COGENERATION PLANT FOR ENERGY SUPPLY OF A MEAT PROCESSING COMPANY: CASE STUDY

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The paper presents a case study regarding the energy efficiency of cogeneration compared to separate heat and power supply of a meat processing company. There has been analysed a solution for a cogeneration plant equipped with internal combustion engine. There have been performed an energetic, economic and environmental analyses of proposed solution compared to existing situation. The conclusions of this case study are that cogeneration leads to better energy efficiency and higher economic criteria. Thus, this solution has been chosen as being the optimal one for this case study.

Keywords: cogeneration, energy efficiency, internal combustion engine

1. Introduction

The objectives set by the Energy Strategy: "Europe 2020 for an intelligent and sustainable growth favourable to inclusion", [1] are very ambitious regarding the energy aspects as well as those ones regarding environmental protection due to climate changes that occur in recent years. The document sets the following priorities:

- Reduction with 20 % of green house gasses emissions.
- Increasing with 20 % the share of energy production from renewable energy sources.
- Increasing with 20 % the energy efficiency.

A major role in the next period of time shall have the promotion, on a large scale, of energy efficiency, [2, 3], due to actual limits of natural energy resources and need of promotion and support of sustainable development.

Cogeneration as a solution for combined and simultaneous production of electricity and heat, through its energetic, economic and environmental advantages, can be included in the category of "clean" technologies for energy generation, thus representing an efficient solution for energy supply.

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2. Presentation of initial situation

The analysed industrial contour includes a company from the meat processing sector. This company has constantly increased its production capacity during the last years, thus the energy consumptions increased as well.

The main energy consumptions of the company are as follows:

- Steam.
- Hot water.
- Electricity.

The supply of all these types of energies to the company is described below.

Heat is produced in a thermal plant, which is equipped with two steam boilers using natural gas and two hot water boilers. Steam is used for technological needs, space heating and for preparing warm sanitary water.

There are following equipment installed in the thermal plant:

- Two steam boilers, Panini type:
  - Boiler no. 1 generates 1 t/h of steam at a pressure of 9 bar and a temperature of 170 °C.
  - Boiler no. 2 generates 1 t/h of steam at a pressure of 7 bar and a temperature of 160 °C.
- Two hot water boilers pipe and casing type.

For electricity supply, the company purchases all needed quantity from the national power grid.

Due to increasing of the production capacity, the company has estimated an increase in energy consumption as follows:

- Increase in electricity consumption with 169 %.
- Increase in heat consumption with 63 %.

For the above mentioned conditions, after increasing installed production capacity, the energy consumptions are as follows:

- 486240 Nm^3/year of natural gas for annual heat generation of 3186 MWhth.
- 2304 MWhe electricity consumption – power purchased from the national power grid for covering all internal needs.

3. Description of the implemented solution

In order to cope with increasing energy demands there has been proposed a solution with installing a cogeneration plant on-site for supplying all types of energies to the industrial consumer. There has been analysed a solution for a cogeneration plant equipped with the following devices:

- Internal combustion engine, type MAN E2842 LE312.
- Electric generator, type HCI 534 E.

Table 1 presents the main characteristics of cogeneration plant.

Table 1

Main characteristics of cogeneration plant

Technical characteristics	Value
Installed electric capacity	384 kW
Installed thermal capacity	531 kW
Electric efficiency	37 %
Thermal efficiency	51 %

Internal combustion engines are the most used technical solution for equipping a cogeneration plant of small and medium size. A major advantage of this technology is that it has a great electric efficiency. In a cogeneration plant with internal combustion engine heat is generated within two heat recovery cycles: high temperature heat recovery – heat is recovered from flue gasses, and low temperature heat recovery – heat is recovered from cooling down thermal agents that cool the engine.

There should be also mentioned that internal combustion engines are manufactured in a very wide range of installed capacity and they are very compact and very efficiency equipped. Usually, internal combustion engines are used for powering a cogeneration plant of small and medium size. This technology has also the advantages of being modular, so they can be used in different size power plants. Internal combustion engines are quite silent, considered to be a "clean" technology and can be used not only for covering peak loads or as back-up, but also for operation at base load.

Internal combustion engines used in cogeneration plants have the following advantages, [4]:

- On-site energy generation.
- Simple maintenance.
- Large maintenance infrastructure.

Figure 1 shows the simplified scheme of a cogeneration plant with internal combustion engine.

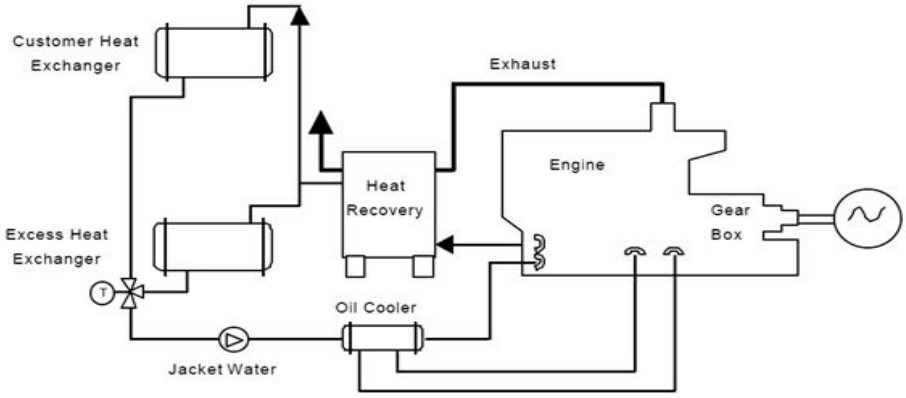

Fig. 1. Simplified scheme of a cogeneration plant with internal combustion engine.

4. Project's objective

The objective of the implementation of a cogeneration plant on-site at the meat processing company is to increase energy efficiency of the analysed industrial contour in order to ensure a sustainable development through promotion and support of high efficiency cogeneration using internal combustion engines.

The main advantages of the proposed solution cover energetic, environmental and economic issues:

- Compared to separate energy production combined energy generation in a cogeneration plant shall lead to significant energy savings in fossil fuel (natural gas).
- After project implementation the meat processing company will consume more natural gas, but will become and independent energy producer. Taking into account that before project implementation electricity has been purchased from national power grid where it has been produced using fossil fuels (natural gas) with much lower electric efficiency, there can be said that project implementation will lead to, from this point of view, to savings or primary energy resources, which has a positive impact upon environment and also has an impact upon economic criteria of the company.
- Reducing environmental impact. Reducing fossil fuel consumption will lead to reducing pollutant emissions, especially of carbon dioxide. At the same time, there shall be a positive indirect impact over the environment due to extending the lifespan of fossil fuels.
- Under the economic aspect there can be mentioned that after project implementation the company's expenses with energy bill will reduce, and

if some eco-taxes shall be applied, it will also reduce the company's expenses at this chapter.

5. Technical-economic analysis of cogeneration solution

5.1. Hypoteses

For technical-economic analysis there have been made the following hypotheses:

- Technical-economic analysis has been performed for a period of 10 years, which is the lifespan of the proposed technical solution.
- The annual operation period of the cogeneration plant has been considered as being 6000 h/year.
- The actualisation rate for the economic analysis has been considered 12 %.
- There have been used the following economic criteria: PayBack Period (PBP), Net Present Value (NPV) and Internal Rate of Return (IRR).

5.2. Methodology

Technical-economic analysis includes the following steps:

- Determination of the global efficiency of the cogeneration plant and of the annual fuel consumption.
- Determination of total annual expenses.
- Determination of the annual cash-flow (ACF).
- Determination, using ACF, of the following economic criteria: Net Present Value (NPV) and Internal Rate of Return (IRR).

The annual cash-flow is determined using the following elements:

- Investment values.
- Annual operation expenses.
- Annual incomes that come from electricity and heat.

The economic feasibility of the project is demonstrated when NPV is positive and IRR is higher than actualisation rate used for economic analysis.

The Net Present Value can be calculated using the following formula:

$$\text{VNA} = \sum_{t=1}^{n} \frac{V_t - (I_t + C_t)}{(1+a)^t} \tag{1}$$

Where: V_t – annual revenue;
I_t – investment value;
C_t – annual operation expenses;
t – analysed period of time;

a – actualisation rate.

An investment project can considered economically feasible if NPV > 0.

The Internal Rate of Return can be calculated using the following formula:

$$\text{RIR} = \sum_{t=1}^{n} \frac{V_t - (I_t + C_t)}{(1 + RIR)^t} = 0 \qquad (2)$$

An investment project can considered economically feasible if IRR > a.

5.3. Results of technical-economic analysis

Tables 2 and 3 show the main results of the performed analysis for project implementation of a cogeneration plant using internal combustion engines. There are also presented different energetic, economic and environmental criteria that clearly show the advantages of the implemented solution over the past situation.

Table 2

Main results of the performed analysis

Criterion	Unit	Value
Annual fuel consumption	Nm^3/year	657660
Lower heating value	kJ/Nm^3	33688
Generated heat	MWh/year	3186
Generated electricity	MWh/year	2304
Purchased electricity	MWh/year	896
Revenues	USD/year	332144
Investment: ▪ Equipment (1 engine, type MAN E 2842 LE 312, electric generator, type HCI 634 H2, etc.) ▪ Design, constructions and mounting	USD	 472692 150746
Net Present Value	USD	1135000
Internal Rate of Return	%	44
PayBack Period	years	2.2

Table 3

Main energetic, economic and environmental criteria

Criterion	Criterion type	Unit	Value
Annual fuel savings in absolute value	Energetic	Nm^3/year	574464
Annual fuel savings in relative value	Energetic	%	18.14
Annual overall cogeneration plant's efficiency	Energetic	%	88
Net Present Value	Economic	USD	1135000
Internal Rate of Return	Economic	%	44
PayBack Period	Economic	years	2.2
Reduction of CO_2 emissions compared to reference solution	Environmental	tCO_2/year	1101
Reduction to the contribution of exhaustion of natural energy resources	Environmental	Nm^3/year	11489.3
Reduction of Green House effect	Environmental	tCO_2/year	134.6

6. Conclusions

After project implementation the company from the meat processing industrial sector manages to achieve a certain value for primary energy/fuel savings. These fuel, natural gas, savings are due to difference between electricity that company is not purchased from the national power grid but produces it within its own cogeneration plant with higher efficiency than at the national power grid (purchased electricity).

The cogeneration plant can be characterised by high technical and energetic performances, much better compared to reference solution: increased reliability, reduced fuel (natural gas) consumption, high overall efficiency, high heat recuperation ratio, simple modular units and reduced values for pollutant emissions guaranteed by internal combustion engine manufacturer.

By reducing the overall fuel consumption the project shall have a positive impact upon the environment through decreasing pollutant emissions into atmosphere. Thus, the annual reduction of carbon dioxide emissions has been estimated at 1101 t/year. The annual reduction of NO_x emissions is also very important.

R E F E R E N C E S

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