MANAGEMENT ORIENTED TOWARDS REDUCING THE ENVIRONMENTAL IMPACT OF INSURANCE SYSTEMS FOR URBAN HEAT

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Abstract - The paper work puts grounds and gives details of the analysis regarding the environment impact of the thermal energy management systems of the urban centers. After presenting the high actuality context, it is presented succinct the characteristics that define the system which is the object of the studied case - the thermal energy management system (TEMS) of Oradea Municipality (OM). In order to stabilize the TEMS structure it is proposed to be applied an optimization model having the function to minimize the costs of producing thermal energy (TE) from primary resources (PR) accessible in the area and having as restrictions the environment impact, as in the maximum availability of the PR. Starting with the three possible scenario for the TEMS of the urban centers (centralized, decentralized and individual) and taking into account the reality of the TEMS analysis, in the paper work are given 8 plausible options of evolution in the next 20 years of TEMS of OM. The comparative analysis of the 8 versions it is made with taking into account the following: the environmental impact evaluated by the quantity of emissions, the TE production evolution and electric energy (EE), the global price of the penalization given by the emissions, the proportion: global environment impact/ total produced energy. The results reflect clear options of evolving of TEMS and provide the specialists with an approach methodology and a way of treating the evolving of TEMS so that it can obtain the structural and functional optimization of TEMS, at the same time with reducing the environment impact.

Keywords: environment, heat, impact, management, urban centers

1. INTRODUCTION

Humanity is facing at present, with few major problems (EC, 2005) such as maintaining environmental impact to an acceptable level and ensures energy resources. (CGP, 2000; EE, 2007).

Conversion of chemical energy of fossil fuels into useful energy for humans, transport and distribution, are the processes most responsible for current levels of pollutants emitted into the atmosphere (Badea and Marculescu, 2010), with harmful impact on the balance of ecosystems.

The Green Paper - A European Strategy for Sustainable, Competitive and Secure energy (CGP, 2000) developed by the European Commission in 2000, has established a comprehensive energy policy in Europe, an essential direction to increase recovery of renewable energy sources (RES), including hybrid energy systems (HES). In the programmatic documents of the EU (CEC, 1997; CEC, 2006; ECD, 1996;) are highlighted the benefits of using RES: increased security of energy supply, reducing long-term volatility of prices paid for fossil fuels, enhance competitiveness of EU energy technology industry, reducing the pollution, including the emissions of greenhouse gas, improving economic and social situation of isolated settlements.

At EU level are set the measures and targets to enhance recovery RES (CEC, 1997; CEC 2006, CGP, 2000; EC, 2005; ECD, 1996). The highest growth rate by 2010 will be achieved by the wind resources (75%), solar - photovoltaic (+200%) and geothermal energy - heat (300). Romania took over, taking it through its own regulations, the imperative of increasing the share of RES in the internal energy balance (GD, 2003; GD, 2005; GD, 2007a; GD, 2007b; Law, 2007). Thus, for 2010, Romania's target is to increase the share of RES to 10% of total consumption of primary energy sources (SPE) and 30% of total electricity consumption. Romania seeks primarily, to increase the recovery of RES: wind, solar, biomass and geothermal, all used within SHE (ARCE, 2003; GD, 2003; GD, 2005; GD, 2007a; GD, 2007b; Gheorghiescu, 2007; Law, 2007; Leca, 2007).

International concerns in the priority area "Energy" refers, equally, at the increasing recovery topic of RES and energy efficiency (EE). Good practices in international energy efficiency (Badea and Marculescu, 2010; CEC, 1997; CEC, 2006; CGP, 2000; EC, 2005; ECD, 1996; EE, 2007) were taken in the Romanian legislation (GD, 2003; GD, 2005; GD, 2007a; GD, 2007b; Law, 2007). For operationalization in 2003 PUND and the Global Environment Fund (GEF) has founded the Energy Efficiency Financing Team in Romania, with a mission to convince companies to invest in energy efficiency.

Operationalization of the national strategy on efficient use of energy and reduce environmental impact of energy processes, involving the application of local strategies that are centered on national targets. In that context, after the development of national strategy (GD,

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2007b) was established the need and framework for developing local strategies, mainly urban centers consumption of TE.

Urban center of the case under study OM is a representative one in terms of energy consumption, but also by the fact that there is a wide range of PR available: fossil fuels (coal, fuel oil and natural gas), geothermal water and biomass.

This paper presents the results of tests carried out on realistic options for insurance of TE on medium term of OM, aiming mainly environmental impact.

2. SYSTEM ANALYSIS AND APPROACH

It has been mentioned that this analysis is dedicated to the TEMS of OM, targeting the identification of development strategy on medium terms (up to 2029) of this system which corresponds to regulations regarding impact on the environment.

Now, in OM the TE is provided mainly by the centralized system which has two sources:Electric central heating Oradea (ECH), with the scheme shown in Fig. 1 and the following main features:

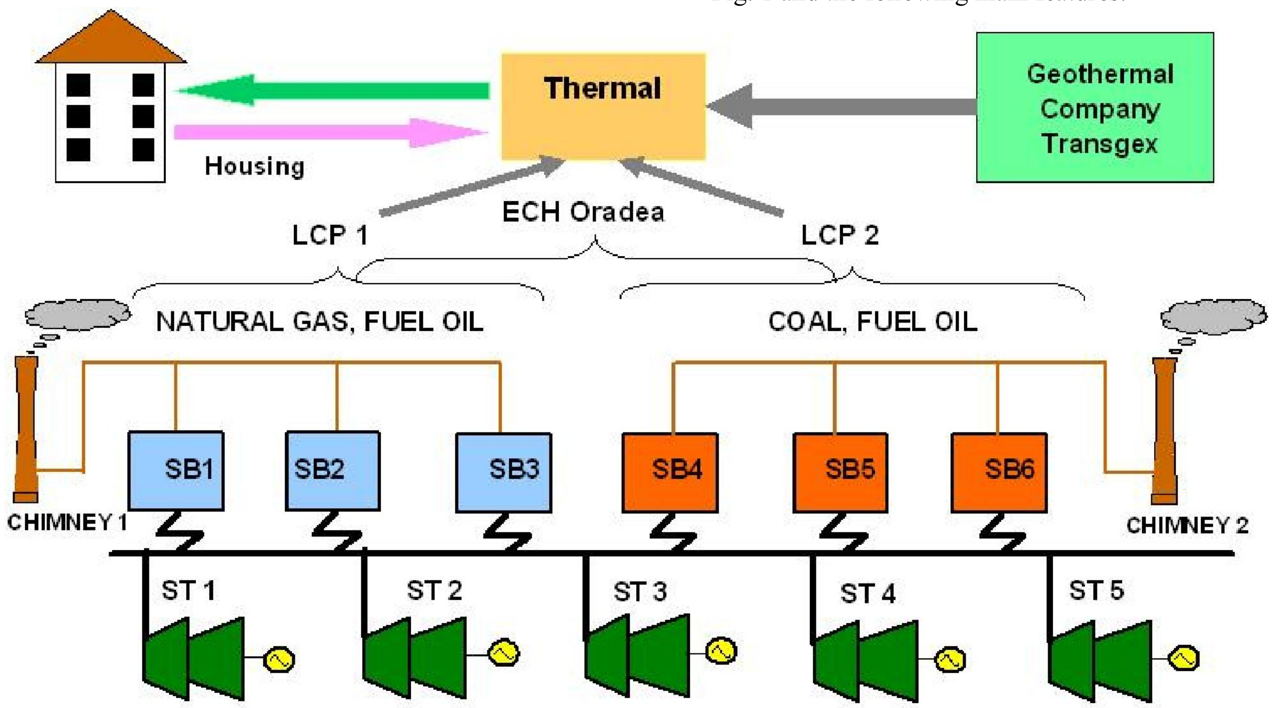

Fig. 1. Schematic diagram of Oradea ECH

In diagram hawe:

- **LCP -** large combustion plant;
- **SB –** Steam boiler with natural circulation;
- **ST -** Steam Turbine<
- **LCP 1** – with an area of 18.1 ha, formed by steam boilers of SB1, SB2 and SB3 (523 MWt): steam boilers SB1 and SB2 operates on natural gas and the waste gas is discharged thru chimney no. , boiler steam, SB3 running on natural gas and fuel oil, in an emergency situation the evacuation of combustion gases is made through the chimney no.
- **LCP 2** - with an area of 10.2 ha, consisting of steam boilers SB4, SB5 and SB6 (869 MWt), which operates on coal (lignite) with support of fuel oil and the exhaust gases evacuation through the chimney flue no.
- **Deposit of slag and ash (DSA) -** is located at a distance of 12 km from ECH Oradea;
- **Water supply** is from Crişu Repede River, and lignite is provided mainly from coal mines Voivozi area, the bazin of Oltenia and Şărmăşag area.

b) The geothermal water reservoir exploited by company TRANSGEX which currently has 12 active wells in OM (11 production wells and one drilling injection) with a production of 210.000Gcal/year.

Evolution and forecast of TE in MO consumption is shown in Fig. 2.

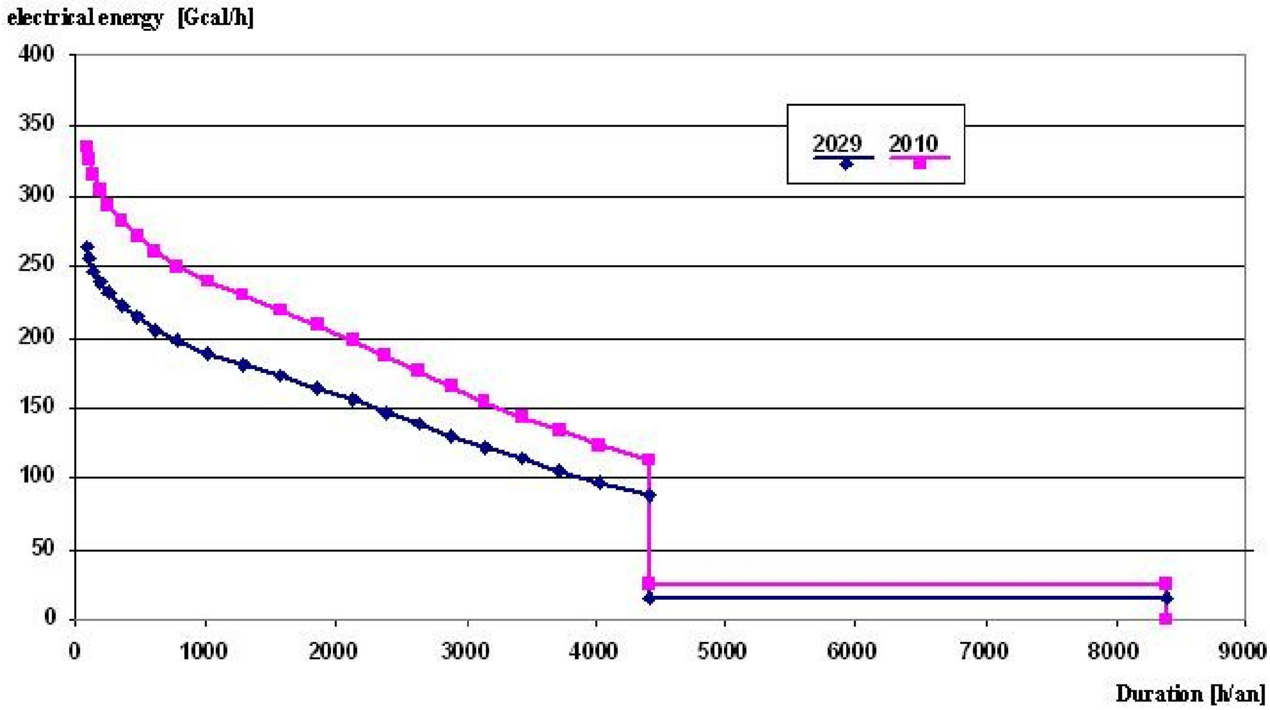

Fig. 2. Evolution and consumption forecast of TE in MO
[classified curve for those two years that define the range of analysis]

To determine the structure TEMS the model of optimization - I (Eqs. 1÷3) for some realistic alternatives is applied under technologically aspect and accessibility of resources:

$$(I)\begin{cases} \sum_{i=1}^{n} \alpha_i \cdot A_i \rightarrow \min & (1) \\ \sum_{i=1}^{n} \sum_{j=1}^{m} \beta_{ij} \cdot A_i \leq \sum_{j=1}^{m} B_j^{max} & (2) \\ \frac{A_i}{q_i} = C_i \leq C_i^{max} & (3) \end{cases}$$

where:

n - number of available PR;

m - number of harmful substances (HS) for the environment and for which are restrictions on the quantity emitted that are pollution charges;

α_i – the specific cost of the insured TE from *PR"i"* [MU/Gcal];

β_{ij} - the specific amount of *HS"j"* produced by the *PR"i"* [kg/Gcal];

A_i - TE ensured from *PR"i"* [Gcal];

B_j^{max} - maximum permissible values for H*S"j"* [kg];

g_i - the calorific value from *PR"i"* [Gcal/t];

C_{and}^{max} - the maximum amount that can be provided from *PR"i"* [T];

MU - monetary unit [EUR, USD, RON].

As seen, equation (1) serves as an "objective function", and (2, 3) are the restrictions. In the specific cost structure *(α_i)* are included all categories of expenses: investment, mining (including consideration of environmental impact) and damage to consumers TE failure. The mathematical model (MM) showed in the system (I) is one synthetic, its application requires detailing the period of analysis and structure of RP and SN. MM is recommended for a reasonable period of analysis of major investments (20 years), which involves operation with updated values (Felea, 1996).

With reference to the TEMS of OM may be taken in discuss three scenarios (ISPE, 2009):

a). Scenario I - the supply of TE in the centralized system:

Defining this scenario is based on the existence of infrastructure: thermal power generator and the transmission and distribution system. It was considered that the system of centralized supply of OM is a living system, characterized by stability.

b). Scenario II - the supply of TE in the decentralized system:

Defining the scenario of how decentralized power infrastructure started from the existence of infrastructure developed over time for the centralized system, given the need not to affect people in the city by reconfiguring the system works. Decentralized system is designed to lead to positive environmental effects and minimal effects (investment, period of implementation) with direct impact the welfare of the population.

c). Scenario III - the supply of TE in the individually system:

In this case we consider ceasing operation of ECH Oradea, population of OM will be fitted with apartment natural gas station.

Given the consistency of the centralized system of insurance in OM with TE during the 20 years of riding in the market economy, economic and social benefits of this system (ISPE, 2009) only **scenario I** is realistic and will be detailed below.

Given the range of PR and the variety of technical

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solutions offered by the current structure of TEMS, **scenario I can be divided into eight types**, detailed in (ISPE, 2009) and summarized in Table 1.

Table 1.TEMS development versions of the MO

Variant	*Equipment / facilities maintained in the current TEMS and PR used*	*Equipment / Plant / new /works and used PR*	*Contribution of renewable energy sources (RES)*
0	**1**	**2**	**3**
1.	- Steam boilers SB1, SB2 and SB3, with operation on natural gas; - SB6 steam boiler, operated on coal/oil; - Steam turbines ST1, ST2, ST3 and ST5; - Thermal power from geothermal sources (about 1-2 Gcal/h).	- Low NO_x burners to SB2, SB3; - Installation of flue gas desulphurization (IGD) at SB6; - Upgrading electrostatic SB6; - Compliance of the deposit of slag and ash; - Expanding deposit of slag and ash; - Slag and ash disposal facility in the dense sludge; - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
2.	- SB1 and SB3 steam boilers with natural gas operation; - SB6 steam boiler, operated on coal/oil; - Steam turbines ST1, ST3 and ST5; - Thermal power from geothermal sources (about 1-2 Gcal/h).	- Low NO_x burners SB3, SB6; - IDG at SB6; - Upgrading electrostatic SB6; - Compliance of the deposit of slag and ash; - Expanding deposit of slag and ash; - Slag and ash disposal facility in the dense sludge; - Provision of a new installation of gas turbine and heat recovery boiler (IGT + HRB) designed for summer; - Provision of a new steam turbine (ST), which will replace the existing turbine ST2; - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
3.	- SB1 steam boiler with natural gas operation (only for the production of steam); - SB6 steam boiler, operated on coal/oil; - ST1 steam turbine; - Thermal power from geothermal sources (about 1-2 Gcal/h).	- Low NO_x burners SB3, SB6; - IDG at SB6; - Upgrading electrostatic SB6; - Compliance of the deposit of slag and ash; - Expanding deposit of slag and ash; - Providing a IGT + HRB fitted for summer; - Provision of ST, which will replace the existing turbine ST5; - Installation of two hot water boilers (HWB) on natural gas; - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
4.	- SB1 and SB3 steam boilers with natural gas operation; - ST1 and ST3 steam turbines; - Heat supply from geothermal sources (about 1-2 Gcal/h).	- Low NO_x burners SB3; - Compliance of the deposit of slag and ash; - Expanding deposit of slag and ash; - Providing a IGT + HRB fitted for summer; - Installing a new cogeneration power generating group which operates on coal, which includes a steam boiler SB (350t / h) and ST (50 MW); - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
5.	- SB1 and SB3 steam boilers with natural gas operation; - ST1 and ST3 steam turbines; - Heat supply from geothermal sources (about 1-2 Gcal/h).	- Low NO_x burners SB3; - Compliance of the deposit of slag and ash; - Expanding deposit of slag and ash; - Installing a new cogeneration power generating group, which includes a steam boiler (280t/h) and ST (40MW) counter operating in winter, and condensing in the summer; - Slag and ash disposal facility in the dense sludge; - Rehabilitated transmission and distribution system	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
6.	- SB1 steam boiler with natural gas operation; - ST1 steam turbine; - Heat supply from geothermal sources (about 1-2 Gcal/h).	- Compliance of the deposit of slag and ash; - Providing a IGT + HRB fitted for summer; - Installation of two HWB natural gas; - Installation of a steam boiler of 12t/h of water added to provide added water in the heating network during the summer; - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
7.	- SB1 steam boiler with natural gas operation; - ST1 steam turbine; - Heat supply from geothermal sources (about 1-2 Gcal/h).	- Compliance of the deposit of slag and ash; - Installing a gas-steam combined cycle, which will operate in winter; - Providing a IGT + HRB fitted for summer; - Installation of two HWB natural gas; - Installation of a steam boiler of 12t/h to assure the make-up water in the heating network during the summer; - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.
8.	- SB1 steam boiler with natural gas operation, only to seasonal production of industrial steam; - ST1 steam turbine; - Heat supply from geothermal sources (about 1-2 Gcal/h).	- Compliance of the deposit of slag and ash; - Providing a IGT + HRB fitted for summer; - Installation of two new HWB which runs on natural gas and oil; - Installing a new gas HWB; -Installation of 3 steam boiler of 14t/h to assure the make-up water in the heating network; - Rehabilitated transmission and distribution system.	Carry out three new drilling geothermal water extraction, extraction capabilities are provided, geothermal injection and water pumping.

3. ENVIRONMENTAL IMPACT ASSESSMENT OF TEMS FROM OM

For each analyzed variant was evaluated the environmental impact by calculating the pollutants emission (SO_2, NO_x, CO_2 and dust), using dedicated computer program EMPOL 2 (EMPOL, 2003). The obtained results are shown in Figures (3 ÷ 6).

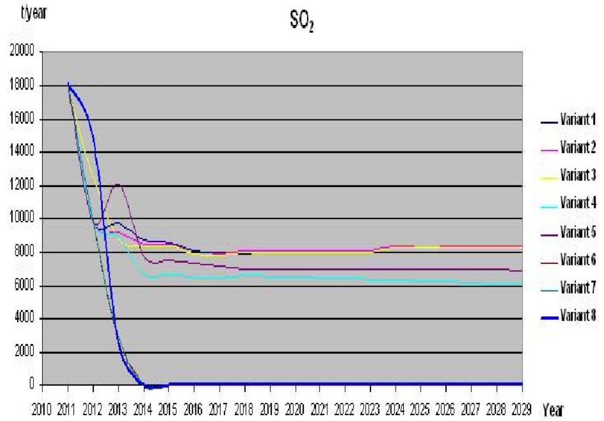

Fig. 3. Evolution of SO_2 emissions during the period of analysis

From the evaluation made and described in Fig. 3, it results that the estimated emissions of SO_2 will be decreasing in [2011÷2014] period of time, except for the option number 5 which involves an increase in [2012÷2013] period of time. After the structural and functional stabilization of TEMS - OM (the year 2011) the 8 analyzed options are graded from minimum to maximum of the environment impact this way: 6=7, 8, 4, 5, 3, 2=1.

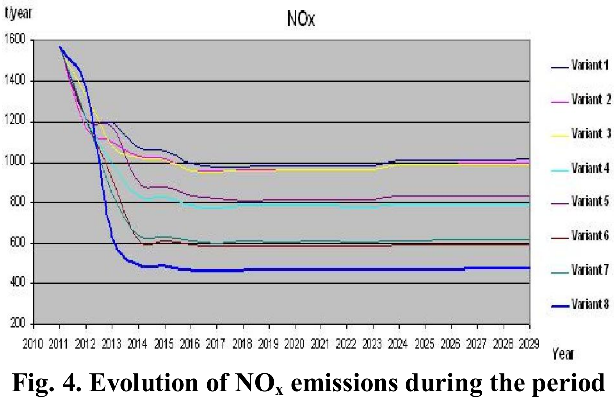

Fig. 4. Evolution of NO_x emissions during the period of analysis

From the evaluation made and described in the Fig. 4, it results that the estimated emissions for NO_x tend to evolve in time just like the SO_2 emissions, decreasing for [2011÷2015] period of time and stabilization after year 2015. We can see that regarding the NO_x emissions there are four levels of the 8 options, the options (1, 2, 3) having the biggest impact, and option number 8 having the smallest impact. Between the two levels of the environment impact (minimum → maximum), the options [1-8] are graded in the following manner: 8, 6, 7, 4, 5, 2=3, 1.

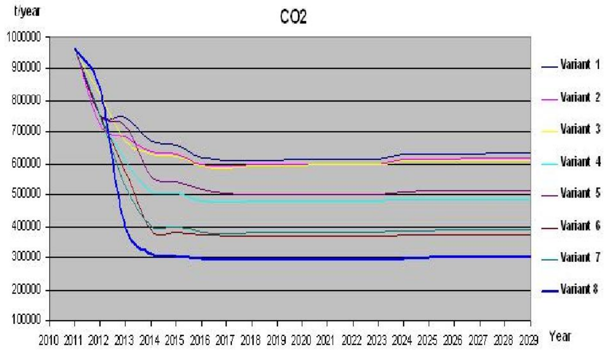

Fig. 5. Evolution of CO_2 emissions during the period of analysis

Regarding the environment impact given by the CO_2 emissions (Fig. 5), we can see that they have the same evolution in time just like NO_x , as in progressive decreasing in transition period of TEMS-OM and stabilization practical on three levels after the structural and functional closing of it. The 8 analyzed options are graded between minimum and maximum under the quantity of CO_2 emissions aspect, in the following manner: 8, 6, 7, 4, 5, 3, 2, 1.

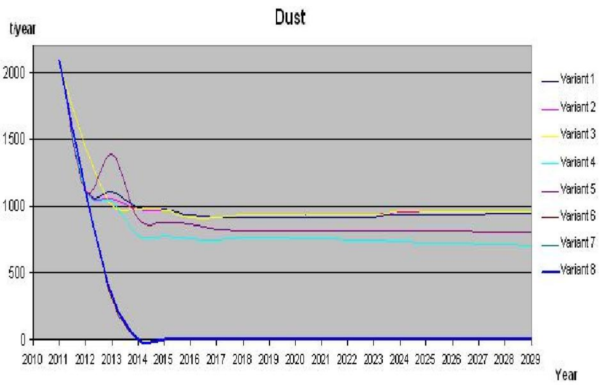

Fig. 6. Evolution of dust emissions during the period of analysis

The powder emissions has the same type of evolving in the analyzed period of time, just like the SO_2 emissions, with cvasi general decreasing period of time between the years [2011÷2014], except for option number 5, which records increasing number of SO_2 emissions between the years [2012÷2013]. After the stabilization of TEMS-OM, the powder emissions are going to stabilize and they can be graded between minimum and maximum, for the 8 options, in the following manner: 8=7=6, 4,5,1,2, 3.

Under the emission balance aspect for the four pollutants, we can see that for the whole analyzed period, the CO_2 emissions are in a much bigger number and they can't be avoided for any of the options. The SO2 emissions are nonexistent for versions 6 and 7 and negligible for version 8 and dust emissions are zero for the three variants.

For comparison of variants and the edification in terms of energy production, were evaluated and presented in Fig. 7 and Fig. 8 the evolution of TE and electrical energy (EE) production during the analysis [2010÷2029].

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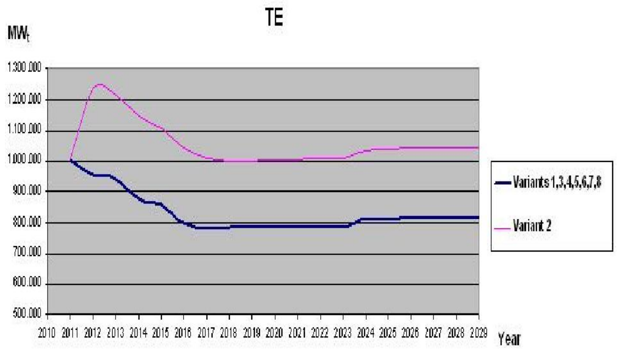

Fig. 7. Developments of TE during the period of analysis

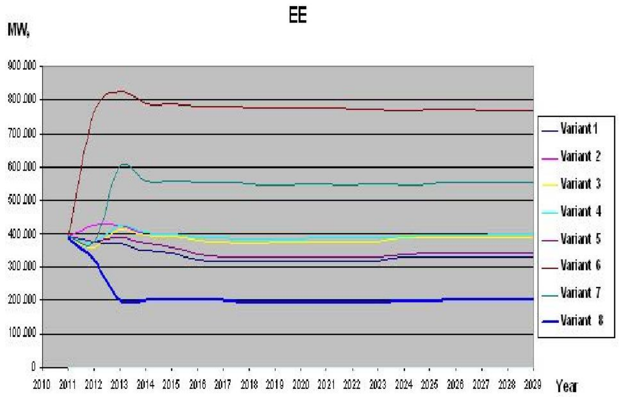

Fig. 8. Developments of EE during the period of analysis

Under the aspect of TE production (Fig. 7), the option number 2 with approximate 1.200 MW_t in the stabilization period, is enough and the other options are equal, ensuring a TE production at the minimum level comparing to the forecast, regarding a TE request. The 8 options ensure different levels of EE production (Fig. 8), subject to the supposed structure for each of these (Table 1), the grading between minimum and maximum is in the following manner: 6, 7, 2=4, 3, 5, 1, 8.

To assess the overall environmental impact was calculated for each variant, the time evolution of the value of penalties related to emissions, in accordance with the current methodology (OR, 2005). Global values obtained for each variant, during the analysis are presented in Table 2.

Table 2. Values appropriate penalties overall emissions of pollutants related TEMS of OM

Variant	The amount of penalties during the analysis [thousand EUR]
1	132878
2	110788
3	110511
4	123103
5	153450
6	140956
7	127130
8	**74395**

Taking into account the differences between the options, regarding the EE and TE production and regarding the environment impact, for closing the analysis it is imposed the evaluation of an indicator of the type: "global impact of the environment / total produced energy" (GIE/TPE).

The values of this indicator, calculated on the basis of penalties for environmental impact and value (TE and EE) produced, at current unit prices, for the analyzed TEMS are given in Table 3.

Table 3. The values of the indicator of global impact of the environment/total produced energy

Variant	GIE/TPE [-]
1	0,543
2	0,803
3	0,655
4	0,788
5	0,603
6	0,865
7	0,831
8	**0,456**

4. CONCLUSIONS

Conversion of chemical energy of fossil fuels in thermal and electrical energy is the process with the largest share of negative environmental impacts.

To ensure the premises of sustainable development the establishment of some management strategies are required (design, development, operations) aimed towards the reduction of the environmental impact of heat assurance systems for urban centers.

If case of multiple primary resources TEMS, such as the analyzed system, and to identify its optimal option it is imposed the applying of optimization model based on minimum updated total discounted cost, with restrictions on resource availability and environmental impact.

Referring to analyzed urban center (OM), TE can be provided, theoretically, in three ways which correspond to three levels of aggregation of TEMS: centralized, decentralized and individual.

Considering the consistency over time and benefits of centralized TEMS, this being the realistic scenario for the concrete conditions of TEMS from OM, can be detailed in medium-term development options, reflecting the differentiated levels of TEMS modernization of current use of RES (geothermal water) and improving the environmental impact.

Regarding the 8 options of evolving of TEMS of OM the evaluation of the environment impact for the 4 pollutant substances, reflects the following global grading (for the 4 substances), from minimum to maximum: 8 (minimum), 7, 6, 4, 5, 2=3, 1 (maximum).

The evaluation of EE and TE production for the 8 options analyzed reflects the following grading of it (from maximum to minimum): 2 (maximum), 6, 7, 4, 3, 5, 1, 8 (minimum).

From the analyze results that under the environment impact aspect, it is preferable the option number 8, and under the aspect of relative impact (GIE/TPE), find that the options [1÷8] are graded in the following manner of minimum to maximum: 8 (minimum), 1, 5, 3, 4, 2, 7, 6 (maximum). Given the above, recommend the application options 8.

The presented methodology is applicable also for other TEMS with multiple primary sources, operating by the TEMS features and the characteristic PR vector, with objectification of the optimization model (I).

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