ABSTRACT
The aim of this study is to analyse the technical and economic potential of a real situation concerning the acquisition of a new cogeneration natural gas facility in a given company, replacing the actual existing one working with fuel oil (at the end of its useful life, 18th years old) for energy supplies to the users. The economic risk associated with the investment project in a cogeneration plant lies in the possibility to check if the operating results are consistent with the originally planned study of economic and technical feasibility. For that, besides the energetic analysis carried out, a detailed economic analysis was done in order to evaluate its feasibility and risk regarding the main parameters to be taken in account, namely the NPV (Net Present Value), IRR (Internal Rate of Return) and Payback Period. The influence of fluctuations of the selling prices of the electricity to the main grid, of the fuel costs, of the initial investment and of the company production on the stated parameters were studied. The main conclusions to be withdraw are that those fluctuations that always happens, influence the final decision to be taken. Thus, the "business" of cogeneration should be managed by experts and should be viewed in terms of investment as one more equipment associated with the production unit whose goal will be to increase the global competitiveness of the productive unit.

Keywords: CHP, NPV, IRR, PES, Energetic analysis.

INTRODUCTION
Energy is an indispensable factor for any human activity. Transport, industrial production, trade, communications, etc. depends on the energy availability. The generation, rational and efficient use of energy in a way influence the actual society, either for economic reasons (competitiveness), either for the environmental impact due to its use.

However, the satisfaction of our energy needs has been made mostly at the expense of conventional energy such as oil, coal and natural gas. Although, present in large-scale in the planet, they are not renewable on a human scale, bringing negative consequences to the environment. This leads to a new concept, called sustainable development (rational use of energy and energy needs) that emerges to try to reduce this issue.

Traditionally, consumers satisfy their energy demand by purchasing separately electricity and fuel from distribution companies. Regarding the electricity acquired by consumers, much is produced in thermal power plants. In most modern plants operating in combined cycle the efficiency is about 52.5 %. If it is taken into account the losses inherent in the transportation of electricity, the figure becomes 48.5 %. So it can be seen that over 50 % of the energy used to generate electricity in large power plants power is inevitably lost to the environment, without the possibility of practical use.
The power generation of thermal energy produced from fuels purchased by consumers is obtained in burning systems which average efficiency is, at best, about 90% (referred to the lower calorific value of the fuel). From the foregoing it can be seen once again that at least about 10% of the fuel energy used to generate heat is also lost to the environment without the possibility of practical use.

Given these issues, arises the need to increase the efficiency of production processes for electricity and heat generation in order to reduce the financial and environmental costs.

Thus, as an alternative to large power plants and distribution networks of high voltage emerges the decentralized production of electricity, and in particular the Combined Heat and Power (CHP) or Trigeneration (CHCP), in order to take advantage of the inherent limitations on the conversion of heat into work (Afonso, C., 2012. Commission of the European Communities, 1997). Pinto, A.B., 2011). Through a succinct definition, CHP is a process of exploration and production of combined heat and power, in an integrated system, from the same primary source, (Afonso, 2014), Fig. 1. The use of the same primary energy source to generate electricity and heat simultaneously results in high levels of savings and hence a very significant reduction of the energy bill without changing the production process of the consumer.

Fig. 1 - The cogeneration principle (Cogeneration-Fact).

**MAINTENANCE of COGENERATION SYSTEMS**

The CHP systems as any other type of system requires maintenance over its lifetime due to wear from the intensive and material wear. In general, cogeneration systems have higher maintenance costs than conventional systems based on separate production of electricity and heat, due to the fact of having a greater number of moving parts and hence cause greater wear with use. However, this cost may be higher or lower depending on the type of technology used in a cogeneration system.

This fact should not be interpreted as a point of disadvantage of using this type of systems, since the favourable points allow extensively cover this increased cost of maintenance of equipment (sale of electricity to the grid, the primary energy savings, and greater efficiency). Associated with maintenance of cogeneration systems there are two types of maintenance: preventive and corrective, Fig. 2.
Preventive maintenance is a preventive work of defects that can cause a stop or low performance of the equipment in operation. To perform this it is necessary to proceed to oil changes, filters, spark plugs, lubrication of rotating components, etc. Curative maintenance is the preparation of the work that is done after analysis of malfunction and when emergency permits.

Curative process is normally maintained in the following steps:

• Detection of failure;
• Analysis of the causes of failure;
• Repair;
• Fixed error;
• Storage of data of the intervention;
• Evolution for maintenance planning towards preventive maintenance.

Table 1 summarizes the preventive vs curative maintenance.

<table>
<thead>
<tr>
<th>Preventive maintenance</th>
<th>vs</th>
<th>Curative maintenance</th>
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<tr>
<td>Schedule stops</td>
<td></td>
<td>Unscheduled stops</td>
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<tr>
<td>Protection of more valuable components</td>
<td>Uncorrected small defects, may cause malfunctions in engines, etc.</td>
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<tr>
<td>Controlled costs</td>
<td></td>
<td>Unpredictable costs</td>
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ANALYSIS OF CURRENT SITUATION

This work analyses a situation arising from the application of the new rules imposed by the last legal framework established by Decree-Law No. 23/2010, (Official Gazette, 2012) and respective associated decrees in force in Portugal.

The company for this energetic and feasibility study is one of the tourist sector, whose thermal energy consumption is basically for water and space heating.
The actual cogeneration facility of the company has a cogeneration plant with a fuel engine of 5994 kW, which runs for about 18 years, lying at the end of its useful life.

In terms of specific thermal consumption, currently only the energy of the HT (high temperature) circuit for production of hot water for different utilisations is used. The recuperative boiler is not operating.

The recovery equipment of thermal energy present in the system is as follows:

- heat exchanger HT (high temperature) circuit;
- heat exchanger LT (low temperature) circuit;
- intermediate heat exchanger circuit connection (HT circuit links the consumer circuit);
- recuperative steam boiler (not in operation).

Given the current low heat consumption, the new study will focus on a new more realistic profile. Therefore it was realized that the power of a new cogeneration will also be lower than the current one. Otherwise it could not be, since oversizing causes a waste of thermal energy that does not fit with the definition of cogeneration, i.e., the overall efficiency of the system drops by not harnessing the thermal energy and the penalties that come here make unfeasible the investments.

**ENERGY SURVEYS**

An important point in this feasibility study is the design of the new cogeneration system from the profile of the annual heating requirements. It is from these data that cogeneration and their auxiliaries are planned as well as the selection of the motor generator set, [6].

There have been provided the following energy surveys:

a) electrical consumption of the company;

b) current consumption of thermal power.

The electrical consumption was considered as an historical data provided by the client, concerning the year 2012, Fig 3.

As can be seen from figure 4, in the summer months (June to September), the thermal power fall sharply. Roughly, it passes up from approximately 1000 kW in winter to 300 kW in summer. Through this thermal power profile and based on the profile of the user operating time, Table 2, it was estimated the annual thermal energy consumption, Fig.5.

**FEASIBILITY STUDY**

As already mentioned, a feasibility study for a possible scenario was performed. For that the following assumptions were admitted:

Reference year: 2012
Fuel: Natural Gas
Period of plant operation: Hours Floods and Tips
Period of operation of user: 13 hours / day (8h to 21h)
Estimated fuel prices:
- Electricity consumed from the grid: € 0.129 / kWh
- Fuel oil: 600 € / Ton
- Natural Gas: € 0.4435 / Nm³
Fig. 3 - Current needs of electricity recorded monthly in the user.

For the heating power, it was also taken the historical data from the client, Figure 4.

Fig. 4 - Current consumption of thermal power of the user.

Table 2 - Anticipated operational profile for the user.

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Fig. 5 - Actual energy consumption of the user
Mode: Special Mode. This is applicable to cogeneration installations with an installed electrical power not exceeding 100 MW. These should access the licensing of the facility after first obtaining a connection to the mains utility (RESP). It enables the delivery of electricity to the grid in return for a standard fare complemented by the payment of a premium efficiency calculated in terms of primary energy savings and CO\textsubscript{2} not emitted from each cogeneration unit, i.e., the energy is sold to the grid with bonus rate. In this mode the remuneration of electricity produced is conducted in accordance with the calculation procedure defined by the legislation (Official Gazette, 2010).

For the present study it was considered the full recovery of the energy generated by the motor generator group, i.e., all the energy produced by the cogeneration plant will be exported to the grid and all that it is necessary to consume, including supplies to the end user, will be purchased to the grid. This is because the sale price exceeds the purchase one.

As already mentioned, the current cogeneration operating with fuel oil will suspend its operation due to lack of profitability.

NEW COGENERATION SYSTEM

In this scenario, and according to energy surveys already performed, it will be designed a new cogeneration plant in order to meet the current consumption of the thermal indoor pools, i.e., 4079 MWh/year (in the present scenario corresponds to 419 Ton of fuel oil with an approximate price cost of 600 € / ton).

Therefore, in this study it was considered that the system will be based mainly on:

- ICE (internal combustion engine);
- Harnessing heat of HT (high temperature) circuit, similar to that currently occurs in the fuel engine whose operation will be suspended;
- Flue gases circuit with a recuperative boiler capable of producing hot water, also for heat consumption.

LT (low temperature) circuit has been ignored in this study due to its meaninglessness in terms of power and their low temperature. However, that does not mean in the design phase, a heat recovery for this circuit is not provided.

Once planned to obtain energy just hot water for consumption, it was considered in the study that the annual heat consumption can be shared by HT circuit and the flue gases equally, i.e., it was considered that the 4079 MWh\textsubscript{t}/ year required, 2040 MWh\textsubscript{t}/ year come from the HT circuit and 2040 MWh\textsubscript{t}/ year come from the flue gases.

With these data it was performed a simulation for determining the generator set. This simulation has the following criteria as a basis for the selection conditions:

- PES (Primary Energy Savings) > 0%
- Minimum engine load regime: 60%
- Percentage Maximum speed: 97.5%
- Availability of the group: 95%
- Auto-electrical consumption: 3%

With this data as input to the software developed, the following results were obtained:
In the summer months the regime motor load must be reduced to its minimum allowable: 60%.

In the summer months the PES falls to 2.8%, while in the remaining months, is maintained at about 25.6%. The reason for this decrease is related to the heat rejected in the summer months, with thermal power of rejection ranging from 280 kW, and 480 kW.

- useful electric efficiency: 40.1%
- thermal efficiency: 39.3%
- global efficiency: 79.4%
- PES: 21.2% (high-efficiency cogeneration)

As regards the economic analysis results were as follows:

- Estimated investment: €870000
- Simple Payback: 6.8 years
- NPV (net present value): €85241 (7% rate)
- IRR (internal rate of return): 9%

RESULTS

After defining the scenario, Table 3 presents a summary of the results obtained.

<table>
<thead>
<tr>
<th>Scenario</th>
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<tr>
<td>Annual thermal needs</td>
<td>MWh(t)/year</td>
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<tr>
<td>Annual electrical needs</td>
<td>MWh(e)/year</td>
</tr>
<tr>
<td>Electrical power from generator</td>
<td>kW(e)</td>
</tr>
<tr>
<td>Thermal power from generator</td>
<td>kW(t)</td>
</tr>
<tr>
<td>Recover thermal energy in flue gases</td>
<td>MWh(t)/year</td>
</tr>
<tr>
<td>Thermal energy recovered in HT</td>
<td>MWh(t)/year</td>
</tr>
<tr>
<td>Rejected thermal energy</td>
<td>MWh(t)/year</td>
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<tr>
<td>Electrical efficiency</td>
<td>%</td>
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<tr>
<td>Thermal efficiency</td>
<td>%</td>
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<tr>
<td>Global efficiency</td>
<td>%</td>
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<tr>
<td>PES</td>
<td>%</td>
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<tr>
<td>Investment</td>
<td>%</td>
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<tr>
<td>Loan</td>
<td>%</td>
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<tr>
<td>Payback</td>
<td>years</td>
</tr>
<tr>
<td>IRR</td>
<td>%</td>
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<td>NPV</td>
<td>€</td>
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CONCLUSION

The aim of this study was to analyse the technical and economic potential (Zunido, 2006) of a real situation concerning the acquisition of a new cogeneration natural gas facility in a given company, replacing the actual existing one working with fuel oil (at the end of its useful life, 18th years old). The main conclusions are as follows:

Simple Payback: The simple payback is one of the most common parameters of existing investment analysis. Consists of the time required for the net income equals the value of the investment, i.e., corresponds to the number of years that must be wait to recover the money
invested. In this case, the company invest € 870000 to recover the initial investment in about 7 years.

**NPV:** The net present value is the difference between inflows and outflows of cash (cash flows), duly updated during the life of the project. Normally a project becomes considerably profitable when this value is positive. Thus, for an investment of € 870,000 company values the capital invested at a rate of 7% (cost of the loan), and at the end of 10 years in addition to recover the capital invested, will have a surplus of 85,241 €.

**IRR:** The internal rate of return of an investment project is the refresh rate that overrides the net present value (NPV). Then it can then be said that the IRR is the highest rate that an investor can contract a loan to finance an investment without losing money. In this case there was obtained an IRR of 8.9%, thus meaning that the company will be able to realize the value your investment capital at a rate of 8.9%.

**Comparison of NPV and IRR:** These two methods are often used in a complementary way in order to correspond to the different needs of analysis. Thus, the IRR allows evaluating projects in an immediate way, selecting projects whose IRR is above a certain predefined value and eliminate those which IRR is below this value. Two projects may have the same IRR's and different NPV's, all depending on the intensity of each investor. It is the financial policy of the company that invests that selects the projects to be implemented according to availability and the various alternatives. [20]. So it can be said that if:

- IRR>TA (refresh rate) implies that NPV>0. So one is facing a project with a rate of return higher than the opportunity cost of capital: System economical viable;
- IRR<TA implies that NPV<0. In this case the project fails to generate a rate of return higher than the opportunity cost of capital: System uneconomical.

The criteria for assessing the financial viability of the new cogeneration system present indicative values of a profitable investment. Therefore it is up to the investor the ultimate decision, which was taken for the implementation of the new CHP system.

**REFERENCES**


