess the geothermal reservoir potential for sustainable utilization based on more than 4 decades of exploitation, mostly in artesian mode;
e) Identifying potential projects – maps of geothermal potential and local applications;
f) Update and expand the surface exploration and exploration drilling aide programme in Romania (the state should not drill, old system thought);
g) A coherent geothermal development concept and project pipeline;
h) Projects initiation and implementation.

Considering the previous geothermal input analysis and the situation regarding the geothermal utilization in Oradea, mainly for the local centralised district heating system, correlated with the current energy market situation and thermal energy demand, the main starting points for further development in Oradea are:

- Natural gas prices are increasing;
- The market demand for heat energy is growing – (residential and industrial development);
- There are other known geothermal reservoirs in the area, which can be harnessed more efficiently in the local and metropolitan energy market;

- It is more feasible to increase the efficiency and volume of the geothermal energy in the local thermal energy mix of district heating (socio-economic feasibility, energy mix security);
- Highest efficiency in low-temperature geothermal utilization is to use it for hot tap water production in the DH system;
- Reducing the heat and water losses in the district heating distribution and transportation network;
- Adding value for the geothermal resource by implementing a cascaded utilization system, creating a connecting system to reutilize the spent (return) geothermal water for other applications;
- Geothermal power production is present but not at full potential;
- Oradea geothermal producer – it is an option considered by the local administration;
- Oradea Geothermal Cluster – a platform for geothermal R & D in Romania, national policy of state support for exploration & drilling, green certificates);
- Legislation and financing issues have to be solved (geothermal resource = renewable resource, state support subsidies for geothermal development, allocation of green certificate MWth, etc.).

Oradea has a tradition for geothermal utilization and research in Romania. The main target is to develop the utilization of the Oradea geothermal reservoir and metropolitan area up to its maximum potential.

Why should the development of geothermal energy be furthered in the Oradea metropolitan area?

- The resource is there and not fully exploited;
- Geothermal input from the metropolitan area (Phase 3 of model) can supply 90% of the needs of thermal energy in the district heating system;
- Based on the model of Phase 3, it can generate heat production cost savings, of approx. 27.5 million Euros;
- There is an increased market demand for thermal energy - not all buildings in the city are connected to the DH system and the city population is growing;
- It is cheaper than fossil fuel and more environmentally friendly, reducing air pollution;
- It increases energy supply safety by using a local energy source;
- Geothermal input generates savings that can reduce the DH energy prices;
- Oradea Geothermal City – a cluster assumed by the local administration to be a part of its development strategy and an Oradea city brand.

How should the development of geothermal be carried out?

- Through more efficient use of the existing infrastructure and adding further development projects;
- Through further improvements to the district heating system connections for the geothermal fluid;
- By preparation of a coherent geothermal strategy, project pipeline and an investment plan;
- With added value through cascaded utilization models;
- With metropolitan approach (common management of geothermal resources in the metropolitan area).

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APPENDIX I: Monthly consumption of thermal energy (Gcal) in the Oradea DH system in 2015 (Termoficare, 2016)

2015 - Gcal	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Termoficare, fossil fuel												
Total	107,607	93,361	81,429	53,993	10,411	8,202	7,815	6,671	6,193	25,731	58,134	61,261
Hot water	8,835	7,989	8,737	7,943	10,411	8,202	7,815	6,671	6,193	8,123	6,515	5,680
Space heating	98,772	85,372	72,692	46,050	0	0	0	0	0	17,608	51,619	55,581
Transgex, geothermal												
Total	5,523	4,926	4,610	3,236	1,527	1,229	1,171	953	949	2,566	3,719	3,336
Hot water	1,624	1,551	1,791	1,572	1,527	1,229	1,171	953	949	1,345	1,214	1,049
Space heating	3,899	3,375	2,819	1,664	0	0	0	0	0	1,221	2,505	2,287
Total / month	**113,130**	**98,287**	**86,039**	**57,229**	**11,938**	**9,431**	**8,986**	**7,624**	**7,142**	**28,297**	**61,853**	**64,597**

APPENDIX II: Historical data on import price for natural gas for European Union in USD per Million Btu (YCHARTS, 2016)

Period	Price	Period	Price
31-Aug-16	4.47	31-Jul-14	9.27
31-Jul-16	4.51	30-Jun-14	9.77
30-Jun-16	4.13	31-May-14	10.2
31-May-16	4.04	30-Apr-14	10.73
30-Apr-16	4.13	31-Mar-14	10.88
31-Mar-16	4.26	28-Feb-14	11.3
29-Feb-16	4.9	31-Jan-14	11.59
31-Jan-16	5.35	31-Dec-13	11.55
31-Dec-15	6.1	30-Nov-13	11.42
30-Nov-15	6.24	31-Oct-13	11.37
31-Oct-15	6.43	30-Sep-13	11.25
30-Sep-15	6.71	31-Aug-13	11.64
31-Aug-15	6.95	31-Jul-13	11.6
31-Jul-15	6.93	30-Jun-13	11.92
30-Jun-15	7.29	31-May-13	12.29
31-May-15	7.27	30-Apr-13	12.88
30-Apr-15	7.42	31-Mar-13	11.87
31-Mar-15	8.27	28-Feb-13	11.77
28-Feb-15	8.27	31-Jan-13	11.87
31-Jan-15	9.25	31-Dec-12	11.79
31-Dec14	9.83	30-Nov-12	11.83
30-Nov-14	8.9	31-Oct-12	11.58
31-Oct-14	9.77	30-Sep-12	11.08
30-Sep-14	9.24	31-Aug-12	11.18
31-Aug-14	9.14	31-Jul-12	11.13

APPENDIX III: Oradea metropolitan area - geothermal projects in the pipeline
(based on discussion/interviews with local administrators in Oradea metropolitan area, September, 2016)

Year	Location	Projects in pipeline	Investment	Budget M Euro	Financing source
2017	Oradea	Rehabilitation of distribution system	10 km primary and 20 km secondary distribution network	4	EU grants
2020	Oradea/Bors	Well drilling (prod. & reinject.), geothermal plant, thermal station, distribution network	Electricity, district heating	8	National funds
2020	Nufarul	Well drilling (prod. & reinject.), geothermal plant, thermal station, distribution network	District heating for Nufarul & Sanmartin (Baile Felix)	14	EU Grants
2025	Santandrei	Exploitation of existing well	Geothermal plant, district heating industry, agriculture spa, medical research	11	EU Grants
2030	Girisu de Cris	Well drilling (production & reinjection) 60 l/s, T = 170°C.	Electricity plant 3 MWe 20 ha. greenhouses	50	EU Grants
Total				87	