COMPARATIVE ANALYSIS BETWEEN CHP PLANTS AND SEPARATE PRODUCTION

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Abstract – **The proposed paper presents a methodology for the evaluation of the competitiveness of the CHP plants in the context of both energy markets. Using this methodology one can assess the competitiveness of CHP plant respect to the actual situation of the separate production of both types of energy. More over, respect to the future rehabilitation of the heat only plants and/or of the power plants we might estimate the needed global efficiency for the CHP plant in order that it maintains it's competitiveness. The last part of the paper presents an analysis of different types of technologies used in CHP plants and their sensibility regard the rehabilitation of other plants.**

Keywords: *CHP, cogeneration*

1. INTRODUCTION

A major advantage of the cogeneration plants over the separate production is the fuel saving.
The fuel saving implies two major advantages respect to the separate production (with power stations and heat only plants):

- smaller fuel cost;
- smaller costs for eco-taxes.

In order to underline this advantage many authors propose as an important index for the evaluation of the power plants the Fuel Energy Savings Ratio defined as [1]:

$$FESR = \frac{Qchsep - Qchcg}{Qchsep} \tag{1}$$

where:
Qchsep- fuel's chemical heat at separate production;
Qchcg- fuel's chemical heat in cogeneration.
Beside FESR for our method we use another two very important indexes introduced by Athanasovici and al. [2]:

- the CHP combined index:

$$y_C = \frac{Ec}{Qc}; \tag{2}$$

- the plant combined index:

$$y_S = \frac{Es}{Qs}; \tag{3}$$

where:
Ec, Qc- is the electricity, respectively the heat demanded by the consumers;
Es, Qs- is the electricity, respectively the heat produced by the CHP plant.

2. THE NECESSARY GLOBAL EFFCICIENCY FOR THE CHP PLANT

The purpose of each paper is to bring something new to the readers in a matter of common interest. The new thing introduced by this paper it's a relation between Fuel Energy Savings Ratio, the global efficiency for separate production and the global efficiency for the CHP plant, that allows a comparison of different technologies that compete on the same energy market.

The global efficiency for the separate production might be written as follows:

$$\eta_{gsep} = \frac{Es + Qs}{Qch_{CTE} + Qch_{CT}} \tag{4}$$

where:
Qch_{CTE}, $_{CT}$- is the chemical heat of the fuel burned in power station (with CTE index), respectively in the heat only plant (with CT index);

$$Qch_{CTE} = \frac{Es}{\eta_{CTE}} \qquad Qch_{CT} = \frac{Es}{\eta_{CT}} \tag{5}$$

η_{CTE}- the electricity production efficiency of the power plant;
η_{CT}- the heat production efficiency of the heat only plant;
Tacking into account the relation of the plant combined index we might write

$$\eta_{gsep} = \frac{y_S + 1}{\frac{y_S}{\eta_{CTE}} + \frac{1}{\eta_{CT}}} \tag{6}$$

Assuming that the cogeneration plant produces the same amount of electricity and heat we might express the global efficiency for the CHP plant as:

$$\eta_{gcg} = \frac{Es + Qs}{Qchcg} \tag{7}$$

The Fuel Energy Savings Ratio might be express as a function of the global efficiency for the CHP plant as follows:

$$FESR = 1 - \frac{Qchcg}{Qchsep} = 1 - \frac{\dfrac{Es + Qs}{\eta_{gcg}}}{\left(\dfrac{Es}{\eta_{CTE}} + \dfrac{Qs}{\eta_{CT}}\right)} = \qquad (8)$$

$$= 1 - \frac{y_S + 1}{\eta_{gcg}\left(\dfrac{Es}{\eta_{CTE}} + \dfrac{Qs}{\eta_{CT}}\right)}$$

Comparing relation (8) with relation (6) we observe that the Fuel Energy Savings Ratio has the final expression:

$$FESR = 1 - \frac{\eta_{gsep}}{\eta_{gcg}} \qquad (9)$$

The relation (9) presents **for the first time** a relation between the Fuel Energy Savings Ratio, the global efficiency for the CHP plant and the global efficiency for separate production allowing a technical comparison between these two technologies.
The use of the relation (9) for a comparative analysis between cogeneration and separate production is very simple.
We have to start from the hypothesis that the major advantage of cogeneration versus separate production consists in fuel savings.
In other words the use of CHP has sense only if it leads to a positive Fuel Energy Savings Ratio: FESR>0.
The relation (9) allows us to impose a restriction for the global efficiency of the CHP plant:

$$\eta_{gcg} \geq \eta_{gsep} \qquad (10)$$

Under these circumstances, we might draw the conclusion that if the same type of fuel it's used, the efficiency of the CHP plant is in strict relation to the competitiveness of the separate production.
For the particular case of an existing power plant that means that any progress in terms of an increased efficiency for the power plants or for the heat only boilers must be followed by rehabilitations measures in order to increase the global efficiency up to the necessary value.
Losses in the transport and distribution systems might increase the necessary value of the global efficiency of the CHP plant.
In order to understand the influence of these losses it's necessary to write a generalized expression for the separate production global efficiency.

3. THE GENERALIZED EXPRESSION FOR THE GLOBAL EFFICIENCY FOR THE SEPARATE PRODUCTION

If we note with:
η_{qtd} – the efficiency of heat transport and distribution, we might write the following relation between the heat produced by the heat only plant and the heat demanded by the consumers:

$$Qs = \frac{Qc}{\eta_{qtd}}; \qquad (10)$$

In the same way if we note with η_{etd} – the efficiency of electricity transport and distribution:

$$Es = \frac{Ec}{\eta_{etd}}; \qquad (11)$$

With the equations (7) and (8) we might express the plant combined index respect to the CHP combined index:

$$y_S = \frac{Es}{Qs} = \frac{\dfrac{Ec}{\eta_{etd}}}{\dfrac{Qc}{\eta_{qtd}}} = y_C \frac{\eta_{qtd}}{\eta_{etd}} \qquad (12)$$

The previous equations allow to write a generalized expression for global efficiency at separate production:

$$\eta_{gsep} = \frac{y_C \dfrac{\eta_{qtd}}{\eta_{etd}} + 1}{\dfrac{y_C}{\eta_{CTE}} \dfrac{\eta_{qtd}}{\eta_{etd}} + \dfrac{1}{\eta_{CT}}} \qquad (13)$$

The generalized expression for global efficiency at separate production, has the advantage of covering all the possible situations:

- centralized production of both types of energy (η_{etd}<1, (η_{qtd}<1);
- centralized electricity production, and local production of heat with heat only plants (η_{etd}<1, η_{qtd}=1);
- local production of both types of energy (η_{etd}=1, η_{qtd}=1, y_S=y_C).

The relation (13) it's another novelty brought by this paper that allows the use of one relation for the technical evaluation of a large scale cogeneration system or for small scale cogeneration..
With the hypothesis given by the relation (10), we might calculate the variation of the minimum necessary value of the CHP global efficiency as a function of heat and electricity demand (expressed through the CHP combined index).
First proposed example assumes a separate centralized production of heat and power.

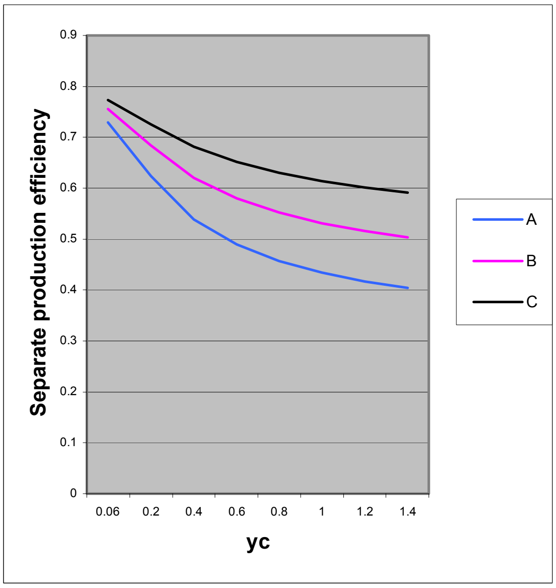

Figure 1. Minimum necessary efficiency for the CHP plant (equal to the global efficiency in separate production) respect to the energy demand

A- η_{CTE}=0,3 ; η_{CT}=0,8; η_{qtd}=0,87; η_{etd}=0,85
B- η_{CTE}=0,4 ; η_{CT}=0,8; η_{qtd}=0,87; η_{etd}=0,85
C- η_{CTE}=0,5 ; η_{CT}=0,8; η_{qtd}=0,87; η_{etd}=0,85

Comparing the variation curves we can reach to two conclusions:

- The rehabilitation of the power plants might lead to very high efficiencies for separate production;
- For small electricity demands (the case of domestic consumers) the global efficiency for the separate production is very high (making the competition very tuff on both markets for the cogeneration plants).

The most difficult case is no doubt, the case of the domestic consumers. For this type of consumers, the producers must be extremely cautious, and the rehabilitation measures are usually a „must".

From the previous figure we might observe that for a CHP index of 0.1 the global efficiency in all the presented cases it's over 70 %.

Calculations show that the CHP plants in Romania have an efficiency of 40..50 %. This modest efficiency is largely due to certain specific operation conditions for the CHP plants:

- a smaller heat demand than the designed demand;
- an overproduction of electricity at national level, a situation that might get worse with the new groups from the Cernavoda Nuclear Power Station;

In the previous example we've consider only the case of centralized production of heat.

The use of local production might lead to an even higher global efficiency, as we might see bellow:

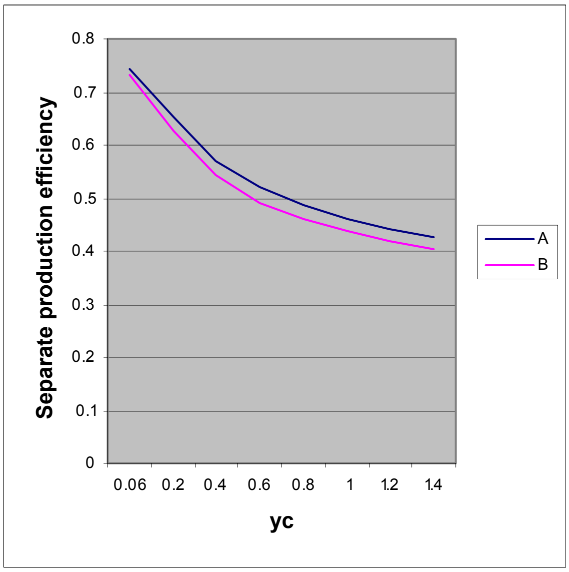

Figure 2 The influence of the transport and distribution losses over the global efficiency.

A- η_{CTE}=0,3 ; η_{CT}=0,8; η_{qtd}=η_{etd} =1 ;
B- η_{CTE}=0,3 ; η_{CT}=0,8; η_{qtd}=0,67; η_{etd}=0,85.

Comparing the variation curves we might see that the transport losses have a relatively smaller influence over the global efficiency in separate production.

The method might also be used in order to evaluate the Fuel Energy Savings Ratio in the conditions of the competition on the market. In this way one can estimate the benefit that might be achieved by rehabilitating the CHP plants.

In the table presented bellow we present a very simple estimation of the FESR in the case of a weak competition (for separate production: η_{CTE}=0,3 ; η_{CT}=0,8):

	ST- bp	ST-se	GT	TE
ηgcg [%]	75-85,9	65-84,3	40-84	37,9-86
FESR [%]	3,3-39	0-44,1	6-45,1	9-51,9

Table 1. Estimated FESR for a weak competition on electricity market

For a stronger competition for separate production (η_{CTE}=0,5 ; η_{CT}=0,8)the estimated values of FESR are:

	ST- bp	ST-se	GT	TE
ηgcg [%]	80-85,9	75-84,3	62-84	60-86
FES [%]	3,5-21,5	1,7-24	8,2-24	9,5-32

Table 2. Estimated FESR for a strong competition on electricity market

ST-bp- Steam backpressure turbine;
ST-se- Steam extraction turbine;
GT- Gas turbine;
TE – Thermal engine.
The calculations presented in the previous tables show that a stronger competition on the electricity market, materialised in a better electricity production efficiency decreases the fuel energy savings that may be achieve through cogeneration.

4. CONCLUSIONS

In this paper the authors present a very simple yet efficient method that might be used for two purposes:
- The calculation of a minimum necessary efficiency for the CHP plant;
- The estimation of the Fuel Energy Savings Ratio that might be achieved by rehabilitating the CHP plant;

In the last part of the paper we present a few simple calculation made using the proposed method. Those calculations show a great sensibility of the CHP plants respect to the existing competition, rehabilitation measures being especially needed in the area of domestic consumers.

References

[1] J.H. Horlock, *Combined Power Plant, ,* Pergamon Press, Oxford, 1990
[2] V. Athanasovici, I. S. Dumitrescu, C. Răducanu, *Metodă unitară de definire a indicatorilor tehnici caracteristici soluţiilor de cogenerare de mică şi medie putere*, Energetica, 1998.
[3] R. W. Haywood *Analysis of engineering cycle,* Pergamon Press, Oxford, 1980