CASE STUDY OF AN ENERGY-INTENSIVE CONSUMER

The energy sector is one of the pillars of growth and development for industries and it has been increasing in the last decades. Due to the need of rationalizing energy in industries, the concept of energy efficiency arises. For a rational use of energy, it was created strategies and measures to reduce energy consumptions in a sustainable way – social, economic and environmental. To analyze these consumptions, this paper contains a case study of an energy-intensive industrial installation. This study consists of analyzing all the energy consumptions of the installation, through the obtained values of energy indicators.

Keywords—energy efficiency, energy indicators, EICMS.

I. INTRODUCTION

The industrial sector is one of the sectors with the highest energy consumption of non-renewable energy, representing about 30% of final energy consumption in Portugal. [1] From a global perspective, this sector consumes about 54% of the world's total provided energy. Beyond energy consumption, industries also emit large quantities of carbon dioxide, related to both their energy consumption and their production processes. [2] The industry is therefore incentivized by governmental entities to improve energy efficiency. Expected energy efficiency improvements in the industrial sector temper have growth of industrial energy demand, particularly for the energy-intensive industries. Industries are unaware of efficiency increases that can be realized quite simply and are extremely cost-effective. The outcome of reducing energy use is the production of clean, cost-competitive and environmentally reliable energy by modern power industry. Through counselling and energy audits, industries are introduced to several solutions focused on reducing energy consumption. [3] The main objectives of energy efficiency solutions are minimizing energy waste, promote the use of renewable energy sources, reduce the emission of polluting gas.

This study case is based on the analysis of the energetic consumption of an energy-intensive consumer, that, in this case, is an industrial entity. This way, the respective energetic vectors are analyzed after collecting some data about them. The main objective of this case study is to expose that energy consumption reduction is one of the pillars of energy efficiency, particularly in energy-intensive consumer industries.

II. ENERGY INTENSIVE CONSUMER MANAGEMENT SYSTEM

The Energy Intensive Consumer Management System (EICMS) is one of the predicted strategies of the National Energy Efficiency Action Plan. It is a strategy aimed at the country's biggest energy consumers: the industries.

Under the Portuguese law and the National Energy Strategy, the Decree-Law number 71/2008 was published, creating the EICMS with the purpose to promote energy efficiency and supervise the energy consumptions of energy-intensive users. In this way, it also intends to reduce the dependence on the use of non-renewable energies. [4] The Decree-Law number 7/2013 approves the realization of energy audits and energy rationalizing plans, as well as its control and progress. [5]

The EICMS is applied to energy-intensive users that have energy consumptions higher than 500 tons of oil equivalent (toe). The consumers are obligated to do energy audits every 8 years and to reduce 4% or 6% of the energy indicators. [6] The EICMS's objectives are promoting energy efficiency and control energy consumptions mostly in energy-intensive industries consumers. It also contributes to the reduction of greenhouse gas emissions, like CO_2.

The EICMS is subordinate to a functional structure, which depends on some energy entities.

A. System structure

This management system requires regularly energy audits in order to understand the several energy utilizations conditions. It is also necessary to elaborate Energy Consumption Rationalization Plans (ECRP) which should contemplate minimum energy efficiency targets. After the plan's approval, it will turn out to be Energy Consumptions Rationalization Agreements (ECRA). Following, an Implementation and Progress Reports (IPR) must be elaborated to verify the energy efficiency targets evolution. Briefly, the scheme below represents the structure of EICMS. [6]

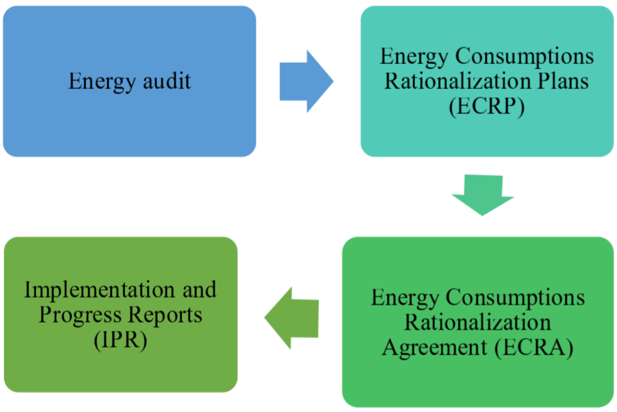

Fig. 1. Energy Intensive Management System's structure

B. Energy Audit

Nowadays energy is recognized as a key role for industrial competitiveness. It is, therefore, important to manage it according to the social and economic resources that entities have. A detailed knowledge of energy consumptions it's essential so that entities can reduce their costs. That way, an energy audit it's the first step in order to reduce energy consumption in an industrial sector.

An energy audit is an inspection, survey and analysis of energy flow for energy conservation in a building, process or system to reduce the amount of energy. An energy audit is the first step in identifying opportunities to reduce energy expenses and carbon footprint. [7]

An energy audit allows us to know where, how much and how energy is being used and to understand where energy waste occurs, recommending posteriorly solutions for the listed anomalies. It has recognized a very important way to identify wastage energy and able to find out several ways to reduce that waste. It's crucial to know the actual energetic reality of the installation and, after that, establish and implement a plan to make the facility more energy efficient.

Some measures that are established after an energy audit are: [8]

- Control of ventilation and climatization systems;
- Optimizing the operation of electrical motors;
- Efficient illumination (LED);
- Reactive energy reduction;
- Renewable energy production.
- Use of more efficient equipment and production tools;
- Employees' behavioral changes.

According to Energy Intensive Consumer Management System, energy audits are obligatory in energy-intensive consumer installations and must be done every 8 years. [4] In order to implement an energy audit, it's important to define a sequence of actions and steps that make it possible to fulfill the objectives that arise. In a general way, those steps are identified in figure 2.

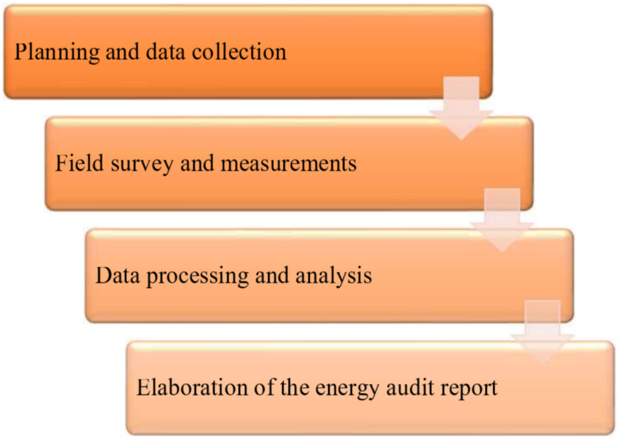

Fig. 2. Preparation steps of an energy audit

The ECRP is elaborated based on energy audits reports and includes minimum energy efficiency targets.

This plan also set targets related to Energy Intensity (EI), Carbon Intensity (CI) and Specific Energy Consumption (SEC), considering the indicators that are presented in the next subchapter. [9]

1) Energy indicators

Energy indicators are determinant for the analysis of the energy consumption of an installation and are calculated as follows:

- Energy Intensity (toe/€) – Measured by the quotient between the total energy consumption (toe) and the result of productive activities linked to the industrial installation (€).

$$EI = \frac{Energy}{Productive\ activities} \quad (1)$$

- Carbon Intensity (Tongas/toe) – Measured by the quotient between the tons of greenhouse gas emissions (gasTon/year) and the total energy consumption (toe).

$$CI = \frac{Greenhouse\ gas\ emissions}{Energy} \quad (2)$$

- Specific Energy Consumption (toe/m^3) – Measured by the quotient between the total energy consumption (toe) and the production volume (m^3).

$$SEC = \frac{Energy}{Production} \quad (3)$$

Targets are set for the energy indicators mentioned above in order to rationalize energy consumption. Those targets depend on the annual's industrial facility's energy consumption.

For annual energy consumptions equal or above 1 000 toe, the targets are: [6]

Fig. 3. Reduction targets for consumptions above 1000 toe

For annual energy consumptions between 500 and 1 000 toe, the targets are:

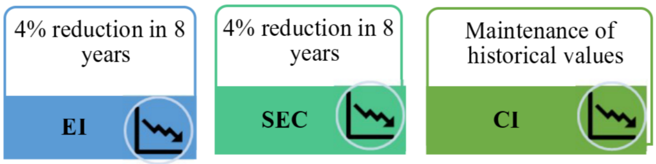

Fig. 4. Reduction targets for consumptions between 500 and 1 000 toe

III. METHODOLOGY

In order to elaborate an energy monitoring report under the EICMS, it is necessary to collect a set of the installation's energy data to proceed with its analysis. Thus, the facility must send the invoices for each form of energy consumed as well as the production values.

The most common forms of energy consumed are electric energy, natural gas, diesel and fuel oil. In this way, all invoices are diverse and need different kinds of analysis. The begin of an energy study starts with the examination of electrical energy invoices because it's the most consumed form of energy nowadays.

In addition to being essential to know the quantity of energy consumed, it is also necessary to identify the quantity of gas emissions that are emitted due to energy consumption.
That way, it is essential to know all the values about energy consumption, production, emission of polluting gases in order to calculate energy indicators.

After calculating energy indicators, the results are analyzed in the Implementation and Progress Reports. This report should be delivered in each biennium of the ECRP, that is, every two years it's necessary to send it.

IV. CASE STUDY

This chapter refers to the set of procedures that are necessary to obtain the results of energy monitoring. In this case, the analyzed installation was only able to accomplish two of the objectives set for energy indicators.

This installation has as main activity the production of furniture for offices and commerce. Its first energy audit was elaborated in 2010, so 2009 is the reference year. The values of energy consumption in the reference year are shown in the following subchapter.

A. Reference year

The reference year is the previous year relative to the year in which the energy audit was realized. This installation consumes energy in several ways, such as electricity, natural gas and diesel.

The energy consumption of the installation in the reference year is shown in table I, as well as its value in toe and tons of CO2 that were emitted.

TABLE I. ENERGY CONSUMPTION IN THE REFERENCE YEAR

	Consumption	Toe	Ton CO_2
Electricity	2 606 276 kWh	560	1 225
Natural gas	267 ton	287	771
Diesel	53 ton	55	171
Total		903	2 167

Analyzing the data above, the installation has a consumption lower than 1000 toe. So, according to laws and to figure 4, it's mandatory for the installation to reduce energy indicators in, minimum, 4%. This reduction is converted into a decrease of about 40 toe in the energy consumption value.

In the following tables (II, III and IV the indicators that will be monitored are presented, as well as their respective reduction objectives at the end of the plan.

TABLE II. ENERGY INTENSITY REDUCTION

Energy Intensity Reduction: 4%/8 years				
Energy (toe/year)	Productive activities (€/year)	Energy Intensity (kgtoe/€)	Energy Intensity Reduction (kgtoe/€)	Energy Intensity at the end of the reduction years (kgtoe/€)
903,0	1 511 226,0	0,597	0,024	0,574

TABLE III. SPECIFIC ENERGY CONSUMPTION REDUCTION

Specific Energy Consumption Reduction: 4%/8 years				
Energy (toe/year)	Production (m3)	Specific Energy Consumption (kgtoe/ m3)	SEC Reduction (kgtoe/ m3)	SEC in the end of the reduction years (kgtoe/€)
903,0	176 229,0	5,123	0,205	4,919

TABLE IV. CARBON INTENSITY REDUCTION

Carbon Intensity Reduction: Maintenance of historical values/8 years			
CO2 emissions (tCO2 /year)	Energy (toe/year)	Carbon Intensity (tCO2 /toe)	Carbon Intensity that should be achieved in 8 years (tCO2 /toe)
2 167,2	903,0	2,4	2,4

B. Energy efficiency solutions implemented

All eight measures proposed in the ECRP were implemented. These measures were: steam generator regulation and isolation, steam leakage removal, valve and steam pipe isolation, purge control, elimination of compressed air leaks, energy management system guidance. This measure's implementation caused a saving of 33.901,00€ to the installation and a total reduction of 45,4 toe and 107,9 tons of CO_2.

C. Energy consumption evolution

As said previously, the forms of energy consumed for this installation are electrical energy, natural gas and diesel. The total energy consumption values of each form are shown in the tables 2,3,4. For a clear interpretation, the results are indicated in toe because it is a conventional energy unit.

TABLE V. EVOLUTION OF ELECTRICAL ENERGY CONSUMPTION

	2009	2011	2013	2015	2017
	Toe	Toe	Toe	Toe	Toe
Total	560,0	868,0	724,0	529,0	621,0

TABLE VI. EVOLUTION OF NATURAL GAS CONSUMPTION

	2009	2011	2013	2015	2017
	Toe	Toe	Toe	Toe	Toe
Total	287,0	409,0	428,0	382,0	309,0

TABLE VII. EVOLUTION OF NATURAL GAS CONSUMPTION

	2009	2011	2013	2015	2017
	Toe	Toe	Toe	Toe	Toe
Total	55,2	69,1	58,1	62,0	55,1

Interpreting the results of tables V, VI and VII, it is possible to affirm that the vectors of electricity and natural gas increased in the last biennium (2017) compared to the reference year (2009). The energy vector of diesel was the only exception because it got a slight decrease.

Observing the total values of table VIII, in the last biennium (2017), the installation had a total energy consumption of 985,56 toe. Analyzing this table, it can be concluded that energetic consumption suffered some discrepancies over the years, oscillating between consumption increases and decreases.

TABLE VIII. TOTAL ENERGY CONSUMPTION

	2009	2011	2013	2015	2017
	Toe	Toe	Toe	Toe	Toe
Total	903,0	1 346,0	1 210,0	973,0	986,0

To calculate energy indicators, it is also necessary to know some values about the installations' production, as well as the monetary result of productive activity. In the graphic below (figure 3) is shown the production's evolutions along the years of Energy Consumption Rationalization Plan, relatively to each month.

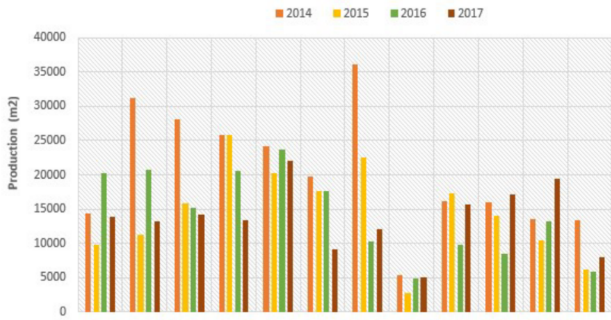

Fig. 5. Graphic of productions' evolution

In the final year (2017), the production suffered a decrease of about 8% in comparison to the reference year. Just as energy consumption, the production also had inconsistent values. If the production decreases, the energy consumption will also decrease, so these two variables are associated with each other.

In similarity with production, the monetary result of productive activity also revealed inconsistent values, as it is possible to see in table IX.

TABLE IX. PRODUCTIVE ACTIVITY EVOLUTION

	Productive activity (€)
2009	1 511 225,5
2011	5 274 313,0
2013	4 589 390,0
2015	2 691 591,0
2017	3 857 538,0

After gathering all the necessary information (energy consumptions, production and productive activity) for the calculus of energy indicators, those calculated values will be analyzed in chapter V.

V. ANALYSIS OF ENERGY INDICATORS

The evolution of the energetic indicators (EI, CI, SEC) in the final year (2017) of the ECRP is presented in tables X, XI and XII. These values are calculated through the equations (1),(2) and (3).

The energy indicators' analysis is realized using the expected values for each year of the Energy Consumption Rationalization Plan and the calculated values for the corresponding biennium.

As shown below, the variation is obtained trough the difference between the expected value and it is possible to conclude whether there was a positive or negative variation.

TABLE X. ENERGY INTENSITY EVOLUTION

	Biennium 4 - 2017		
	Energy (toe)	Productive activity (€)	Energy Intensity (kgtoe/€)
Expected values	821	1 511 226	0,543
Obtained values	986	3 857 538	0,260
Variation	20%	155%	-53%

According to the analysis of table X, the obtained value of Energy Intensity was reduced in more than half (53%) compared to the expected value, despite the energy consumption increase in that year.

This indicates that there was a very positive variation of this indicator, which is related to the significant increase in productive activity.

TABLE XI. SPECIFIC ENERGY CONSUMPTION EVOLUTION

	Biennium 4 - 2017		
	Energy (toe)	Production (kg)	Specific Energy Consumption (kgtoe/kg)
Expected values	821	176 229	4,657
Obtained values	986	163 122	6,042
Variation	20%	-7%	30%

Relatively to the Specific Energy Consumption indicator, the obtained value was about 30% higher than the expected value. Due to the increase in energy consumption, this indicator didn't reach its target.

TABLE XII. CARBONIC INTENSITY EVOLUTION

	Biennium 4 - 2017		
	Energy (toe)	Gas emissions ($tonCO_2$)	Carbon Intensity ($tonCO_2$/toe)
Expected values	821	1 965	2,39
Obtained values	986	2 359	2,39
Variation	20%	20%	0%

According to table XII, the indicator Carbon Intensity didn't have a significant variation, maintaining the same value, as it was supposed. The energy consumption and the gas emissions had the same variation, causing a zero variation of this indicator.

Concluding, the objectives set for Energy Intensity and Carbon Intensity were achieved. Given that Specific Energy Consumption suffered a significant increase, the targets were not achieved.

VI. CONCLUSIONS

Through the energetic analysis of this installation, the energy management system has demonstrated satisfactory outcomes, decreasing the energy consumption of a few years of the Energy Consumption Realization Plan. This decrease is due to the implementation of several measures to rationalize energy use. However, in some cases the indicators' targets were not achieved, obtaining unfavourable energy results.

Concluding, the energy efficiency in industry and sustainability are, nowadays, progressing themes due to climate change issues. Therefore, energy efficiency is seen as a big challenge for the future.

REFERENCES

[1] "ERSE," Novembro 2019. [Online]. Available: http://www.erse.pt/consumidor/eficienciaenergetica/Paginas/default.aspx.

[2] "Energy Intensive Industry," [Online]. Available: https://www.sciencedirect.com/topics/engineering/energy-intensive-industry. [Acedido em Outubro 2019].

[3] M. Kott e J. Kott, "Indicators of energy intensity in industry," 2014.

[4] "Diário da República Eletrónico," [Online]. Available: https://dre.pt/pesquisa/-/search/249821/details/maximized. [Acedido em Novembro 2019].

[5] "Diário da República Eletrónico," [Online]. Available: https://dre.pt/web/guest/pesquisa/-/search/257073/details/maximized. [Acedido em Novembro 2019].

[6] "SGCIE - ADENE," [Online]. Available: https://www.sgcie.pt/sistema-de-gestao-dos-consumos-intensivos-de-energia/o-regulamento/enquadramento-e-objectivos/. [Acedido em Novembro 2019].

[7] S. K. Rajput e O. Singh, "Energy audit in textile industry: a study with ring frame motor," 2016.

[8] "EDP Distribuição," [Online]. Available: https://www.edpdistribuicao.pt/pt-pt. [Acedido em Novembro 2019].

[9] M. Vaz, "Estudo dos consumos energéticos de Empresas," Instituto Superior de Engenharia do Porto, 2016 .

NOTA DISPERSA

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Para além de elaborarem as normas portuguesas (NP) do sector elétrico e de participarem na elaboração das normas europeias (Cenelec) e internacionais (IEC), as CTE emitem pareceres técnicos sobre assuntos da sua competência específica e produzem documentos que auxiliam os profissionais e as empresas a terem cada vez mais qualidade e eficiência no seu trabalho.

Uma dessas Comissões, a CTE 81 – Proteção contra descargas atmosféricas e seus efeitos, elaborou recentemente o Guia Técnico de Apoio à Utilização da série de normas NP EN 62305 – Proteção contra Descargas Atmosféricas.

O Guia pode ser obtido gratuitamente no sítio de internet do IEP, sendo constituído pelas seguintes partes: Introdução; Parte 1; Parte 2; Parte 3; Parte 4.