COST ANALYSIS FOR CENTRALISED AND DISTRIBUTED COGENERATION

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Abstract - The method proposed in this paper is based on economical competitiveness at the end consumer. This involves a detailed modelling of the major components of a combined heat and power (CHP) system, tacking into account both economical and technical factors. The results appear in a very comprehensive and simple form – the calculation of a limit value for the global efficiency of the analysed solution in order to maintain a financial advantage for the consumers respect with other possible solutions.

Keywords: cogeneration, district heating.

1. INTRODUCTION

In many cases the decentralisation of the markets lead to an increased price of energy due to a higher number of companies between the producers and consumers. This phenomenon tends to tighten the competition and increases the pressure on all the market actors.

Under these conditions a simple technical analysis is in many cases unsatisfactory since the competitiveness of one producer on an energy market is also influenced by other factors such as: fuels price variation, tariffs applied by transport operators and energy providers, introduction of eco-taxes, etc.

The use of all those factors within a model necessitates the introduction of new indices that allow a proper evaluation of an existing solution.

2. THEORETICAL FUNDAMENTS OF THE MATHEMATICAL MODEL

The basic idea behind the proposed model is an analysis of an existing system (CHP or separate production) respect to market conditions. In other words it works based on the hypothesis that a consumer will always prefer the solution that allows him to obtain the highest financial saving.

For this purpose we need to find two things:

- an indicator based on this economical advantage for the consumer;
- a connection between the economical indicators and the technical ones.

The proposed index is the Financial Savings Ratio of the consumer.

The Financial Savings Ratio of the consumer might be defined as:

$$FSR = \frac{c_{fEualt} - c_{fEucg}}{c_{fEualt}} = 1 - \frac{c_{fEucg}}{c_{fEualt}} \qquad (1)$$

cfEucg- the specific cost of the energy delivered to the consumer for the analysed solution (CHP plant or separate production);

cfEualt- the specific cost of the delivered energy for the alternative solution.

The use of specific costs in the definition relation of the Financial Savings Ratio offers to the mathematical model an increased flexibility since the analysis might carried out for:

- an average cost of useful heat obtained for all the consumers connected to the source of energy;
- specific groups of consumers;
- for individual consumers.

For all the consumers of a CHP system the specific cost of delivered energy might be determined with the relation:

$$c_{fEucg} = \frac{C_{tcg}}{Ecl + Qcl} \qquad (2)$$

Ecl – Electricity delivered by the CHP system;

Qcl – heat delivered by the CHP system;

The total cost for the production and transport of the useful energy (heat and power in this case) is:

$$C_{tcg} = Ctot_S^a + Ctot_{tQ}^a + Ctot_{tE}^a + C_{E_{SEN}}^a + C_{Qpi}^a \qquad (3)$$

$Ctot_S^a$ - the cost of the useful energy (heat and electricity) at the producer (at the CHP plant);

$Ctot_{tE}^a$ - cost for the transport of electricity, given by the tariffs of all the companies involved in the process;

$Ctot_{tQ}^a$ - cost for the transport of electricity;

$C_{E_{SEN}}^a$ - the cost of electricity bought from an external source;

C_{Qpi}^a - the cost of heat bought from an external source.

Q_{chcg} - the fuel energy for the studied period of time for the existing plant;

In order to analyse a centralised CHP system we have used in our model the global efficiency of a CHP system (η_{gcg}) an indicator introduced by V. Athanasovici and S. Dumitrescu in 2005 as an extension of the energy utilisation factor, applied now as a function of the electricity and heat delivered to the consumers, thus including the electricity and heat transport losses.

$$\eta_{gcg} = \frac{Ecl + Qcl}{Q_{chcg}} \Rightarrow Ecl + Qcl = Q_{chcg} * \eta_{gcg} \tag{4}$$

For the alternative solution (considered a small scale cogeneration plant) the global efficiency is (η_{galt}):

$$\eta_{galt} = \frac{Ecl_{alt} + Qcl_{alt}}{Q_{chalt}} \Rightarrow Ecl_{alt} + Qcl_{alt} = Q_{chalt} * \eta_{galt} \tag{5}$$

Q_{chalt} - the fuel energy for the studied period of time for an alternative solution.

Ecl_{alt} - electricity delivered by the alternative solution;

Qcl_{alt} - heat delivered by the alternative solution.

These losses are considered by means of transport efficiencies:

- electricity transport efficiency:

$$\eta_{qtd} = \frac{Qcl}{Qs} \tag{6}$$

Qs- Produced heat;

- heat transport efficiency:

$$\eta_{etd} = \frac{Ecl}{E_S} \tag{7}$$

E_S - produced electricity

Taking into consideration the equations (4) and (5), the specific costs from the FSR definition become:

$$c_{fEualt} = \frac{C_{talt}}{(Q_{chalt} * \eta_{galt})} \tag{8}$$

$$c_{fEucg} = \frac{C_{tcg}}{(Q_{chcg} * \eta_{gcg})} \tag{9}$$

If we use the last two equations Financial Savings Ratio becomes:

$$FSR = 1 \; \frac{C_{tcg} * (Q_{chalt} * \eta_{galt})}{C_{talt} * (Q_{chcg} * \eta_{gcg})} \tag{10}$$

Theoretically in order to maintain the existing solution the FSR must be positive. However, the existing CHP plant has an advantage: even if the consumer doesn't obtain a financial advantage the construction of a new plant might not be economically feasible.

For this condition (FSR=0) we obtain a limit value for the global efficiency of an existing CHP system, for all the alternative solutions (η_{gcgnec}):

$$\eta_{gcgnec} = \frac{1}{Q_{chcg}} \left[\frac{C_{tcg} (Q_{chalt} * \eta_{galt})}{C_{talt}} \right] \tag{11}$$

Usually we would use the last equation to compare different cogeneration or separate production solution as in [4]. However in this paper we will use the last equation to compare a centralised system with the same CHP system that lacks a cost that might be avoided by decentralised production or a higher efficiency due to smaller energy transport losses.

3. THE OPERATING PARAMETERS OF THE ANALYSED CENTRALISED CHP SYSTEM

The analysed centralised solution is a CHP system consisting of a large scale cogeneration plant with two groups of 150 MW installed power and a district heating system with 94 thermal stations. In table 1 we present the main data regarding the primary energy consumption and the production of electricity and heat.

The efficiency of the CHP plant is negatively influenced by the competition on electricity market that causes an operation for long periods of time with a very small electricity production.

A direct consequence of this fact it's the use of peak boilers for heat production that lead to an efficiency of only 44.3 % for the last year. The losses for the district heating system aggravate the situation leading to global efficiency for the CHP system of only 37.4 %.

Table 1. System operation

Indicator	**Value**
Heat produced with heat exchangers [TWh/year]	0.73
Heat production with peak boilers [TWh/year]	0.25
Electricity production in cogeneration regime [TWh/year]	0.3
Separate production of electricity [TWh/year]	1.14
Primary energy consumption for coal [TWh/year]	5
Primary energy consumption for natural gas (used as support fuel) [TWh/year]	0.5
Power to heat ratio for the delivered energy	1.59
Efficiency of the CHP plant [%]	0.443
Efficiency of the district heating system [%]	0.77
Efficiency for the electricity transport [%]	0.85
Global efficiency of the CHP System [%]	0.374

4. THE MARKET EFFECT

For all the cases presented in this analysis we will consider that the decentralised CHP plant has an efficiency of 37.4 % equal to the efficiency of the centralised system. With this hypothesis we will calculate the limit value for the global efficiency of the centralised system necessary to compensate some costs that don't occur in a decentralised solution.

By simply owning a CHP plant consumers can avoid a series of costs such as:

- costs associated with the value added tax for energy (they will pay this tax for fuel)
- costs associated with fees of different providers (for electricity and heat);
- cost associated with the energy tax (if this tax applies only to producers).

It may be defined as a market effect the sum of all costs that might be avoided by distributed electricity and heat with equipments owned by consumers.

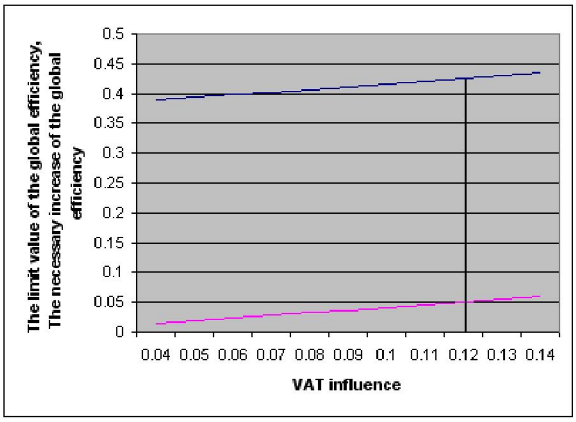

Figure 1. The VAT influence over the efficiency limit value of the centralised CHP system

The vertical line in figure 1 shows that by simply owning the CHP system and therefore avoiding the payment of the VAT for the final energy price (but still paying the tax for the fuel used to produce electricity and heat) a decentralised solution could be competitive on the market with a 5 % smaller global efficiency.

In many cases for the economical inefficiency of such a large centralised CHP system consumers usually blame the high heat transport losses. In figure 2 we have presented the variation of the global efficiency of the CHP system respect to the heat transport losses.

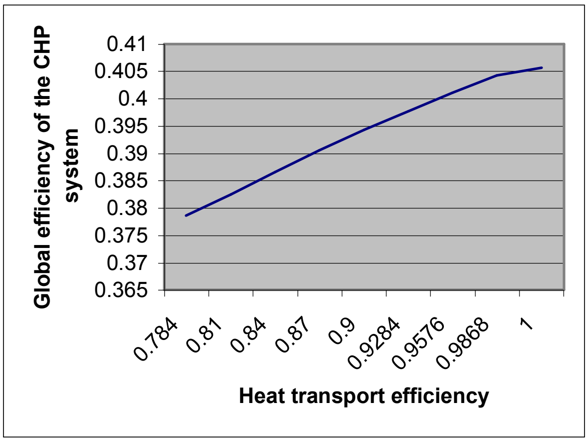

Figure 2. Heat transport losses influence over the global efficiency of the centralised CHP system

The figure indicates a rather small influence of the heat transport losses over the global CHP system efficiency. The figure presents a typical engineering analysis where in order to compensate the transport losses (for both types of energy) the efficiency of the CHP system should be equal to the efficiency of the CHP plant.

By including the costs into the analysis we have obtained a rather different image.

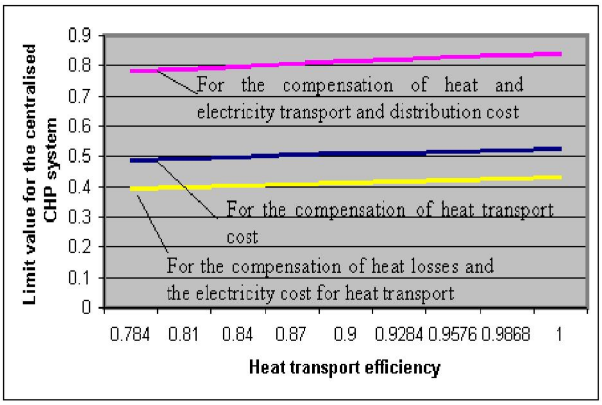

Figure 3. The limit value for the centralised CHP system efficiency

The third figure shows that in order to compensate the heat losses and the cost of electricity used for heat transport, the centralised system has to operate with an efficiency of 43 %. However in order to compensate the heat transport cost (increased by the operator's fee) the centralised system has to operate with an efficiency of about 50 %.

If the electricity transport and distribution cost is consider the centralised system has to operate with 78 % efficiency, in order to obtain the same price at the end consumer.

The analysis presented before represents a comparison between a centralised CHP and distributed cogeneration when the same fuel is used. If the centralised system uses coal as before and the small scale cogeneration plants use natural gas the same analysis looks different.

Table 2. Results

No.	Type of the CHP plant	Power to heat ratio	Small scale CHP plant efficiency	System's limit global efficiency [%] (natural gas price 250 €/1000 m^3)
1	Gas turbine	0.125	0.86	50.1
2		0.175	0.81	50.3
3		0.2	0.79	50.4
4		0.525	0.72	60.3
5	Internal combustion engine	0.125	0.87	46
6		0.175	0.83	47.6
7		0.2	0.81	48.6
8		0.525	0.76	60.3

The results presented in table 2 show that a further increase of the natural gas price would make the centralised system competitive with small rehabilitating measures or a slight decrease of the profit of the companies involved into the process.

6. CONCLUSIONS

The decentralisation of electricity and heat market lead to a division of the large centralised cogeneration systems between several companies. Because each of the companies must have a profit and has to pay taxes the overall fee perceived by these transport operating companies becomes higher than the effective cost of transporting electricity and heat. Large taxes complicate even further the competitiveness of a centralised system.

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