CONSIDERATIONS REGARDING THE COMPETITIVENESS OF THE CENTRALIZED HEATING SYSTEM

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Abstract: The study synthetically presents the advantages that it has, in certain conditions, the solution of district heating compared to individual heating. To describe the energetic efficiency of these two heating solutions, a calculus of the global energetic efficiency is presented. The result of these calculations, processed in graphic form, reflects the cases which the adoption of district heating system is justified, a system in which the production of thermal and electric energy is realized in cogeneration.

Keywords – centralized system, cogeneration, efficiency

1. INTRODUCTION

Enclosed spaces must provide optimal parameters of the thermal conditions, visual conditions, acoustic conditions and air quality. The major objective is to provide the conditions mentioned above so the occupants of the enclosed space should be in total comfort, (thermal, visual and acoustic) in a healthy environment.

Human thermal comfort is defined as the sum of conditions for which a person would not prefer a different environment. It is a complex concept because it depends on a series of physical, organic and external parameters. The parameters that influence the human thermal comfort can be organized in three main categories [2]:

- *Physical parameters* which include: air temperature, mean temperature radiated by the enclosure's walls, relative humidity, relative air velocity within the enclosure, barometric pressure, light intensity, noise level;
- *Organic parameters* which include: age, sex and national characteristics of the population;
- *External parameters* which include: human activity level, clothing type and social conditions.

The parameters which influence the thermal comfort the most are: air temperature, relative humidity, air velocity, barometric pressure, clothing, working activity.

Thermal comfort can be achieved from different combinations of these parameters. The positive or negative effect of one parameter can be improved or balanced by another parameter. In this manner we can say that thermal comfort is achieved when heat produced by the human body is equalized to the heat discharged and absorbed by the environment. Sensorial temperature [1] at which this balance is achieved is called comfort temperature.

The purpose of heating systems is therefore to provide for the consumer the necessary thermal energy in order to achieve thermal comfort in different type of rooms. But there is a requirement of the current energetic and environmental situation, that in order to achieve thermal comfort minimum energy consumption must be realized.

This study presents the results of a study on the possible optimal solution that can be applied in order to provide the necessary thermal energy for heating different places from large urban areas. Two different heating solutions have been studied: using centralized power systems and using individual systems.

2. STRUCTURE AND CHARACTERISTICS OF THERMAL ENERGY SUPPLY SYSTEMS

2.1 Structure of district heating system (DH)

As main distinct sources to produce thermal energy cogeneration plant and/or thermal plant are used, which can use non-renewable energy resources (fossil fuels – natural gases, fuel oil, coal, combustible waste) or renewable energy sources (biomass, geothermal energy, solar power)

In a cogeneration plant (CHP - Combined Heat and Power) electrical and thermal energy are produced simultaneously in a single process named cogeneration. The electrical energy obtain can be used locally or can be delivered in the national power system, while the thermal energy can be used in the urban heating system and/or in industrial processes.

A thermal plant can produce heat either for local use or to be delivered in DH.

DH (fig.1) represents a technological and functional assembly constituted of constructions, installations, equipment, specific features and measurement methods. The purpose of DH is production, transport and delivering thermal energy.

It consists of thermal plants and/or electrical plants in cogeneration, transport networks, thermal substations, distribution networks, auxiliary constructions and installations, connections to delimitation/separation points, measurement control and automation systems. The most common thermal agent used in urban heating systems is water; hot water, for transportation and warm water for distribution.

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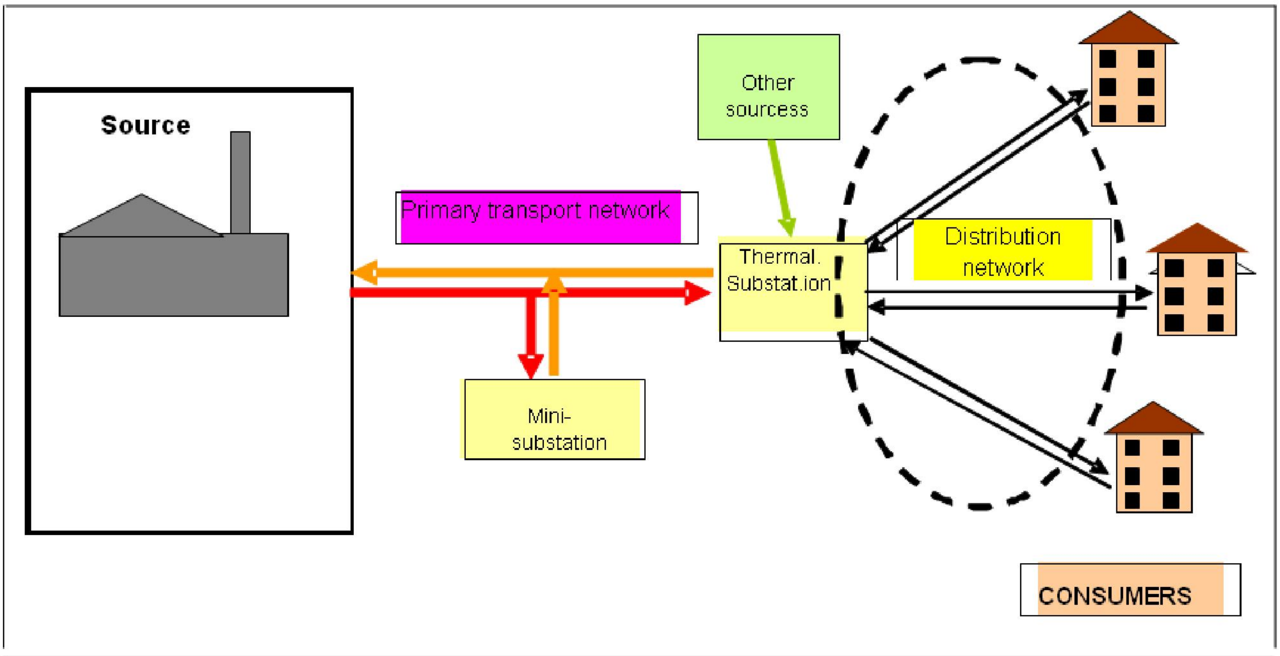

Fig. 1 DH - District Heating - Principle Scheme

Thermal energy produced in the source is transported in form of hot water (primary agent), through primary thermal network to thermal substations. In thermal substations, it occurs the heat exchange between the primary and the secondary agent and thermal energy is delivered to the final consumer using secondary thermal networks. There is a possibility to provide to some of the consumers thermal energy directly from the primary thermal networks, in this case the heat exchange between the primary agent and final consumer's installation occurs in thermal mini-substations, apartment building or individual building level.

Because of the importance, complexity and multiple implications which providing heat it has, establishing a heating solution must consider the following aspects: energetic, ecological, sociological and economical.

This study focuses on the energetic aspect. In terms of energy important elements are: thermal load and consumption curve, consumers displacement – consumption density (with respect to area or network length), method of producing thermal energy (cogeneration or individual sources).

2.2. Thermal charge

Thermal energy supply systems fills all heat needs for low and medium temperatures as long as thermal load's size, concentration and disposition allows to economically use centralized supply method. Thermal energy consumes may be characterized using the several criteria. Most important of them are: goal, annual consumption duration, thermal agent type used for transport and distribution.

Urban consumption represents the thermal energy consumption with the purpose of creating imposed home or work conditions and supplying domestic hot water. This type of consumption consists of two components: heat consumption during the whole year (domestic hot water) and seasonal consumption (used for home heating)

An example of thermal energy consumption duration curve is presented in Fig.2. The curve reflects that the variation of thermal charge during a year is changing between 15% (in summer) and 100% (in winter). This requires choosing the type and the number of supplies to ensure functioning in the maximum efficiency area.

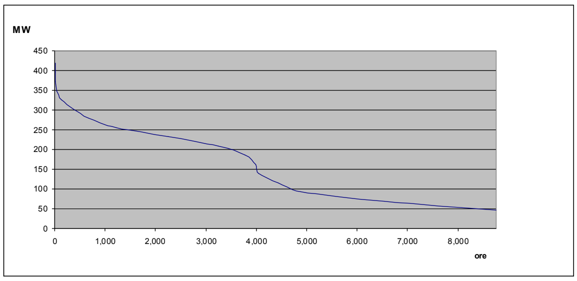

Fig.2 Annual consumption duration curve for thermal energy

2.3. Consumption density

Thermal energy losses when transporting it by hot water or warm water, depends on the absolute value of the thermal load, on the temperature of the primary thermal agent in the outgoing pipeline and in return pipeline, on the ambient environment temperature and on the transport and distribution network characteristics (length, diameter, insulation, assembling solution). As a relative value, expressed in percentages of the transported heat quantity, they depend on the thermal consumption density, on mean transport distance and also depends on the network load compared to the nominal transport capacity.

At partial loads of the transport and distribution system, losses of the transported thermal energy are greater than 10 - 20%, the percentage values can be even higher if the load is lower so they can reach over 50% [1]. This can justify the use of a centralized system in large urban areas where an optimal load of the transport and distribution networks does exist.

2.4. Thermal energy production methods

Producing thermal energy for heating and domestic hot water must be realized at a high level of energetic efficiency and low production costs at high quality, safety and continuity standards, and a low pollution level. An important solution for thermal energy production is cogeneration (CHP).

Cogeneration provides, using the same system and the same fuel source, the combined and simultaneously production of thermal and electrical energy with primary fuel energy usage at a high overall efficiency, which can reach mean values of over 85% compared to individual energy production, in this case, overall efficiency can reach 68-70% [4].

In this manner lower costs of thermal and electrical energy are obtained, because of the fuel saving obtained in the combine thermodynamic cycle, and also results an environment pollution reduction, because of the lower quantities of fossil fuel used for the same amount of energy produced.

Lately, across Europe and the world, one can notice an increased interest in cogeneration, including low and medium power because of the important contribution to increase the efficiency in energetic field, of the existing technologies (by this way reducing the usage of primary fuel) also maintaining a cleaner environment by reducing pollution levels.

3. THE COMPARATIVE ANALYSIS OF THE SUPPLY SOLUTIONS FOR THE URBAN CONSUMER

Comparative analysis between the cogeneration and separate production of electricity and heat, must consider the entire system of production-transportation-distribution-consumption of the two forms of energy.

Chosen for analysis was the case of heat and electricity supplying to the urban consumer by CHP or by separate sources. Separate sources, in this case, are the heat-only-plant, located at the place of consumption, and the power plant, electric energy produced here is brought to the consumer by high voltage electrical networks.

The main elements of the whole system of production-transportation-distribution-consumption by CHP and separate sources are presented in fig. 3 the following notations were used: S.PTDC CCG – production-transportation-distribution-consumption system for electric and thermal energy with a cogeneration power plant, CCG – cogeneration power plant, TEE – power transformer, RD.EE – electricity distribution network, RTP – thermal agent primary transmission network, PT - thermal substation, RTS – thermal agent secondary transmission network, S.PTDC.PS – separate electric and thermal energy production system, CTE – thermoelectric power plant, REIT – high voltage electric network, C.EE – electricity consumers, C.Q – thermal energy consumers.

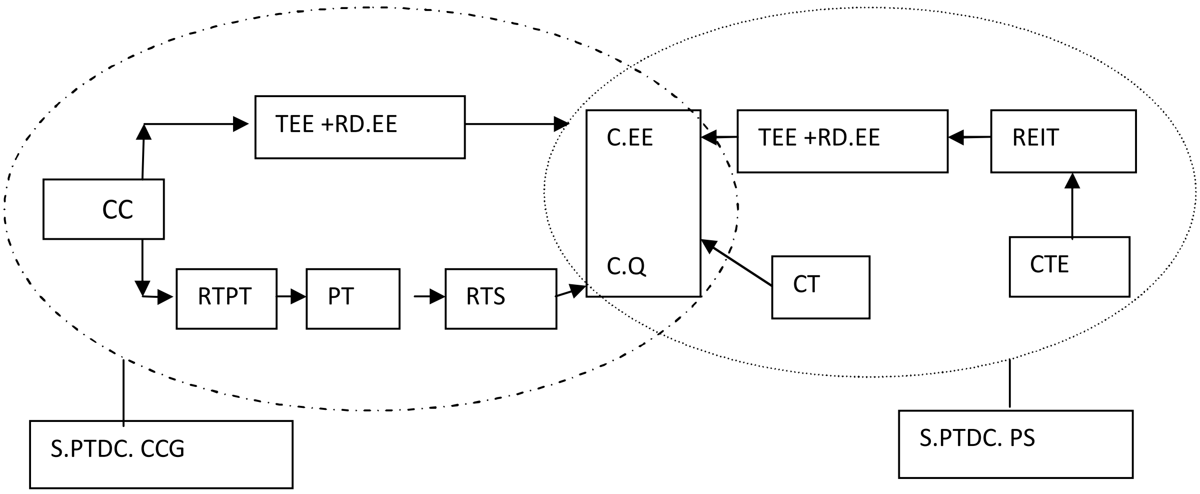

Fig. 3. Block diagram of the electric and thermal energy supply for the urban consumer through S.PTDC.CHP and S.PTDC.SP

Determining energy production overall efficiency for the two forms of energy, for the two production ways separate production and cogeneration, was performed considering the following hypotheses:

- Energy produced has the same amount;
- Both solutions use the same fuel;
- The combustion efficiency are identical in both cases;
- Energy quantities considered at the sources boundaries are as follows:
  - Separate energy production case: thermal and thermoelectric power plants boundaries (there aren't considered the electric energy losses in the transportation and distribution networks);
  - Cogeneration case : boundary of the CCG;

In the case of S.PTDC.CCG both energy types are considered to be produced strictly in cogeneration

In order to compare overall efficiency for the whole S.PTDC of the two energy types, we assume that:

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- At the consumer's level electric and thermal energy the population receives is identical – quantitative and qualitative – for both cases;
- The electric energy produced in a cogeneration system is consumed at the level of the distribution network in which it is inserted (e.g. an urban setting identical with the one the thermal energy supply is provided for);
- Electrical appliances have the same technical and functional characteristics in both energy production solutions (they set the same qualitative and quantitative frame);
- The transportation distances between different subassemblies of the S.PTDC are the same for both energy production solutions.
- Technical and functional characteristics of different transportation and distribution subassemblies for each type of energy taken into consideration are the same in both energy production solutions.
- Different subassemblies that together compose the S.PTDC have same efficiency coefficients independent of the type of energy production that has been used.

Related to these assumptions, mathematical expressions for the global efficiencies are given by the following relations [1]:

a) S.PTDC. PS case:

$$\eta_{SPS} = \frac{y_c + 1}{\dfrac{y_c}{\eta_{SPS}^E} + \dfrac{1}{\eta_{SPS}^Q}} \qquad (1)$$

b) S.PTDC. CCG case:

$$\eta_{S.CCG} \frac{y_c + 1}{\dfrac{y_c}{\eta_{STDC.CCG}^E}\left(\dfrac{1}{\eta_{ICG}} + \dfrac{1}{\eta_{ICG} \cdot y_{ICG}} - \dfrac{1}{\eta_{ITV} \cdot y_{ICG}}\right) + \dfrac{1}{\eta_{ITV} \cdot \eta_{STDC.CCG}^Q}} \qquad (2)$$

Symbols used:

y_c – consumption structure index [kWhe/kWht];

η_{SPS}^E - the total efficiency for production, transportation, distribution and consumption of thermal energy produced separately;

η_{SPS}^Q - the total efficiency for production, transportation, distribution and consumption of thermal energy produced separately;

$\eta_{STDC.CCG}^E$ - the total efficiency for production, transportation, distribution and consumption of thermal energy produced through cogeneration;

$\eta_{STDC.CCG}^Q$ - the total efficiency for production, transportation, distribution and consumption of thermal energy produced through cogeneration;

y_{ICG} - the cogeneration index of the cogeneration power plant [kWhe/kWht];

η_{ICG} - the efficiency of the cogeneration power installation

η_{ITV} - the efficiency of the peek thermal system

Usual subassembly energetic efficiencies values [1] for electricity (S.PTDC.EE) and thermal energy (S.PTDC.Q) transportation, distribution and consumption are presented in the table below:

Using (1), (2) relations and efficiency values similar to those presented in table no. 1, global efficiency variation has been calculated for individual production (η_{SPS}) respectively in case of cogeneration (η_{SCCG}), the calculations were made considering the load structure that must be fulfilled. The mean values for the following parameters have been considered: cogeneration index y_{ICG}=0,7 kWhe/kWht, corresponding to a CCG with a gases turbine, η_{ICG}=84%, η_{ITV}=88%, η_{SPEE}=35%, η_{REIT}=95%, $\eta_{TEE+RDEE}$=90%. For S.TDC.Q in S.PDTC case. CCG the efficiency is:

$$\eta_{STDC}^Q = \{60, 70, 80\}\ \%$$

and in S.PDC.PS case the efficiency is:

$$\eta_{STDC}^Q = \{60, 80, 95\}\ \%.$$

The results are presented in the graph fig.4

Table no.1. The energetic efficiency of the S.PTDC.EE and S.PTDC.Q subassembles

The characteristic S.PTDC subassembly		Efficiencies' nominal value [%] minimal	maximal	current
Energy Production (SP)	Energy production system (SP.EE)	30	50	35
	Cogeneration system (ICG)	78	88	84
	Power plants (CT)	80	92	88
	Peek thermal system (ITV)	80	92	88
Transportation, distribution and consumption (S.TDC.EE)	High voltage electrical network (RE.IT)	94	96	95
	Transformers +electricity distribution network (TEE +RD.EE)	88	92	90
	Appliances functioning on electricity (AC.EE)	AWP	100	AWP
Transportation, distribution and consumption (S.TDC.Q)	Primary thermal network (RTP)	87	94	92
	Thermal Substations (PT)	95	99	98
	Secondary thermal network (RTS)	83	92	90
	Appliances functioning on electricity (AC.Q)	AWP	100	AWP

AWP - In accordance with the appliance

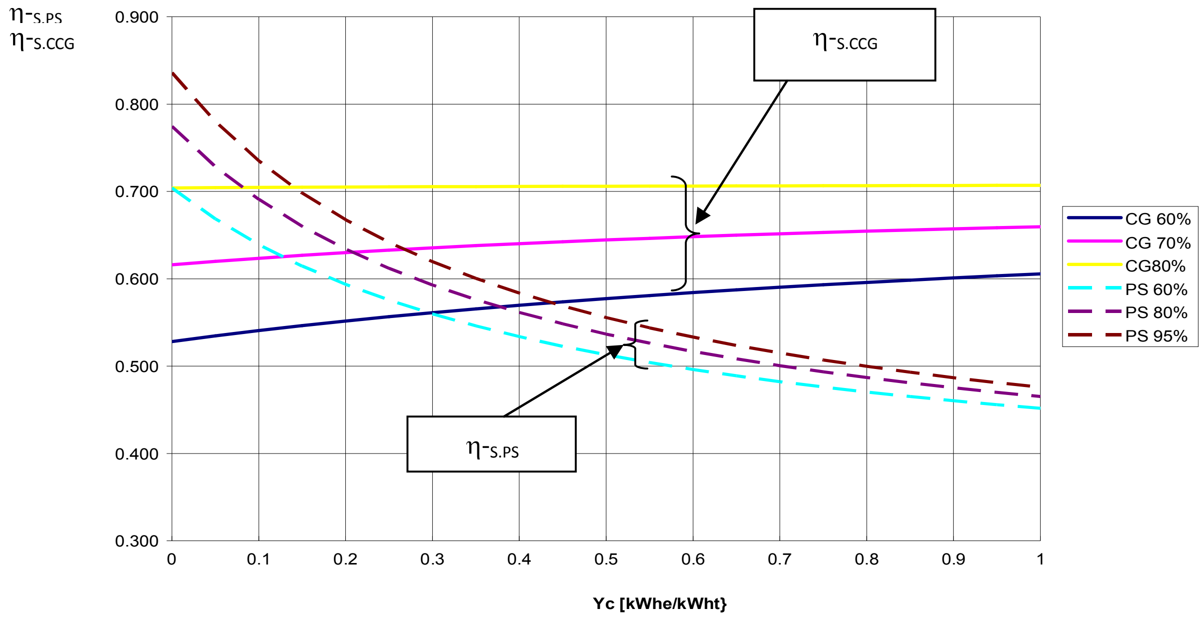

Fig. 4 η-S.CCG şi η-S.PS varation function of the structure index

In order to determine the variation domains of η_{SPS} and η_{SCCG} function of the structure index (y_c=0,5 – 1,0 kWh_e/kWh_t), for limited values of η^{Q}_{STDC}, η_{SPEE} and η_{ICCG} as fallowing $\eta^{Q}_{STDCCCG}$ ={60, 80}%, η^{Q}_{STDCPS} ={80, 95}%, η_{SPEE}={30, 50}%, η_{ICCG}={80, 88}%. Using these values we obtain the results from fig. 5.

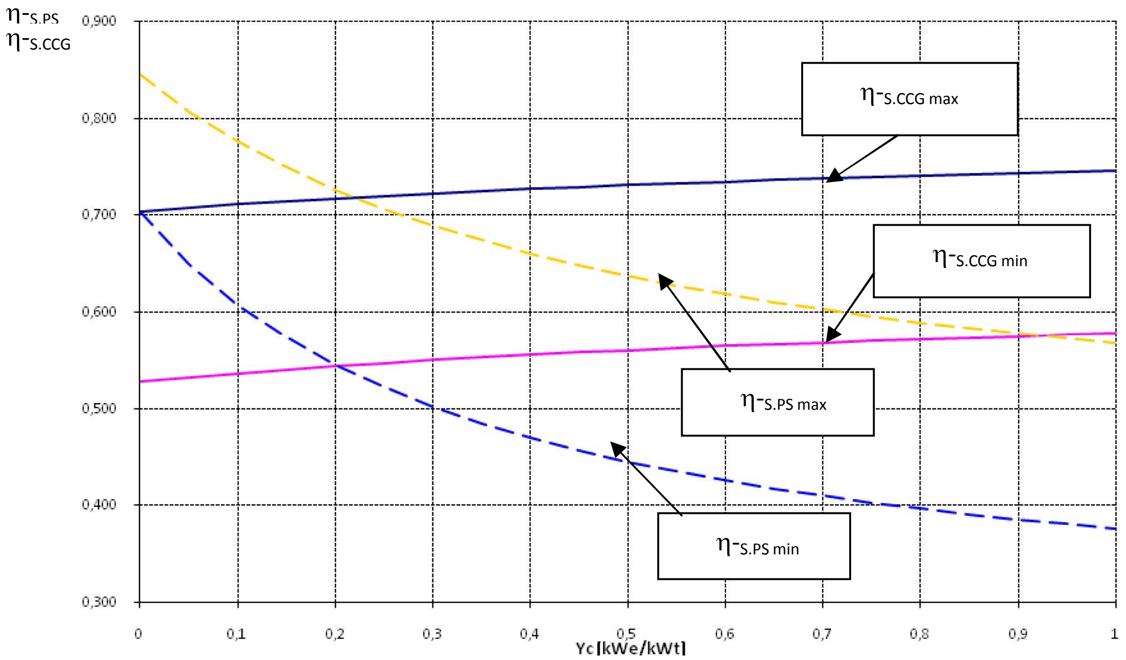

Fig. 5. Variation domains of η_{SPS} and η_{SCCG} function of y_c (y_c=0,05 – 1,0 kWh_e/kWh_t), for limited values of η^{Q}_{STDC}, η_{SPEE} and η_{ICCG}.

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The results obtained highlight the following conclusions:

a) Global efficiency η_{SPS} and η_{SCCG} depends on:

- The structure of the energy need of the consumers y_c;
- Overall efficiency of production-transport-distribution-consume for the two energy forms using:
  - → η_{SPS}^{E} and η_{SPS}^{Q} for individual production;
  - → (η_{ICG}, η_{ITV}) and, ($\eta_{STDC.CCG}^{E}$ $\eta_{STDC.CCG}^{Q}$), in case of cogeneration;
- Thermodynamic performances cogeneration, through y_{ICG}.;

b) In S.PTDC.PS case, η_{SPS} is highly influenced by y_c, η_{SPS} decreasing while the electric energy consumption is increasing in the analyzed area.

c) In S.PTDC.CCG case, η_{SCCG} is influenced very little by y_c. This is explained by the fact that in cogeneration what is being reduced with the delivered electric energy is increased in form of delivered thermal energy, thus while y_c is being modified the total energy production from ICG (thermal energy + electric energy) is modified very little. Thus, η_{ICG} is being influenced very little bye the y_c variation so η_{SCCG} is almost not sensitive to y_c variation.

d) η_{SCCG} is highly affected by $\eta_{STDC.CCG}^{Q}$.

e) While the transport and distribution of heat system efficiency from the individual system is decreasing, the centralized heating solution using cogeneration power plants is more efficient than the individual solution ($\eta_{SCCG} > \eta_{SPS}$), for values lower than y_c. Values for which $\eta_{SCCG} > \eta_{SPS}$ are limited, y_c must have values over 0,2 kWhe/kWht and $\eta_{STDC.CCG}^{Q}$ over 75%.

Considering the above mentioned results, according to the system ensemble it results that the cogeneration solution may be more efficient than the individual solution if y_c >0,2 and the heat losses in STDC are maximum 25%. Consume structure is realized in large urban areas and keeping losses under mentioned level is possible using: modern distribution and transport networks, pre-insulated pipes, correct sizing of RTP and RTS, unitary heating areas implementation which ensure an optimal thermal load (consumption density) of RTP and RTS. (primary and secondary transport networks)

Once set the limits where the centralized system becomes more efficient, from an energetic point of view, we may go on by appraising the other factors that characterize a heating system, mainly ecological, social and economic factors, starting from the energetic factor.

a) Ecological factors

Energetic efficiency is a decisive in determining the heating system solution, because of the significant fuel savings it may generate. Low fuel consumption leads to decreased pollutant emissions along the entire chain: extraction, transport, handling at the consumption site, burning process.

Energy production by medium and high capacity cogeneration plants, allows introducing new, more advanced, depolluting technologies, not applicable at individual systems.

b) Social factors

A centralized system eliminates some major inconveniences of the individual systems, like fire, explosion and pollution.

Through its position towards the users, the cogeneration plant represents a safe energy source, as it is able to function independently, in case the public grid is interrupted.

The centralized supply system may include more cogeneration plants that use different fuel types (considered more sources for the same system), offering flexibility, safety and adaptability to accessible fuels. This is not possible in case of individual systems.

c) Economic factors

Reducing fuel consumption implies reducing production costs of thermal and electric energy.

The cogeneration solution can be seen as bringing the production source closer to the consumer, compared to supplying their households from the national transport system. As a result, the electricity transport losses will decrease, as well as the costs of electricity at the consumer level. The closer the cogeneration plant is to the consumers, the bigger these savings will be.

4. CONCLUSIONS

1. Providing thermal energy for heating systems is a necessity not an option. Energetic resources beeing limited, choosing a heating system needs a specific approach, where the energetic efficiency is the major factor.
2. The analysis model presented in this paper highlights the elements needed for an energetic assessment of the heating system. These are:
   - Losses of RST, PT, RTP, influenced by:
     - consumption density;
     - quality and reliability of the RST, PT, RTP;
   - Existence of electric energy consumers in the area;
   - Energetic efficiency of the cogeneration plant.

3. The consumption density, as well as the quality and reliability of the RST, PT and RTP make a crucial contribution to the maintenance of STD losses under the maximal value of 25%.
4. The urban energy consumer guarantee a high consumption index (y_c>0,2kWhe/kWht) which makes the centralized cogeneration systems to be more effective than separate production.
5. The essential conditions, to be more exact, the consumption density and the urban electricity consumers, are met in urban areas, a fact that creates the premises for legitimate investments for creating/modernizing DH in the aforementioned urban settings.

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