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Energy Audit for PETRATEX®

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NOMENCLATURE

Ap	Living floor area	m^2
IEE	Energy Efficiency Indicator	kgep/m^2. year
IEEnominal	Nominal energy efficiency indicator	kgep/m^2.year
IEEreal	Real energy efficiency indicator	kgep/m^2. year
IEEI	Energy efficiency indicator in heating	kgep/m^2.year
IEEV	Energy efficiency indicator in cooling	kgep/m^2.year
FF	Form factor	
NI1	Maximum heating demand allowed by RCCTE in reference area I1	kWh/m^2.year
NIi	Maximum heating demand allowed by the RCCTE in the area of the building concerned	kWh/m^2.year
NV1	Maximum cooling demand allowed by the RCCTE in the reference zone I1-V1	kWh/m^2.year
NVi	The maximum cooling demand allowed by the RCCTE in the area of the building concerned	kWh/m^2.year
Q_{out}	Energy consumption not linked to heating and cooling processes	kgep/m^2.year
Rph	Airtime Replacement	h^{-1}
T	Air temperature	ºC
ΔT	Temperature variation	ºC
U	Thermal transmission coefficient	W/(m^2 ºC)
msi	Useful superficial mass of each constructive element	kg/m^2

1. INTRODUCTION

1.1 The importance of Energy Audit

Legislative Decree 115/08 defines "energy diagnosis" or also known as "energy audit" is a systematic procedure whose aims are mainly:

- Provide knowledge of the energy consumption profile of a building or group of buildings, an industrial activity or plant, or public or private services;
- Identify and quantify cost-effective energy saving opportunities;
- report on the results.

In almost the same way, the draft European standard EN 16247-1: 2011 "Energy audits - Part 1: General requirements" defines the "energy audit" as:
Systematic inspection and analysis of energy use and energy consumption of a system or organization with the aim of identifying energy flows and the potential for energy efficiency improvements.

If you wanted to have a simpler idea in immediate terms, you could say that the audit procedure is a sort of picture. It is true that the analysis starts from a data history, but the goal is to define the situation in terms of consumption, transformation, distribution and detection of any waste of energy at that particular moment, such as a picture. Subsequently, an assessment can be made on the basis of well-defined and standardized parameters and, if necessary, proposed an improvement on the basis of economic technical considerations as it is a procedure that precedes any project that aims at energy efficiency. It is a very important work and it also aims to create the conditions for the development of a long-term: documented, objective and systematic action plan.

A difference that needs to be clarified is between efficiency and savings. Saving is a procedure in which it is expected to give up to something to avoid the use of energy in the widest sense of the term, such as not moving the car to save fuel and emissions. On the other hand, efficiency is a procedure that allows you to do the same things but with less energy needs, so to continue the example, you have efficiency when you choose a car that consumes less fuel per kilometer and therefore, of course, will consume less fuel than before. The same applies when you choose a more relaxed and careful drive-style that allows you to consume less that is a method to do efficiency.

So, you want to do the same things using the energy in the best way, here's the goal of an audit: to understand how to use energy and to develop the best and most effective methods to use it.

Another important point is that energy efficiency does not necessarily mean generating energy from renewable sources. In common sense, it is often thought that it is not so important how much energy is consumed but from which source it comes from. This reasoning is not entirely consistent, though it is true that using the same amount of energy from renewable sources is less polluting (in general), it is good to specify that the goal is different in case you want to decrease the amount of used energy. This is a different vision, not necessarily better or longer term, just different. Of course, the best strategy is the synergy between the two development methods.

Approaching the procedure may have some difficulties such as insufficient documentation and knowledge by the customer of his own plant and energy flows. Also, very often, there is no technical documentation of the machines, a reliable historical data involving energy consumptions and ways of use.
As discussed later on, workers are sometimes unaware of good practices, intended as proper behaviors, to use energy, nor are managers who should know the best ways of managing and rationalizing their use.

Sometimes buyers do not know other methods, technologies or solutions to make energy more effectively and do not take into account that investing in capital to enhance and improve energy use and management definitely brings advantages in economic terms and reputation, as well as tax breaks and in some cases benefits.
However, it is difficult to find investors who are attentive to energy indicators, as they usually pay little attention to energy efficiency investments, both in the private and public sectors.

Another point, however, which is always the result of low energy sensitivity, is the difficulty in generating total emissions and consumption through general reference energy indicators or the sector concerned.

Through the audit report, it will also be possible to have documented knowledge of the building-plant system in terms of performance, consumption, data, energy indicators, and how the energy is used. In the case of in-depth analysis of the plants, specific reports will be compiled, which include not only the detailed description of the equipment in terms of typology, technical characteristics, state of use and maintenance status, but also verification of compliance with current safety, accident prevention regulations, environmental impact.

In the following, we will see some of the possible intervention areas to improve energy use and will provide numerical examples of the benefits that replacement of certain equipment might entail, thus proposing a sort of simplified study on economic technical aspects. In fact, the audit allows us to understand the current situation and to be able to reduce systematically energy consumption and thus minimize the economic costs and the environmental impact at the same time.

Replacement of equipment not only reduces energy demand, but an "intervention" that can substantially change consumption, are good habits, which actually become zero-cost interventions, that is, they do not require capital outlay, if not the time to form employees.
You want to make your employees more aware and through awareness raising and information campaigns that aim to change their behavior in the company such as optimization in lighting times, rationalization of the use of the air

conditioning system, more attention to the maintenance or adjustment in power factor compensation of the plants.

An industry should do an energy audit for many reasons: not only to get savings (in € or kWh) in the short (medium and long) period depending on the inefficiencies in the beginning but also to know and become aware of their consumer profile, which allows them to obtain better contractual terms with suppliers of electricity, gas and more.
For suppliers, the information about how and when the demand for their service will be, can do the difference because it allows them to provide a stable and better quality service for everyone at the lowest cost, maximizing their profits. In addition, efficiency measures are "no regrets" as they are not aimed at saving and there are no fees to pay (in addition to investment itself) to achieve energy efficiency. It also helps to identify savings opportunities and integration opportunities with new technologies.

In addition to the considerations made so far, it should be noted that technological leadership and image return about their particular attention to the environment is not to be underestimated and it is often difficult to attribute a monetary value. The perception that potential customers have on the company is very important and will lead them in many occasions to prefer this company even if they sell at the same price and / or they are also willing to pay more to ensure a relationship with a sensitive environmental business that enables them to certify and labelling their production as “eco-friendly”.

More generally, energy efficiency acts as a stimulus for innovation and the development of new products and services and professional figures such as auditors and "energy managers" or "carbon managers" as well as obvious positive environmental effects in terms of emissions and secondly, it reduces operating costs in the different sectors that do not have to recharge the costs for waste disposal or to offset their carbon footprint.

Finally, there are also strategic implications that make it less dependent on energy powers and more generally by those who hold fossil fuels, perhaps even self-production for self-sufficiency, even better if it is part of small, totally energy-Renewable, then grow and expand more and more.

The energy system has been changed for structural reasons, not just contingencies, and requires new problems, requiring new solutions such as managing the electricity grid with accumulation of intermittent production (typically renewable), elasticizing demand, shifting consumption towards the most efficient vectors (heat pumps or condensing boilers?), use mobility as a diffuse accumulation.

The obligation for large companies is to do an energy audit to be repeated every four years. Even small and medium-sized enterprises, even if they do not have this obligation, can still be encouraged to undergo energy audits through specific programs drawn up by EU Member States.

1.2 Differences between energy certification and energy audit

It is not always clear whether Energy Audit is actually the Energy Performance Certificate, commonly referred to as APE, which came into force in Italy with D.lgs. 192/05. In fact, they are similar in some aspects, but it is to be stated that the APE is a statutory document that encloses within it some of the information that is the basis of Energy Diagnosis (Energy audit).

The APE and Audit tools provide differentiated information since the former is based on a standard and simplified calculation instead of the Diagnostic Energy, the calculation is adapted to non-standard users, following a logical based way, developing a Dynamic Model, and considering different things case to case.

In an Energy Performance Attestation (APE), the Energy Class determination is attributed to the annual energy consumption per m^2 calculated based on the performance of the building envelope in relation to the performance of the units of the real estate unit under investigation.
The calculation is carried out in accordance with UNI TS 11300, assuming that the unit has a constant internal temperature of 20 ° C and that the plant is accessed 24 hours a day throughout the heating season determined by the day rates stated in the particular climatic conditions. The EAP also includes standard calculation factors such as internal inputs, ie the assessment of the internal thermal inputs is dependent on the intended use of the building and does not take into account the actual occupation or not, as regards the hours of employment for both the actual needs.

When an Energy Audit is performed, a user-tailored and more detailed calculation is performed, many data inputs that are standardized in the Auditor in the EAP are modified according to the type of user as understood by the consumer profile over time. Adapting a user calculation means imputing real-time, non-standard value calculator software, commensurate with actual ways of using the plant, actual occupancy data of the property, and up-to-date climatic data of the site where the building is.

The first step is to analyze the real consumption of the property through user's bills. These utilities are compared to those returned by the model of the building under review created through a computing software. The standardized model, the one used to calculate the energy performance to be returned to the EAP, is customized and calibrated to be comparable to actual fuel consumption.

The model calibration is done by adapting the standard data, which means that the real operating time of the thermal system (eg: 8h-18h) is included in the calculation software, the actual degrees days of the year are included, the real free allowances and all the energy consumptions associated with that building are updated, obtaining a correct energy user profile, closer to the reality.

In the picture below the main differences between APE and Audit are shown:

	APE	AUDIT
Simplified calculation with steady state	✓	✓
Advanced calculation in dynamic mode	✗	✓
Calculation with up-to-date climatic data	✗	✓
Calculation with actual working hours	✗	✓
Energy class determination	✓	✗
Heating consumption calculation	✓	✓
Calculate cooling consumption	✓	✓
Calculating electrical consumption	✗	✓
Comparison of real consumption with invoices	✗	✓
Calculate suggested improvement actions	✓	✓
Reliable estimate of obtainable savings	✗	✓

Figure 1.2.1 - Synthetic comparison between APE and Energy Audit

1.3 Portuguese national energy strategy

Program for competitiveness, growth and energy and financial independence	• Competitiveness in the Portuguese energy market and economy, economic growth and reduction of the country's energy and financial dependence
Investments in renewable energy	• Diversification of the portfolio of renewable energies using already mature technologies • Simplified procedures for assigning new technologies demonstration projects
Promotion of energy efficiency	• Greater focus on transport efficiency (eg Electric Vehicles); • Reinforce the measures with the greatest potential to reducing consumption in the 2020 horizon, in houses, industry and State; • Industry development through energy saving companies (ESCO).
Ensuring security of supply	• Promote the continuation for energy mix diversification ; • Development of new interconnections with Spain for the transport of electricity and natural gas.
Sustainable energy strategy	• Creation of a fund for the equilibrium tariff; • Increase the competitiveness of the renewable sector (selling price to the final consumer); • Progressive decarbonation of the Portuguese economy;

1.4 Portuguese national energy efficiency strategy

Directive 2012/27 / EU of the European Parliament and of the Council of 25 October 2012, transposed into the national legal order by Decree-Law no. 68-A / 2015 of 30 April, established a new framework that promotes energy efficiency in the EU.

The National Action Plan for Energy Efficiency for the period 2013-2016, approved by Council of Ministers Resolution 20/2013, of April 10, includes the themes addressed in the above-mentioned directive.
Based on the areas addressed by the PNAEE of 2008, the PNAEE 2016 covers the following areas: Transportation, Residential and Services, Industry, State, Behaviors and Agriculture. These cover a total of 10 programs in energy efficiency improvement measures.

The following figure shows the proposed targets for 2016 and 2020 for each area.

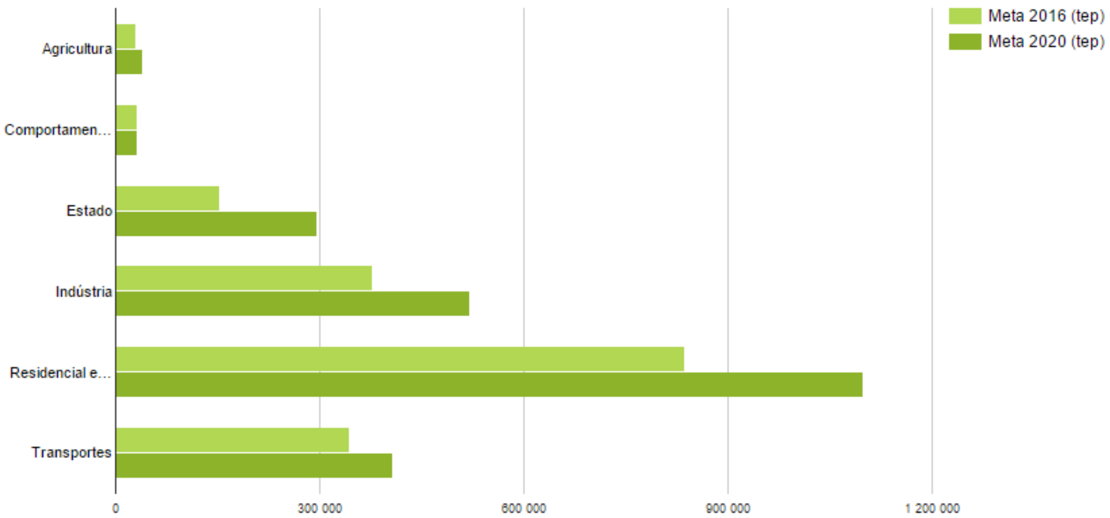


Figure 1.4.1 - Proposed targets for 2016 and 2020 for each area

The estimated saving of the PNAEE by 2016 is 1501 thousand toe, corresponding to a reduction in energy consumption of approximately 8.2%, approaching the indicative target set by the European Union of 9% of energy savings by 2016.
By 2020, the overall objective is to reduce primary energy consumption by 25%, exceeding EU targets by 20%, and in the Public Administration there is a specific reduction target of 30%

1.5 Portuguese energy policies for industries

Decree-Law no. 71/2008, of April 15, regulates the SGCIE - System for the Management of Intensive Energy Consumption, applied to intensive energy-consuming installations with consumption of more than 500 toe/year. It follows from the review of the RGCE, one of the measures contained in the PNAEE.
The Intensive Energy Consumption (CIE) installations are defined, extending their application to a broader range of companies and facilities with a view to increasing their energy efficiency, taking into account the need to safeguard their competitive base in the global economy.

On May 1, 2015, Decree-Law No. 68-A / 2015, of April 30, entered into force by making some changes to the previous legal document.
ADENE (Energy Agency) is the operational manager of the SGCIE and provides a web portal that covers everything from the registration of intensive consumer activities to the validation of the documents inherent to the SGCIE process.

1.6 Portuguese legislation in brief

The Energy Consumption System for Energy Consumption (SGCIE) is one of the measures provided by the PNAEE - National Action Plan for Energy Efficiency, approved by the Council of Ministers Resolution No. 20/2013 of 10 April. This is a legal regime that belongs to the major energy consumers in the country, in particular industries, linked to the regulatory declarations of Directive 2006/32 / EC of the European Parliament and of the Council of 5 April 2006 on the use and distribution of energy as amended by Directive 2012/27 / EU of the European Parliament and of the Council of 25 October 2012 on energy performance.

At national level, the legal regime contained in Legislative Decree No 71/2008 of 15 April, as amended by Law No 7/2013 of 22 January, which establishes the gradual reduction and the constant dependence on non-renewable energy sources, in particular fossil fuels, as well as optimization and use tools that reduce energy consumption without loss of competitiveness, which meet the criteria, and the specific objectives set by the European Union guidelines.

In essence, this legal regime seeks to comply with the global environmental agreements envisaged in the various treaties and foresees lower use of energy from potentially polluting sources and which have a negative impact on the emissions of harmful gases in the atmosphere, especially CO_2, Energy efficiency and acquire some kind of economic independence linked to the lesser amount of energy imported from other markets.

Compulsory audits are carried out in accordance with Order No. 17449/2008 - DGEG of 27 June. The energy audit will focus on the design and state of the services, and the information needed to produce the SGCIE Energy Management

Plan (EE) should be collected in order to streamline energy consumption and the subsequent verification of compliance.

According to the aforementioned decree, the audit consists of:

- Quantify energy consumption (toe);
- Perform visual inspection of systems consuming equipment / energy, supplemented by necessary measures;
- Clarify how energy is transformed and what is the cost;
- Obtain a detailed detection and characterization of the main energy-using equipment;
- To obtain load curves (DDC) electrical systems considered as large electricity consumers;
- Determine the energy efficiency of thermoelectric generators (boilers);
- Check the status of thermal and electrical transmission and distribution systems.

In terms of achieving the objectives, it is essential to parameterize the requirements of the energy management system, something that contributes to the ISO 50001 standard. ISO 50001, published June 15, 2011, has been drafted by the ISO / TC 242 Technical Committee "Energy Management" of the International Organization for Standardization (ISO)[25], according to European Standard EN 160 001: 2009. It should be noted that the European Commission considers that the authorization of standards for energy management systems is important steps towards greater energy efficiency in European industry. The European standard was the result of a working group of the European Committee for Standardization (CEN).

In addition, the Portuguese national legislation recognizes the potential of ISO 50001 and the PNAEE - National Action Plan for Energy Efficiency for the period 2013-2016 is resumed with the following reference: 'With a view to the implementation and evaluation of the SGCIE, it aims to promote the energy review in the sense of extending the scope and improvement of the level of monitoring of energy consumption and encouraging the right to demand incentives to encourage voluntary participation of businesses. It also seeks to improve the control of the implementation of energy efficiency measures, in particular through the use of measurement and verification protocols. With this SGCIE review, it is also intended to increase the number of companies that comply with European standards for energy management systems (eg ISO 50001).

A general goal is to save energy by at least 9% by 2016, to be achieved through energy services and other measures to improve energy efficiency. In order to achieve this goal, policies, programs and measures to improve energy efficiency are established through the National Action Plan for Energy Efficiency (PNAEE), which provides for incentives and other sanctions where necessary to create the conditions more favorable for the effectiveness of the measures.

Also included are Plans to Promote Efficiency of Electricity and Natural Gas Consumption (PPEC) established under the tariff regulation, and the

responsibility of Entidade Reguladora dos Serviços Energéticos (ERSE) and other energy efficiency support programs based on national budgets.
For comparison of energy savings and conversion into a comparable unit, the conversion factors mentioned in Figure 4.1.1 should be applied as published in Despacho No. 17313/2008 of June 26.
The improvement of energy efficiency measures must take into account the general framework for the measurement and verification of energy savings as listed in Annex IV of the Official Journal, 1st series - No. 213 - NOVEMBER 3, 2009 8323.

In addition to the overall objective, an interim target has been established compatible with the overall 2010 energy saving target, as well as a framework for its strategy for achieving these goals: the first Operational Plan for Energy Efficiency.
The oversight and responsibility of overall supervision for achieving the goals mentioned is entrusted to the Energy Minister responsible for the energy sector through the Directorate General of the Department of Energy and Geology Direção Geral de Energia e Geologia (DGEG). The control and the responsibility of the overall compliance supervision associated with the PPECs are borne by ERSE.

Other references to regulations can be found in the European Legislation:

- Directive 2012/27 / EU on energy efficiency;
- Directive 2005/36 / EC on the recognition of professional qualifications;
- UNI-CEI-EN 15900: 2009 "Energy Efficiency Services - Essential Definitions and Requirements";
- ISO 50002 "Energy Diagnosis" standard;
- UNI CEI EN 16247- 2012: "Energy Specification - General Requirements" and the subsequent special prEN 16247.2 and prEN 16247.4 norms.

1.7 Examples of energy efficiency

Here are shown many possible ways to improve energy efficiency and savings. The most important aspect is to understand the concept and the potential of the audit tool coupled with an ecological conscience that allows us to use energy in better ways to consume less or, at least better way. the next examples are based on estimates proposed by the Portuguese agency mentioned, ERSE [1] [12].

1.7.1 Designing Compressors

The correct sizing of n air compressor is based on the consumption profile analysis. The compressor works between two fixed pressure points. When the maximum pressure is reached, the compressor stops and maintains the pressure in the system, to start again when the system, the pressure is lower than a fixed threshold.

During the stand-by period, the compressor can consume up to 25% of the energy consumed during the proper charge. There is the possibility to install a variable speed compressor, which varies working conditions according to the compressed air consumption profile. The compressor should be designed so that working conditions are always around 75% of its potential.

The situation that follows is to install a smaller capacity unit for less-consuming periods, and an electronically controlled variable-speed compressor. The practical case for replacing a classic compressor with a variable speed compressor is analyzed. According to data collected in the control unit, the device worked a total of 88,133 hours, and 37,164 of them in office. Based on these data, the compressor operated only 42% of the loading time, referring to a specific consumption of 5.8 m^3/min.

Classic compressor		
Nominal power	75	kW
Rated rate	13,5	m^3/min
Charging time	42	%
Stand-by time	58	%
Real flow	5,7	m^3/min
Specific consumption	12,2	kW/(m^3 min)

By examining the operating characteristics, replacement with a variable speed compressor has the following advantages:

Variable speed compressor		
Nominal flow	5,8	m^3/min
Specific consumption	6,2	kW/(m^3 min)
Average power	35,27	kW
Annual electricity consumption	77,6	MWh/ year
Energy benefit	56	MWh/ year
Emission benefit	27	tCO2/ year
Reduction	42	%
Annual electricity cost	9895	€/ year
Investment	33730	€
Economic benefit	7197	€/ year
Simple payback time	4,7	years

So replacing air compressors reduces energy consumption by 42% and has a payback time less than 5 years.

1.7.2 Lighting system

Illumination is one of the aspects to be checked when you are looking for building inefficiencies, but it must also provide a suitable environment to carry out activities in terms of visual and thermal comfort (exposure for long periods of time to unsuitable lighting quality can cause eyes fatigue).
It is important to provide a uniform distribution, avoiding light and shade changes such as excessive light or excessively glossy surfaces.

The European Committee for Standardization CEN published in 2002 the EN12464-1 standard, which aims to guarantee the quality of interior lighting where the factors to be considered both for design verification and for checking the conditions Lighting of an existing plant. Other standards are set for outdoor spaces, sports facilities and public lighting.

Lighting has a substantial impact on energy consumption in non-residential buildings. Depending on the situation, 30% to 50% of the electricity used in lighting can be economized by investing in energy-efficient lighting systems especially when a factory is 24h working.
Make a correct choice of lamps, lighting fixtures and related equipment (A1, A2 and A3 power supplies, low loss magnetic type B1 and B2 and Cl C1), that is, choosing the right lights for any situation between availability On the market, and the need to implement or not a control system. It is also of great importance to preventive maintenance of the devices [7].

Lamps with white reflectors have an internal reflection index around 70%, coated aluminum is close to 95%.
The use of these devices designed to do a better use of the luminous flux emitted by the lamps allow significant improvement in lighting.
In general, we can divide the lights into these main typologies:

- Incandescent and normal halogen;
- Fluorescent, tubular and compact;
- Other discharge lamps;
- LED.

Incandescent lamps are suitable for places where lightning is required for short periods of time with very frequent switching allowing them to have a longer operating life due to lower filament wire due to the heat generated, therefore does not justify the investment in a more expensive bulb.

Recent developments have led to the creation of an appropriately shaped microscopic filament capable to transform almost all energy into light; This new type can increase the energy efficiency of incandescent lamps from 5% to 60%.

Discharge lamps have outdoor application, sports facilities and industrial warehouses. Light emission does not immediately reach 90% of its nominal value (depending on the technology, the lamp has a different behavior at startup, depends on whether it is cold or hot and may take from 2 to 7 minutes).

An energy-saving bulb consumes five times less energy than a standard bulb. Performance in Lighting can save from 30% to 50% of the electricity consumed.
The LED (light emitting diode) is a type of lamp characterized by relatively low infrared emission (higher-energy-wavelength radiation), low consumption and high longevity. You can supply the same brightness as a standard 60 Watt lamp, consuming only 13 Watt [10].

The hybrid LED emits a white light similar to that emitted by fluorescent lamps, this is a combination of a normal LED with a very thin layer of crystal film.

Nowadays, LED technology is distinguished by having reached the highest levels of efficiency and has numerous applications in light signaling, portable lighting, indoor and outdoor lighting.

A key aspect to consider is the control system, the objective is to ensure lighting when needed and in compliance with regulatory requirements.
Integrating control and adjustment of lighting systems that allow to vary the lighting intensity of the installation, on/off cycles or control the luminous flux, allow to reduce the energy consumption by 70% [14].

For example, turning off light to save energy is the first task that should be integrated with equipment that is more efficient to turn on and off lighting only when needed and adapt it to occupation and outdoor natural lighting.it can sound weird or obvious but most of the times, workers don't turn off light even if they don't need it.

Lighting Control typically saves up to 30% through the use of:

- Dimmer, timers, presence detectors and time switches, twilight switches (bathroom, hotel, entrance to a building, access to your room, around a building, a room);

- Systems management, analysis and monitoring of energy consumption (information that helps customers understand their energy / economic profile to achieve sustainable savings);

- The BUS system allows users to have comfortable workplaces and makes some energy savings through lighting and heating control.

Automating the lighting, temperature and control of curtains / shutters in a office building allows you to achieve remarkable energy savings whilst ensuring flexibility in use as no new wireless cable is needed.
Adjust the lighting (turn it off) when natural light is enough or as soon as the room is without anyone, it saves energy.

Automation, in addition to ensuring greater energy savings, allows greater comfort and security. Indeed, there are no switchers open to the public (or are made unavailable), it is more hygienic and ensures that lighting does not work when it is unnecessary.

There are now three examples of energy saving: two with replacement of lighting devices and the third with the use of automation for regulation.

1. The first involves the replacement of existing T8 fluorescent lighting with 1,664 58W lamps each with 25W LED lamps. The installation of LED lamps eliminates the use of starter and reactors (in the case of ferromagnetic reactors). The following results:

Initial lighting feature	
Lamp type	Fluorescent T8 da 58W
Power supply type	Ferromagnetic
N lamps	1664
Consumption per unit	72,5W
Work hours	2116
Power consumption	255,27MWh/year
Electricity cost	123,64 €/MWh
Electric annual cost	31562€/year

The results with replacement, the energy savings is 66%, and the payback time is 1.4 years.

Replaced lighting system	
Lamp type	Tubes LED T8 25W
Unit power	25 W
Power consumption	88,03 MWh/year
Electric annual cost	10883 €/year
Savings	66%
Energy benefit	167,25 MWh/year
Emissions avoided	78,6 tCO2/year
Economic benefit	20679 €/year
Investment	27972 €
Simple payback time	1,4 years

2. The second case study is to replace all 186 400W mercury vapor lamps:

Initial lighting feature	
Lamp type	Mercury vapor of 400W
Power supply type	Ferromagnetic
N lamps	186
Consumption per unit	423,5 W
Work hours	2288
Power consumption	180,23 MWh/year
Electricity cost	119,0 €/MWh
Electric annual cost	21447 €/ year

With the replacement of the lighting system the energy saving is about 76% and the simple payback time is 3.6 years.

Replaced lighting system	
Lamp type	Campanula LED 100
Unit power	100W
Power consumption	42,557 MWh/year
Electric annual cost	2.064,26 €/year
Savings	76%
Energy benefit	137,671 MWh/year
Emissions avoided	64,7 tCO2/year
Economic benefit	16.382,88 €/year
Investment	59.721 €
Simple payback time	3,6 years

3. The third study case is to install 45 motion sensors in various areas such as corridors, toilets and lockers. Divisions have the following characteristics:

Initial installation	
Number of analyzed divisions	27
Lighting power installed	18,7 W

Work hours	4450 h/year
Annual energy consumption	92,7 MWh/ year
Annual electricity cost	9847 €/ year

The installation of the proposed sensors allows a 30% savings and a simple payback time estimated in 1.8 years.

Solution: Motion sensor installation	
Number of sensors	45
Reduction	30%
Energy benefit	27,8 MWh/anno
Emissions avoided	13,07 tCO2/anno
Economic benefit	2954 €/anno
Investment	5.340 €
Simple payback time	1,8 anni

1.7.3 Electronic ballast

Electronic ballasts consist of a rectifier and a high frequency modulator, about 30 kHz, the main advantages are described below [15]:

- Reduction of leakage (with the replacement of a magnetic ballast you have a potential energy saving up to 25%);
- Slowly turn on the lights so that they can have a longer life span and lower maintenance costs;
- No need to wait for startup times;
- The use of motion sensors, resulting in many lamps lighting, has a low impact on the life of the lamps.
- It can power double the lamps of a conventional power supply;
- Enables more accurate control of power and current;
- Magnetic ballasts flash at a frequency of 50 Cycles / second, the electronics are about 40,000 cycles / second;

- They are lighter, eliminate noise and reduce energy consumption.

In contrast to magnetic ballasts, electronic ones are more expensive even though prices are currently decreasing.

1.7.4 High Efficiency Motors (EEMs)

Choosing highly efficient engines allows you to have lower running costs by investing a larger sum when buying around 25 or 30% due to the higher quality of the materials used. However, considering that normally electric motors are increasingly used and working hours are usually many during the year, it makes sense to invest significant amounts to buy electric motors with better efficiency because usually the payback time is more than acceptable [16].

The main advantages are:
- Energy saving (less power losses and power factor cosφ increase)
- Increased engine life (thanks to lower operating temperatures).
- Greater reliability.
- Less noise (as less mechanical ventilation is required).
- Better tolerance to harmonic components of the current and voltage variations.

The disadvantages are however:
- Decrease in the starting torque.
- Increase of the starting current.
- Larger volume volumes

Organism	CEMEP	IEC
Standard	Voluntary agreement	60034-30
Year	2000	2008
Power Ranges	1,1 up to 90kW	0,75 up to 315 kW
Super premium	-	IE4
Premium	premium	IE3**
High	EFF 1	IE2*
Standard	EFF 2	IE1
Low	EFF 3	-

Figure 1.7.4.1 - Classification of electric motors depending on their performance

** As of June 2011, all three-phase induction motors (0.75 to 375 kW) with squirrel cage rotor*

*** From January 2015, the engines (7.5 375 kW) must be equipped with Premium or VSV*

It should be noted that a 0.75 kW engine with a 72% efficiency belongs to IE1 class, as well as a 375kW engine, but with 95% efficiency.

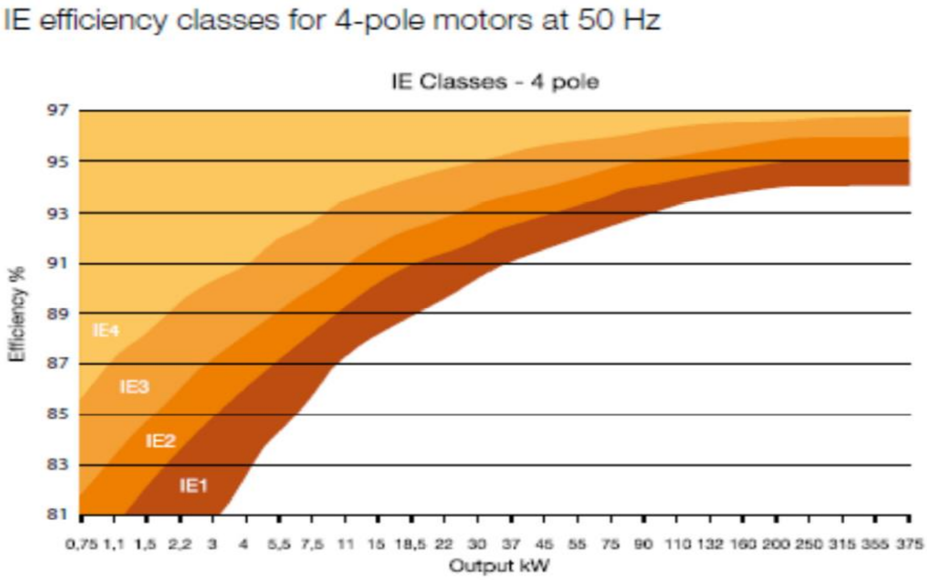


Figure 1.7.4.2 - Comparison Table of Performance Bands according to CEMEP

When designing an engine, you have to expect to operate with a load factor between 65% and 100%, in fact, low load factors involve:

Engine analyzed	
Nominal power	90kW
Number of poles	4
Load factor	59%
Engine output	93%
Hours of service	6240 h/year
Energy cost	107,4 €/MWh
Energy consumption	356.340kWh
Annual Energy Cost	38.271 €

Engine Replaced	
Nominal power	75kW
Number of poles	4
Load factor	67%
Engine efficiency	95%
Work hours	6240 h/year

Energy cost	107,4 €/MWh
Energy consumption	315489kWh
Annual Energy Cost	33.884 €
Investment	15.100 €
Energy benefit	40851 kWh/year
Economic benefit	4387 €/year
Simple payback time	3,4 years

1.7.5 Office equipment

It's good practice to turn off office equipment (computers, monitors, etc.) when they are not used for a long enough time, especially during lunch breaks and during the absence days. During these periods, it would be good to stop the air conditioning system. It is unfortunately customary, leave the shared equipment turned on during the night, such as copiers and printers.

For a more rational use of energy, you need to create a routine to disconnect these devices at the end of the day and turn them on again the next day when they are needed.

A quick and significant example is suggested:

Power plugs in the administrative offices	
Average power consumption	15 kW
Nº of hours of daily use	8
Annual consumption	31 800 kWh

The adoption of awareness-raising measures implemented by employees, such as turning off lighting and computers when they are absent, especially during lunchtime, bring the following results:

With employee awareness to turn off equipment and lighting even for lunch	
Reduction	50%
Annual consumption after the implementation of this solution	29 813 kWh
Energy benefit	1 988 kWh

Economic benefit	236 €
Environmental Benefits	0,93 tCO_2/year

Since it is a measure that does not involve any investment, the return period is immediate and you start saving energy and money in bills.

1.7.6 Thermal insulation

The production, transportation and use of thermal energy (hot or cold) have heat losses due to physical heat exchange phenomena such as conduction, convection and irradiation. Thermal insulation is applied to plants, piping and accessories to reduce heat losses while maintaining the desired temperatures for the purpose of the desired process and for the comfort and safety of the staff. In general, the thermal insulation costs are relatively low and recover rapidly.

The effectiveness of the insulation is measured by the parameter called thermal conductivity (K) which is the ratio, stationary, between the heat flow (ie the amount of heat transferred to the unit of time through the surface unit) and the temperature gradient that causes the passage of heat in the case of thermal conductivity (ie when contributions to heat transfer by convection and by thermal irradiation are negligible). In other words, thermal conductivity is a measure of the attitudes of a substance to transmit heat (that is, the greater the value of K, the less insulating the material). It depends only on the nature of the material, not its shape.

The most used materials for thermal insulation are:

- EPS - expanded polystyrene
- XPS - extruded polystyrene
- MW - mineral wool (rock, glass)
- PUR - Polyurethane
- ICB - black cork agglomerate

An example of thermal insulation on the 32-meter pipeline is now proposed, achieving 75% energy savings and a 1.2-year return on investment.

Energy and environmental analysis	
Pre-intervention linear losses	2433 W
Total post-intervention losses	623 W
Energy benefit	1663 W
Working hours	4380 h
Annual energy benefit	8374,5 kWh

Environmental Benefits	1,9 tCO2
Financial assumptions	
Investment	582 €
Financial result	
Economic benefit	490 €
Payback time	1,2 years

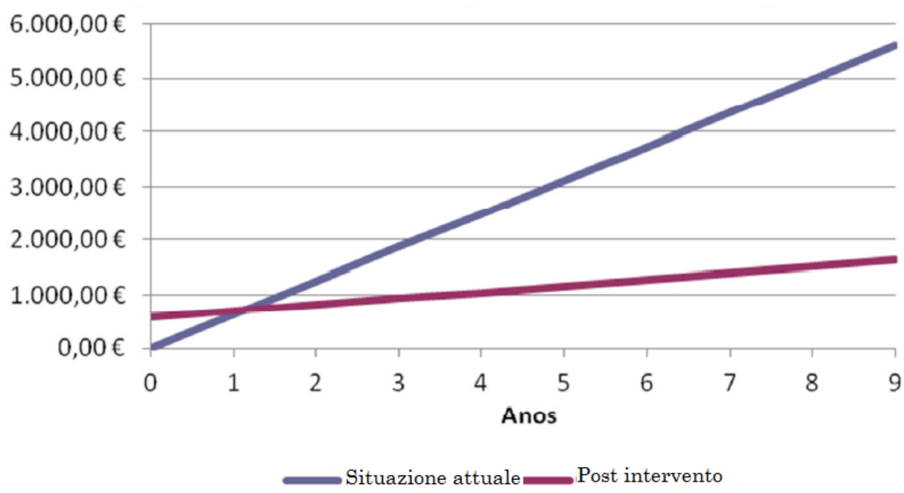


Figure 1.7.6.1 - Cost associated with thermal losses with and without thermal insulation

1.7.7 Solar thermal system

The solar thermal system is associated with the DHW (Domestic Hot Water) hot water production process, with a significant reduction in the needs of other sources of energy. It is one of the renewable energies with low operating costs and can reduce the energy bill of a plant.

The main components of a solar system are the solar panels, through which solar radiation is captured and then accumulated in hot water. These elements are interconnected by a piping network and the circulation of hot water can be natural or forced by pumps between the tank and the panels.
When heating requirements (or DHW requirements) are higher than the panel's production capacity, auxiliary operating systems start working, such as boilers, water heaters, electric stoves, etc.
With proper maintenance, solar power systems last for more than 15 years. The payback time for a typical solar plant investments varies between 6 and 10 years.

The illustrated example refers to a consumption of 16,180 liters / day used for bathing hot water, for a facility in Porto District, to fulfill the needs of DHW, a natural gas boiler is used.

Consumption profile	
Usage temperature	50°C
Annual average bathroom's consumption	16180 liters
Energy consumed	242063 kWh/year
Energy cost	0,66€/m3
Annual energy cost	16.095 €

The proposed solution consists in a plant composed of 60 solar panels sized for an annual solar coverage factor of 48%, meaning a one-year solar system can produce almost half the energy needed for DHW. As a result of the solar system installation, there will be considerable savings in natural gas consumption (7,799 €/year).

Post intervention	
Number of manifolds	60
solar fraction	48%
Collector output	72%
Energy benefit	122182 kWh/year
Environmental Benefits	32tCO2/year
Financial assumptions	
Annual energy cost	16095€/ year
Investment	70.062 €
Financial Results	
Economic benefit	7799€/ year
Simple payback time	9 years

1.8 ESCo

ESCO means **EN**ergy **S**aving **Co**mpany, they are basically companies that allow you to reach the energy efficiency you need/want.

Energy service companies (ESCOs) develop, design, build, and fund projects that save energy, reduce energy costs, and decrease operations and maintenance costs at their customers' facilities. In general, ESCOs act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project.

ESCOs are distinguished from other firms that offer energy-efficiency improvements in that they use the performance-based contracting methodology. When an ESCO implements a project, the company's compensation is directly linked to the actual energy cost savings.

The substantial energy-efficiency retrofits and renewable energy technologies inherent in energy savings performance contract (ESPC) projects typically require a large initial capital investment and may have a relatively long payback period. Debt payments are tied to the energy cost savings guaranteed for the project, so the agency pays for the capital improvements of the ESPC project with the money saved by the project (i.e., the difference between pre-installation and post-installation energy use and other related costs).

Such performance improvement as mentioned above is not only an economic issue, but has multiple returns including tax breaks, image return and various certifications [8].

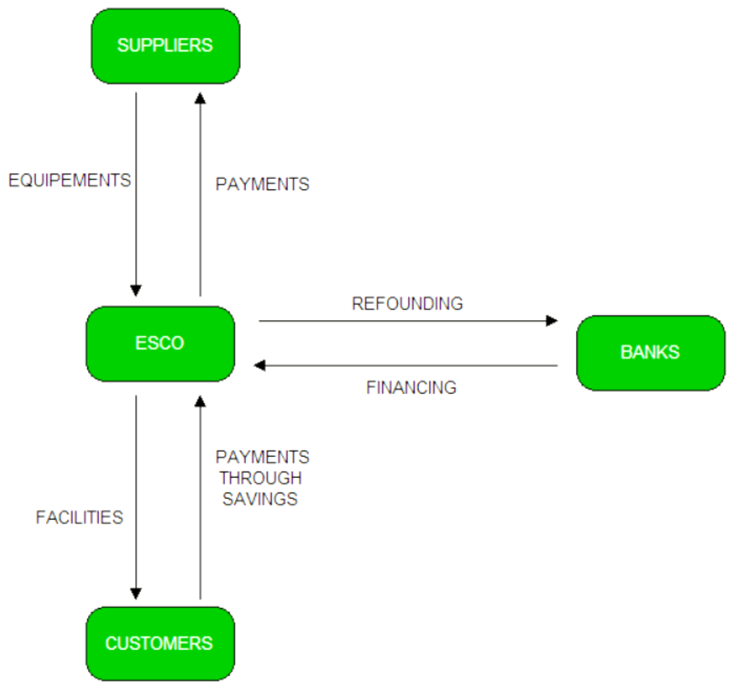


Figure 2.8.1 - Relationship between ESCO, customers, supplier and Banks

- **THIRD-PARTY FINANCING (TPF):** refers solely to debt financing. As its name suggests, project financing comes from a third party, e.g. a finance institution, and not from internal funds of the ESCO or of the customer. The finance institution may either assume the rights to the energy savings or may take a security interest in the project equipment. There are two conceptually different TPF arrangements associated with EPC. The key difference between them is which party borrows the money: the ESCO or the client. The first option is that the ESCO borrows the financial sources necessary for project implementation. The second option is that the energy-user/customer takes a loan from a finance institution, backed by an energy savings guarantee agreement by the ESCO. The purpose of the savings guarantee is to demonstrate to the bank that the project for which the customer borrows will generate a positive cash flow, i.e. that the savings achieved will certainly cover the debt repayment. Thus, the energy savings guarantee reduces the risk perception of the bank, which has implications for the interest rates at which financing is acquired. The 'cost of borrowing' is strongly influenced by the size and credit history of the borrower. Both public and private customers benefit from off-balance sheet financing because the debt service is treated as an operational expense and not a capital obligation; debt ratings are therefore not impacted. For highly leveraged companies this is important because the obligation not showing up on the balance sheet as debt means that company borrowing capacity is freed up.

- **GUARANTEED SAVINGS CONTRACTS:** Under this model, the ESCO gives a guarantee to its customer that an agreed target level of energy savings will be made, with any savings above this level being split on an agreed basis. The ESCO thereby assumes performance risk on the project. This enables the customer, assuming its funders are satisfied with its credit risk and that of the ESCO, to raise finance for the project directly. The level of saving to be guaranteed by the ESCO is then sized so as to be sufficient to meet the customer's costs in servicing its debt. This model also lends itself to an asset finance solution, with the ESCO guarantee being sized so as to enable the customer to make equipment leasing payments.

- **SHARED SAVINGS CONTRACTS:** Under this model, the ESCO company (omen a Special Purpose Vehicle), rather than its customer, assumes responsibility for financing the costs of the ESCO project. Costs savings that are made from the project are, for an agreed period of time following project implementation, split in accordance with an agreed percentage between the customer and the ESCO. The share of costs savings allocated to the ESCO tends to be higher than under a guaranteed savings contract in order to allow the ESCO to service its finance costs.

2. PETRATEX

2.1 Business

The work that is being carried out is an energy audit carried out in collaboration with two specialized engineering firms working in the city of Porto in Portugal: *Infiniplus*[1] and *Soenergia Verde*[2]. Thanks to their experience and their equipment, both electrical and thermal flows were directly measured, by means of special equipment, and in a second phase the energy bills were analyzed and calculated and then studied how to improve energy performance.

The customer company, for which the work of analysis and improvement proposal has been carried out, is Petratex, a company founded in 1989 in Portugal, which carries out its activity in several fields and which has acquired a leading position in the textiles industry in the various markets as fashion, Sport and High Technology clothes. They are famous for designing the swimsuit for Michael Phelps, swimmer and Olympic champion, and to develop highly technical, innovative clothes and without seams.

Company Name	*Petratex Confecções, S.A.*
Responsible for Maintenance	*Sr. Fernando Gomes*
Adress	*Rua de Bande nº.429, 4590-049 Paços de Ferreira*
Telephone number/ fax	*+351 255 868 000*
Website	*http://www.petratex.com/index.php*

PETRATEX is a company that has been developing, producing and providing, according to fashion, fashionable products for various clothing brands that bring the concepts of innovation and prestige to the highest standards for sports and technical clothing but also elegant.

In the history of Petratex, the flagship is a technology developed for competitive swimming, called "NOSEW", designed in collaboration with NASA and the National Sports Institute of Australia and used by Olympic champion Michael Phelps.

The production capacity is around 20,000 pieces per day and the quality control department is subject to verification according to AQL rules. In addition to the Portuguese production, which supplies products for about 60% of the business, Petratex has two production units: Morocco and Tunisia.

The company's impact on Porto's territory has been enormous: it has not only been able to emerge in a business dominated by mobile phone business, but it has

[1] *https://infiniplus.pt/*
[2] *http://www.soenergiaverde.pt/*

also acted as a dragger as it has led to the birth and establishment of other businesses involved in the same field and also in other fields of activity, some of which come from abroad, allowing the area to grow a lot.

Figure 2.1.1 – External views of Petratex

2.2 Company structure

The company has a dynamic soul but in practice keeps the layout of unchanged environments since it needs specific installations for individual machining that can't be easily moved to different locations such as a normal household appliance just plug in the power socket.

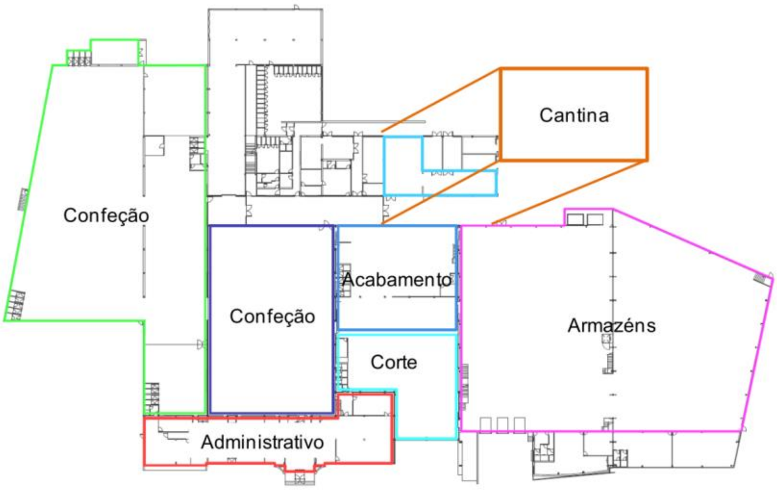


Figure 2.2.1 - Ground floor divisions

The different manufacturing and production areas are distinguished in green and blue, the ironing and finishing area in blue, the area used to cut materials and the part of the warehouses in violet.

Obviously are also present administrative offices in red, and finally the part of the dining room with a kitchen area in orange, under which there is a free gym for employees, fully equipped for them, colored in blue.

The work schedules are:

TIME	DAYS OF THE WEEK	START	END	PAUSE
Normal	Monday to Friday	08h00	18h00	das 12h00 às 14h00
1º Shift	Monday to Friday	06h00	14h00	30 minutes
2º Shift	Monday to Friday	14h00	22h00	30 minutes
3º Shift	Monday to Saturday	22h00	06h00	30 minutes

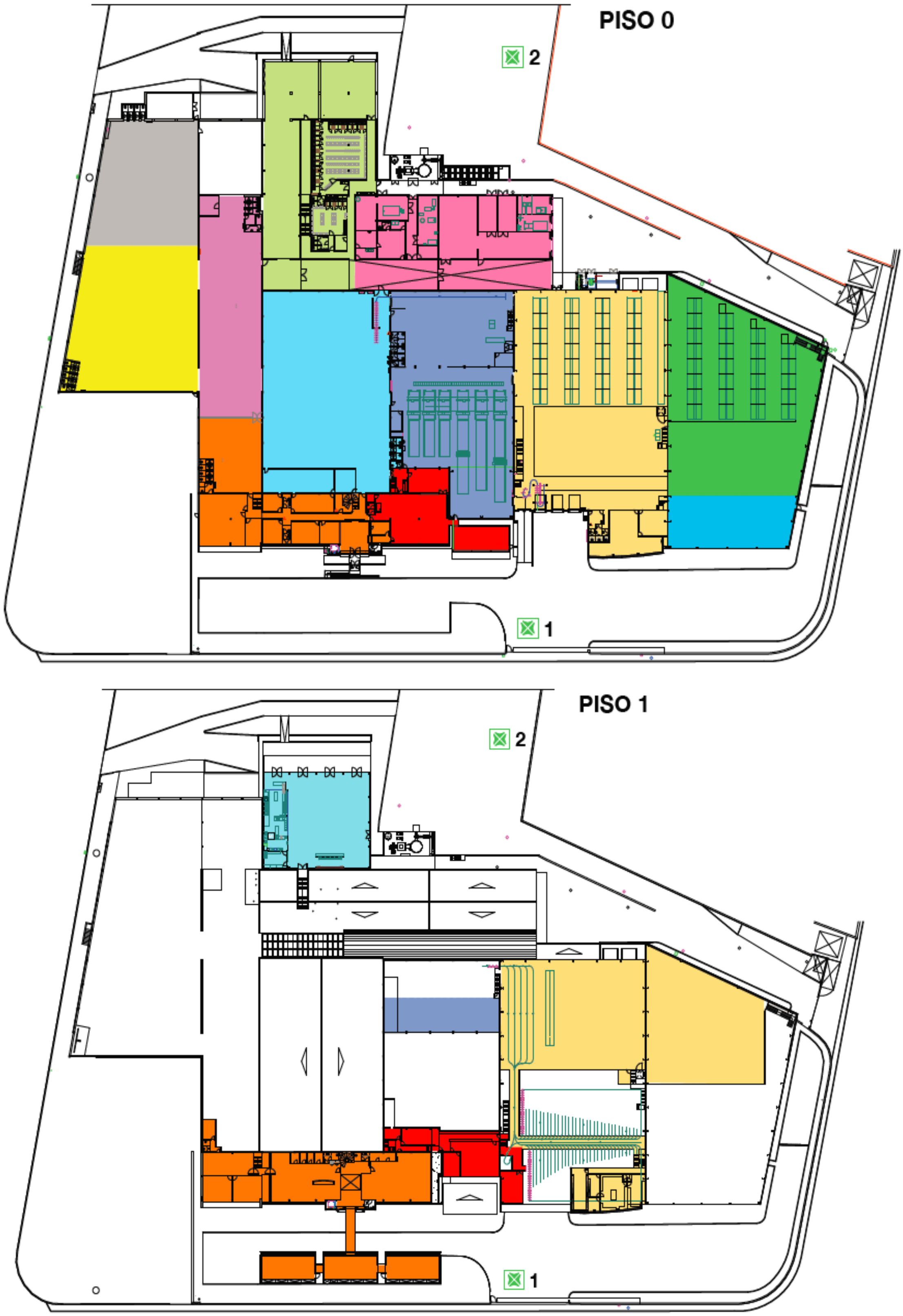


Figure 2.2.2 – Ground and first floor layouts

2.3 The production process

Below is the flowchart of how the company works where the customer is the first mosaic truss and the one to which the production is then shipped at the end of the work. It is the client who commission the work as a set of measurements and projects, complete with materials and quantities and delivery date requested.

The other input from the company is obviously the suppliers from whom they buy the raw materials for production such as fabrics and decorations, such as cloths, cotton, wool, skins, eco-leather and technical material.

Then, with the beginning of the production order, a check is made of raw materials that if not available are sorted, then screened by a production technician and a designer who knows the workings the company is able to do and jointly develop a project to meet customer specifications and then switch to production.

Once the process is outlined, the production dates that are expected to meet the customer's timing are estimated, the product in the ordered quantities is then manufactured.
Then a quality and control check step is passed, which if passed, allows the product to be packed properly and crammed into the warehouse, waiting to be sent to the buyer within the established time.

Below are the main manufacturing processes and related production phases made in Petratex:

- WAREHOUSE

The production process begins and ends in this structure, where rolls of various materials and finished products are stored in a rail that runs along all the storage ceiling.
During the almost 25 years of activity, even the buildings needed evolution, it was decided to expand the storage area and there are currently two interconnected warehouses. The originally-stocked building is where the raw material arrives and where the finished product is left. Raw material storage is made in metal shelves while the final product is first packaged and then stored in a rail along the ceiling by a hanging logistic system.

Packaging is done manually and the clothes on their hanger are sealed in special plastic bags. In this part of the warehouse there are two robotic dispenser cabinets that allow you to select the desired stock and through the rail system, to send it into that section, accessible from the top floor. On the top floor there is also the quality control lab. Instead, in the new warehouse, the storage in metal racks of the finished product takes place. It is equipped with LED lighting and, to ensure optimum storage conditions, floor heating that takes heat from condensed steam in closed loop.

- CUTTING

After the design of the model and related processing, after the selection and approval of the tissues, the production starts with the cutting phase, whose accuracy is crucial for the quality of the final product and is carried out by specific equipment. Guided by the idea of cutting materials used with top technology in relation to the design type, there are automatic cutting and laser cutting tables. Attention to the technologies used will reduce the waste of material and, consequently, the production costs, while also ensuring the highest precision and the best setting for cutting any type of fabric, while respecting the measures in all parts and increasing product quality. The cutting department, being a precision process, requires a quite long time for a single piece, so it is active 24 hours per day with normal shifts of 8 hours each.

- MANIFACTURING:

It is a key step in the production process and requires large quantities of machineries, equipment and, above all, qualified staff. The result of the cut is then sent to the manufacturing department, organizing transport efficiently to make the most of the machines and workers. It is entrusted to three types of equipment such as sewing machines, gluing machines (ultrasonic) and presses (calanders).

A very important and at the same time critical factor for energy management is that, in order to perform its function, each press must be ready for optimum operating temperature. As the time, it takes for a press to reach that temperature is about 20 to 30 minutes, even when not in use, usually the machines remain in standby mode and are kept hot by electrical resistors.

- IRONING

Ironing is very often necessary because of the production process, in fact it allows to correct any problems related to seams and flatten any imperfections. The product has to go to a station with industrial ironing irons and then sealed in its special plastic bag with its coat rack.
Customizing the workpiece is then done by adding labels or applications specifically requested by the customer and properly packaged. The cycle closes with the arrival of the product at the warehouse for inspection and shipping.

- SUPPORT SERVICES

Several support services and infrastructures are required for the production process. The building has a local area for the administrative part, not just commercial and financial services, but also shopping, design, planning and development, all provided with equipment and computers, essential work tools. There is also an office in charge of quality control. The analysis lab with all its equipment will probably be the most energy needing department in the office area due to its so specific technology. There is also a canteen with a cafeteria with 400m^2 equipped to provide lunch, and a free gym for all employees who would like to use it with a weight room, various tools and a treadmill with garden view. The entire structure also depends on specific staff equipped with technical equipment for the maintenance and care of indoor and outdoor spaces, including garden, boiler room, air groups and machine support parts.

2.4 Production reference unit characterization

Another fundamental aspect of drawing up an energy audit is to determine which is the reference production unit to which allocate consumption and allocate costs. It isn't nor simple neither straightforward to determine which one it is, and there is no single or more correct solution: it is to follow common sense, but above all to follow the customer's instructions, who should know in deep (hopefully) his company.

Indeed, in many cases the attribution of energy to the product is not direct, it can depend, for example, on the number, mass, 'extension' of products, but also by the degrees days and/or humidity in the region where the company is located or the lighting that you want to get in your work environment, especially on workbenches that sometimes require high quality light or minimum in light intensity.

3. EVOLUTION OF LEGISLATION APPLIED TO INTENSIVE ENERGY CONSUMER COMPANIES

3.1 The General Regulation of Energy Consumption RGCE

The Energy Consumption Management Regulation (RGCE) was created by Decree-Law 58/82 of 26 February and regulated by Ordinance 359/82 of 7 April, applied to all sectors of economic activity, with the exception of the domestic sector, since 1988.

At the time of implementation of this regulation, the energy situation in Portugal was different from what is currently observed, namely in the issue of energy imports, which was about 90% of the total energy needed in the country.

The RGCE had a wide application sector, and applied to all sectors of activity as already mentioned above. Examples include industries, commercial business, agriculture, hotel, hospitals, etc.
Any energy-intensive installation would be covered by the RGCE if any of these conditions were met:

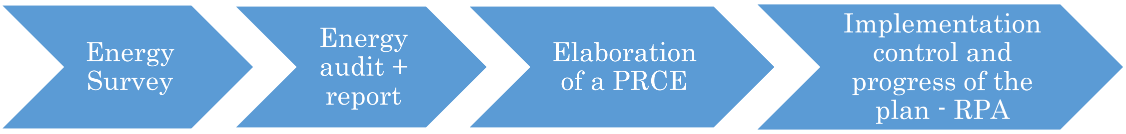
- Consumption in the previous year higher than 1000 toe / year;
- The sum of nominal energy consumptions of installed equipment higher than 0.5 toe / hour;
- Nominal consumption of at least one installed equipment greater than 0.3 toe / hour.

3.2 RGCE Processes

The Regulation introduces several processes to be carried out for the various installations. In order to address the situation and identify whether the activity is included in energy intensive consumers, the first phase addresses an energy survey. Thus, it would be possible to know what and how the fuels would be used and which areas / processes with the highest consumption.
It would then be necessary to examine the installation more in detail, thus resulting in an energy audit. The audits allow the “radiography” of the installation to be carried out and help in the preparation of the next step.

The next step would be the elaboration of the Energy Consumption Rationalization Plan. This plan involves goals, measures and objectives to be achieved over a 5-year period (except for transport, which is 3 years), and there is a need for control of the plan, resulting in an annual progress report.

The sequence is:



3.3 Energy Consumption Rationalization Plans

The regulation introduces the principle of the elaboration of rationalization plans to be carried out periodically and introduces the figure of the energy manager, who should supervise energy consumption and draw up rationalization plans.

The reduction of the consumptions we want to obtain must be carried out during the next 5 years and must respect the previously fixed goals. These should be defined according to the energy situation of the facility at the time of the audit. The Energy Consumption Rationalization Plan (PRCE) should include the main conclusions of the audit, and present schemes considered correct in efficient explanation. It should present the objectives to be met in terms of reducing consumption of energy, year by year.

After setting the targets, the ESRM should include a listing of the sequence of management measures and investments it wants to improve.

The RGCE proposes a calculation method for the reduction of consumption in each year:

$$\mathrm{M} = \frac{C - K}{2} * \left(\frac{N}{5}\right)$$

This would be the formula to obtain consumption reduction (M) until the end of year N, where C is specific consumption before the rationalization plan and K is the reference value.

The benchmarks should be published on a regular basis in order to keep the regulation up to date, taking into account technological developments and successive rationalization plans to which companies would be subject to.
Due to the fact that there has never been an update of the RGCE, these have not been modified, and you should use those, present in the regulation.

Since it is necessary to include all situations, since there are no reference values (which are actually specific consumption), the general situation "by default" was considered. When there are no reference values, the value of 0.9 * C should be used. That is, in order to arrive at the K value of the above formula, we have, at first, to calculate the specific consumption:

$$C = Specific\ Consumption\left(\frac{kgep}{ton}\right) * Production\left(\frac{ton}{year}\right)$$

And then considering K=0.9*C .

The following table presents the calculation formulas for the PRCE goals and objectives:

Specific reference consumption	*K=0.9*Co*
Annual reduction target	$M = 0.005 * K * \left(\frac{N}{5}\right)$
Specific consumption to be obtained at the end of the 5th year	$C_5 = C_0 - (M \times 5)$
Expected reduction of global consumption	E-CTE

In what CTE is the total energy consumption after 5 years and E the initial global energy consumption.

3.4 PRCE implementation control and progress

To perform PRCE control, it is necessary to appoint a responsible person (generally called Energy Manager), with the objectives:

- Follow all the implementation phases;
- Studying possible deviations;
- Know the situation with quarterly reports (maximum) if possible;
- To prepare for the Directorate-General for Energy an annual report on the PRCE's situation in January for the following year to which it refers.

At this stage, according to the regulation, a system of control and management should be implemented with the aim of continuing the programs established with a system that loads the data and the results obtained on the energy system.

3.5 The SGCIE (Intensive Energy Consumption Management System)

Within the scope of the National Energy Strategy, the Decree-Law no. 71/2008 established the Energy Intensive Consumption Management System, a regulation that classifies as Energy Intensive Consumers industries with an annual consumption of more than 500toe.
The SGCIE replaced the RGCE described above. The aforementioned Decree-Law was the subject of two revisions, first in Law 7/2013 and more recently in Decree-Law no. 68-A / 2015. The most important points to be retained on the system will be explained below.

3.5.1 Scope

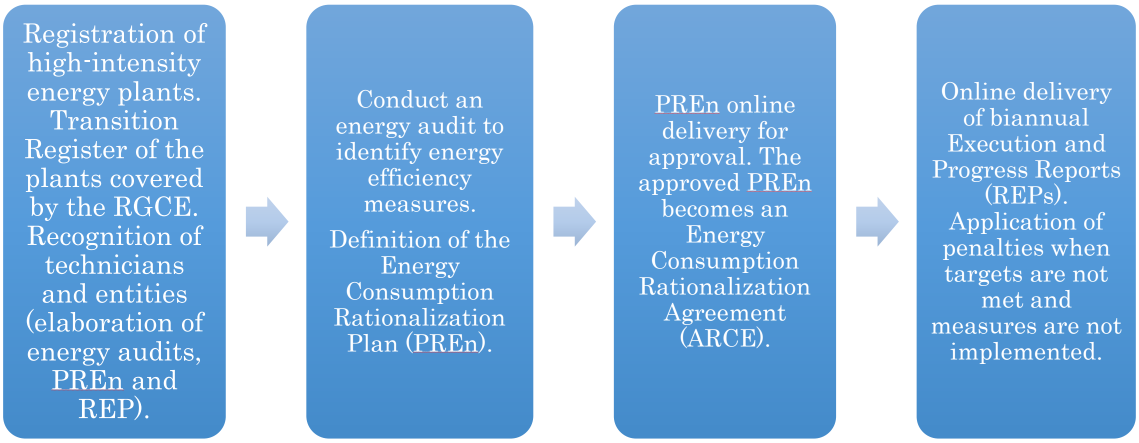
The SGCIE applies to energy-intensive consumer installations which in the immediately preceding calendar year have consumed more than 500 tons of oil equivalent (500 toe / year), with the exception of legally autonomous cogeneration installations of their respective energy consumers.
It may be applicable to undertakings which, despite not being considered as CIEs, voluntarily intend to do agreements to rationalize energy consumption.

3.5.2 Processes and Objectives

According to the SGCIE, CIE facilities must carry out energy audits in certain periods in order to understand the conditions of energy use and subsequently promote energy efficiency.

In addition to audits, Energy Consumption Rationalization Plans should be drawn up, so-called PREn in which energy efficiency objectives should be incorporated. The PREn will subsequently give rise to Energy Consumption Rationalization Agreements (ARCEs), once they have been approved, and then Execution and Progress Reports (REPs) will be carried out every two years to assess the evolution of proposed measures and consumption of the activities.

In the following table, you can see an illustrative diagram of the phases by which an activity must pass:



3.5.3 Audits under the SGCIE

The SGCIE requires the following types of installations to be audited:

- Installations with energy consumptions equal to or greater than 1000 toe, with an interval of eight years. The first of these must be carried out within four months from the registration;
- Installations with consumption between 500 toe and 1000 toe, with an interval of eight years. The first of these shall be carried out in the year after the registration.

3.5.4 Energy Rationalization Plans (PREn)

The ERPs shall be drawn up on the basis of the mandatory energy audit reports and shall provide to the implementation in the first three years of all measures identified with a return period of investment (PRI) of not more than five years for energy consumption equal to or more than 1000 toe/year, or with a PRI less than or equal to three years in the case of other installations.

In the PREn, targets related to Energy Intensity (IE), Carbon Intensity (CI) and Specific Energy Consumption (CEE) should be established.

$$Energy\ Intensity\ (IE) = \frac{Total\ Energy\ Consumption\ \ (tep)}{VAB\ Gross\ amount\ (€)}$$

$$Specific\ Energy\ Consumption\ (CEE) = \frac{Total\ Energy\ Consumption\ (tep)}{Production}$$

$$Carbon\ Intensity\ (CI) = \frac{Emissions\ GEE\ (kgCO_{2eq})}{Total\ Energy\ Consumption\ (tep)}$$

In the specific case of Energy Intensity and Specific Energy Consumption, only 50% of the energy resulting from endogenous waste and other renewable fuels should be considered.

The targets established for each of the indicators are as follows [22]:

CIE <1000 toe	
ENERGY INTENSITY (IE)	Reduction 4% in 8 years
CARBON INTENSITY (CI)	Reduction 4% in 8 years
SPECIFIC ENERGY CONSUMPTION (CEE)	Maintenance of historic values

CIE >1000 toe	
ENERGY INTENSITY (IE)	Reduction 6% in 8 years
CARBON INTENSITY (CI)	Reduction 6% in 8 years
SPECIFIC ENERGY CONSUMPTION (CEE)	Maintenance of historic values

After being evaluated and consequently approved, the PREn gives rise to ARCE.

3.5.5 Execution and Progress Reports

An Execution and Progress Report (REP) must be submitted to ADENE every two years for the Energy Consumption Rationalization Chord (ARCE), indicating the goals and objectives achieved and the deviations that have occurred, as well as the measures taken or necessary to its correction.

In order to evaluate the implementation status of the ARCE, the REP must provide information on the energy efficiency of the facility under analysis, using the indicators defined in the PREn and using the value of the GVA - Gross Value Added - at constant prices for the year and the production values obtained.
The report on the last period of validity of the ARCE should take stock of the implementation of the ARCE with the appropriate analysis as the final report.

3.5.6 Penalties

Failure to comply with the targets or non-implementation of the measures defined in ARCE implies the following actions:

DEVIATION ≥ 25%	DEVIATION ≥ 50%
• Payment of € 50 per toe / year not avoided;	• Payment of the amounts provided in the previous point;
• 100% aggravation in case of recurrence.	• Return of incentives provided for in D.L. 71/2008 and the proportional value corresponding to the benefits of the installation to be cleared by ARCE.

The amounts mentioned may be reimbursed at 75% provided that the operator recovers in the year following the application of the penalties the deviations from compliance with ARCE.

4. ENERGY AUDIT

4.1 Types of audits

Thumann and Younger in Handbook of Energy Audits claim that there are three basic types of auditing:

- Level 1 - Audit of Walkthrough / Audit

As the name implies, it corresponds to a visit to the facility for a visual inspection of the energy consuming systems. It involves an evaluation of energy consumption data and subsequent comparisons with industry averages or reference values of similar facilities.

- Level 2 - Standard Audit

This type of audit involves the quantification of energy use and losses at a more detailed level, including the analysis of equipment, systems and operational characteristics. It can include measurements in situ and other type of tests for energy used quantification and efficiency of several systems. Standardized calculations are used to analyze efficiencies and calculate energy savings and costs, taking into account the improvement measures applied.

- Level 3 - Computer simulation / modeling

Here, an even greater detail of the use of energy by function and a greater understanding of the uses of energy is taken into account. It is performed through a simulation software. The auditor develops the simulation of the installation and takes into account factors such as climate, temperature and other variables expected during the year, using historical value.
The objective is to establish a consistent basis of comparison with the current energy consumption of the facility. After this baseline is created, the auditor should do necessary changes to improve the efficiency of the various systems and measures the effects, comparing with the baseline.
The current SGCIE provides that energy intensive installations will periodically carry out energy audits that focus on the conditions of energy use and promote the increase of energy efficiency.

4.2 Audit procedure

Energy diagnosis is undertaken with a view to providing a description of the energy system, defining the possible improvements in efficiency and quantifying the resulting savings.

The energy diagnosis must take into account needs and limits indicated by the client so as to decide concurrently the scope, the execution mode, the goal of the diagnosis.

The energy diagnosis must meet the following requirements:

- **Completeness**:

Definition of the global energy system including the most significant energy aspects. The degree of detail will be a function of the cost, time and will of the buyer.

- **Reliability**:

Through the acquisition of real data in number and quality required for the development of the inventory of energy diagnosis and inspection of the energy system; subject to exceptionally justified exceptions to the residential civil context when explicitly provided for by current legislation.

- **Traceability**:

Identification and use of an energy inventory, data source documentation, and possible data processing techniques to support energy diagnosis results, including work assumptions.

- **Utility**:

Identifying and evaluating costs / benefits of energy efficiency improvements expressed through appropriate and differentiated documentation according to the sector, scope, and then forwarded to the customer.

- **Verification**:

Identifying the elements that allow the customer to verify the achievement of the efficiency improvements resulting from the application of the proposed interventions.

UNI CEI / TR 11428 [2] also suggests that:

- The energy diagnosis must be carried out by a natural or legal person who possesses the skills, capabilities and tools commensurate with the type of diagnosis undertaken and the objective agreed with the client;

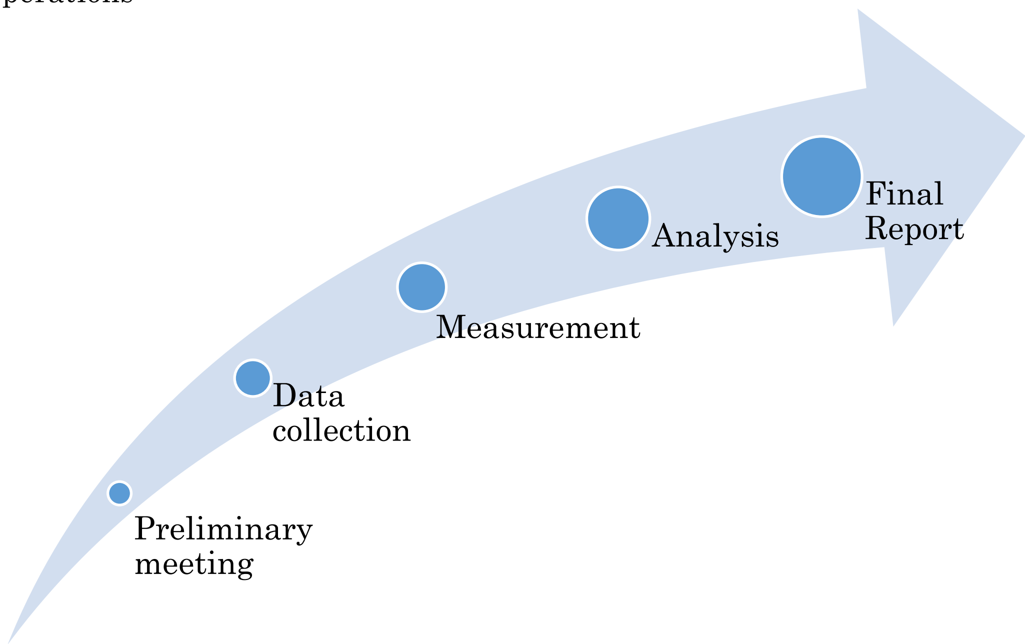
- All information obtained or acquired during the diagnosis procedure should be considered confidential;

- The interest of the purchaser should be considered paramount, acting impartially.

To perform an energy audit, it's good to follow the suggested checklist earlier, but it's also a good idea to remember how to proceed practically. First, having the ultimate goal in mind helps to develop in the right direction and with the proper degree of in-depth diagnosis. In fact, at first it is good to define the purpose and the expectations of the client and from them they approximate the time needed

for the analysis and the degree of relative accuracy. As the solution proposal also agrees with the buyer the criterion for the evaluation of the savings measures.
It reminds the company that automated management systems and "good habits" can contribute significantly, and for this reason it is good to have references within the company's staff, such as the energy manager if there is someone or someone of the office or administration technicians, so be informed in the staff to ensure maximum collaboration between the departments and the auditor.

The methodology to be used in carrying out an energy audit will always depend on the technician who will have to perform it as the responsible subject for the analysis. However, there will always be a common basis used for all types of auditing services.
A method that can be used for energy audits is made up of the following sequence of operations:



- **Preliminary meeting**:

During which all interested parties are informed and the methods and the accuracy of the analysis are decided. Procedures for accessing structures and installations are established, with internal hygiene and safety rules. It is clear that the datas are sensitive and may be private or confidential so, if not provided, must be in some way taken into account with appropriate estimates or corrective factors.
If the datas available from the company are not sufficient, additional measurements can be made by motivating and illustrating the measuring instruments. To simplify the understanding of the plant, it is good to get detailed information on internal relationships that could affect consumption, as most of the times because most of energy losses are already known or at least presumed. Finally, you should know the scheduled maintenance dates or other activities that could affect the diagnosis.

- **Data Collection**:

You want to have invoice documents (invoices) of historical data, maintenance certificates and datasheet of machinery and project. Data collection is the basis on which the energy diagnosis is based. The data to be collected are those for users with significant energy uses (according to UNI CEI EN ISO 50001: 2011). Usually more attention is focused on lighting and electricity users in general, gas or diesel heat generators in general, self-production of energy through renewable sources, cogeneration and water consumption.
At this stage it is important to report the data consistently: while for the electrical users it will be good to get a load diagram, for the thermal ones the reference is not the solar year but the heating season, in fact it wouldn't make sense to compare the thermal demands of two buildings in different climatic zones, characterized by different degrees days.

- **Measurements:**

You have to investigate the whole plant to be analyzed and try to find the most significant aspects from the energy point of view, trying to find out how the behavior of users actually affects total efficiency and consumption. You should try to identify processes worthy of particular attention and for which more detailed data are needed.
Additionally, it is good to verify that collected data and datasheets, aggregated with work hours, effectively deliver consistent results without discrepancies from those obtained from detection devices. Obviously, the person in charge of the diagnosis must be sure that measurements and surveys are carried out reliably and appropriately so that they can be significant and in good environmental conditions, even when surveys are outside of the usual working time, company that can provide him with assistance and / or guidance, and he has also to inform about any difficulties encountered during such activities.

- **Analysis:**

Once you have collected the data you need to processing and then to interpretate them to identify the opportunities for energy improvement.
Once you understand the relationship between consumption and delivery methods and the factors influencing the various flows, you are going to make a mass flow and energy balance divided by purpose.
Be careful not to consider the systems equally efficient during time as they need periodic maintenance and often lose efficiency with wear or more general use, so it's better to plot an energy consumption diagram for several time periods for example, monthly or yearly.
Finally, you have to try to determine and quantify potential energy savings and then evaluate the cost / benefit ratio to find the better solution. The economic assessment must take into account the incentive mechanisms that may be available for each efficiency intervention. The main investment economic indicators that you can use in these ratings are:

  - **NPV** (Net Present Value), which identifies the total gain as a current monetary value deriving from an investment after a predetermined time interval. In other words, it's a measurement of the profitability of an undertaking that is calculated by subtracting the present values (PV) of cash outflows (including initial cost) from the present values of cash inflows over a period of time. Incoming and outgoing cash flows can also be described as benefit and cost cash flows, respectively.

- **IRR** (Internal Rate of Return), The internal rate of return on an investment or project is the "annualized effective compounded return rate" or rate of return that sets the net present value of all cash flows (both positive and negative) from the investment equal to zero. Equivalently, it is the discount rate at which the net present value of future cash flows is equal to the initial investment, and it is also the discount rate at which the total present value of costs (negative cash flows) equals the total present value of the benefits (positive cash flows).

- **RT** (Simple Return Time) or SPT (Simple Payback Time): Payback period in capital budgeting refers to the period of time required to recoup the funds expended in an investment, or to reach the break-even point[19].

- **Final Report**:

All the most significant results are summarized in a synthetic way, giving you operational indications on energy efficiency and the expected savings.
Initially you have to explain the hypothesis of work and define which are the analysis' bonds you took into account.
For any possible solution that has been previously studied during the analysis phase, the person in charge of the diagnosis will report the possible passage to higher energy merit classes, followed by a detailed description of the relative measures that will also include technical and economical estimation of the proposed solutions.
You should therefore estimate the expected economic and energy savings on an annual basis and improvements in agreed benchmarks. It is clear that if machinery replacement / modification of the production process is proposed, an estimate of the costs of maintenance operations and at the same time the hypothetical variation of the energy supply contracts should be provided.
Often, many implementations are possible and can be more interesting if combined together, you have to try to have a unique solution that includes those that have some interdependence or that are in some way compatible. On the other hand, it is to be considered that some measure may interfere with and burden negatively with others: you need to know if and how and when this can happen.

After the analisys and the proposals of the auditor, it is only the client who will decide what to do on the basis of the report, his own sensitivity to environmental issues, to the economic and image interests of the company. Not always companies have the technical know-how needed to fully understand what and how they will affect their energy approach more effectively, but it is the duty of a good auditor to convey the importance of a more environment friendly approach and how much is the potential value due to the remuneration of non-used energy.

Observe the flowchart for the energy auditing procedure under UNI CEI TR 11428/11, with the various points explained a little more in detail.

1. Collecting data on energy supply bills and reconstruction of actual electricity and fuel consumption for one or more years, possibly monthly. Better if you manage to have an average daily consumption profile for each month, especially for the electric user.

2. Identification and collection of the adjustment factors to be used for energy consumption, ie the units to which consumption is allocated. They can be productive areas, product units, added value products.

3. Identification and calculation of an actual energy performance index expressed as energy ratio/reference factor. Classicly and also for the Portuguese energy authority is this, referring to the energy intensity [toe/€], specific energy consumption [CEE] and carbon intensity [tCO_2/toe]. The conversions between the forms of energy are tabulated and provided by the body in charge and / or the regulations.

4. Analysis of the production process as the gathering of the information needed to create the energy inventory and to carry out the diagnosis. Understanding the process means improving it if it presents inefficiencies with regard to the machines used, but also, and often more profitable, reinventing the production system by avoiding intrinsic inefficiencies of the processes or energy sources / vectors needed for the processes.

5. Do energy inventories related to the subject of the diagnosis, quantifying exactly or through estimates, extrapolations, regressions the necessary quantities.

6. Calculation of the operating energy performance index you want to investigate.

7. Comparison between calculated and actual operating performance index. If the indexes tend to converge, the analysis proceeds to the next step, otherwise it returns to step 4 and refines the analysis of the production process and energy inventories by identifying the causes of the lack of convergence.

8. Finding the Target Energy Performance Index. The law or authority that is in charge provides a minimum level of performance threshold or a maximum level of emissions, but the company may have more ambition goals, for example aligning with established protocols or subscribing to voluntary commitments.

9. If the values of the calculated indicators meet the constraints imposed, then the diagnosis may be considered as completed because the target has been reached.

10. If there is a significant gap between the operating performance index obtained in point 6 and the target performance index, you must try to identify efficiency improvement measures that will allow constraints to be met.

11. For these measures, their respective technical and economic feasibility should be compared.

12. The identified solutions are sorted according to the agreed indexes between the person in charge of the diagnosis or the auditor and the client, in accordance with criteria such as pay back time, NPV or the most significant emission abatement. At the end of this operation, return to step 9 and if the comparison produces positive results, the diagnosis is considered complete.

When energy analysis is complete, it is a good rule to keep track of performance over time, with measurement tools that allow performance monitoring and / or detection of any anomalies.

In the following picture there is diagram that explains the completemprocedure how to do an energy audit.

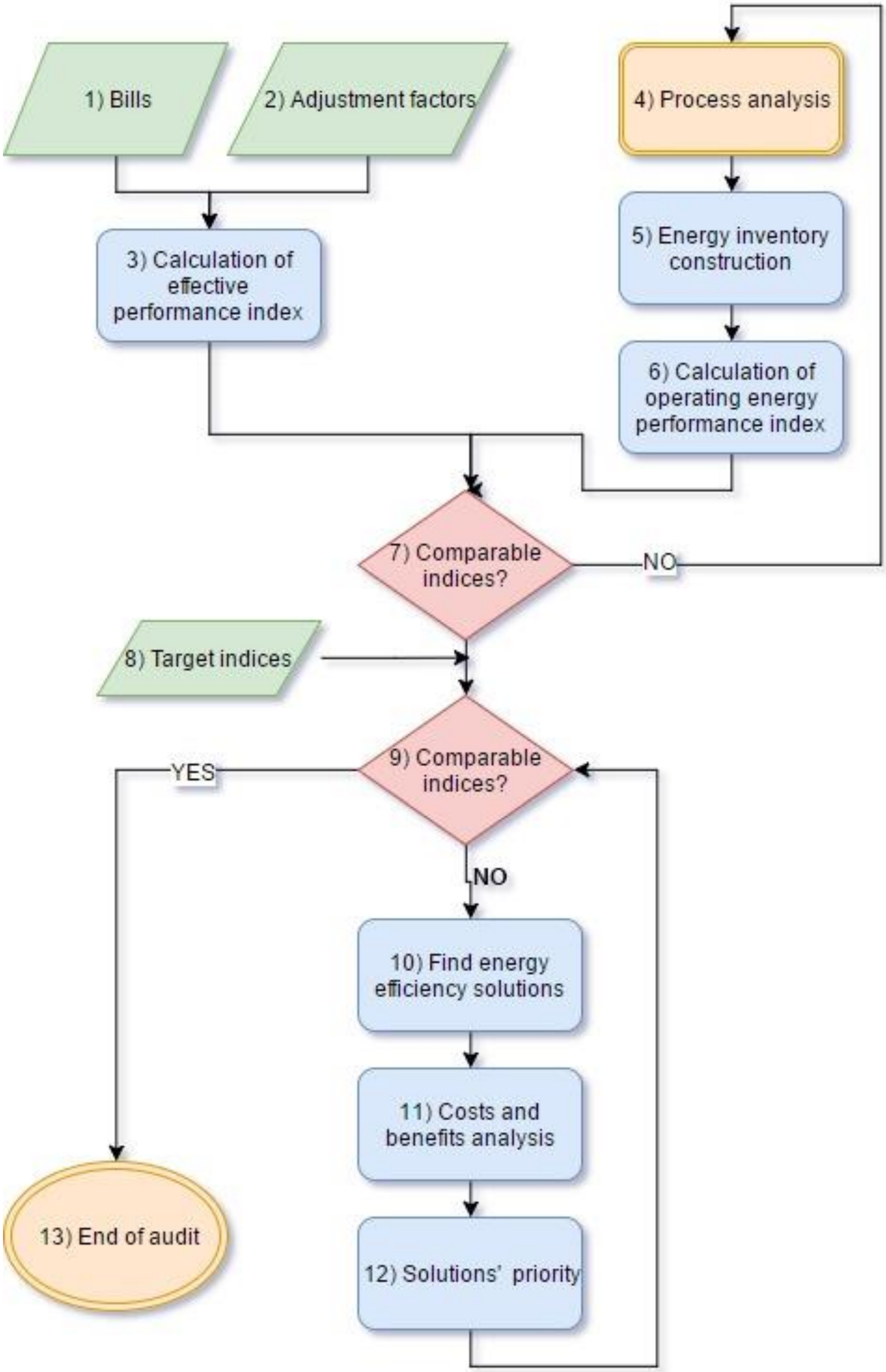


Figure 4.2.1 – Energy audit flow chart

4.3 Checklist Energy Audit

Portugal's power sector authority is ADENE[3], and more specifically the SGCIE[4], which deals with control / legislation for companies with over 500toe of annual consumption. This company has drawn up an operational checklist[5] to facilitate and guide auditors in their analysis. This discussion is translated and commented to be exhaustive and clear.

1. Quantify energy consumption for general installation and main sections and / or equipment and their importance on the final cost of the product.

In order to quantify consumption in general, it starts with utility bills: more data are collected to get a wider picture of the energy consumption situation. Then you want to find the final product unit to refer to subsequent calculations. It is a quick step if the company has a single product output (eg produces only wooden tables), but the situation gets very complicated when it comes to dealing with multi-product companies (eg produces tables, chairs and wooden cabinets) and even worse when the products are very heterogeneous (eg wood and steel tables, kitchens and furniture using wood, plastic and steel).
One way to solve the second case would be to refer to the basic raw material with which the products are constructed (eg wood tons) but when starting to use different materials in different proportions the allocation becomes very complicated and laborious. In reality there is a common output allocation unit found in agreement with the customer. However, there is no doubt that, by doing so, there are some strong simplification hypothesis and therefore errors.

2. Perform visual inspection of energy-consuming systems and/or equipment, and related measures to quantify consumption and time profile of consumption.

Performing visual inspection and careful observation is crucial as there are often inefficiencies that can't be derived only from data analysis. To do a classic example of inefficiency, think about a company that works with compressed air. The consumption of this company will be mostly due to the compressor systems, but often the workers, for convenience, use compressed air to "blow" dust from clothes and machinery, consuming unsuitable amounts of energy which, at the end of the month, will weigh heavily on electricity consumption.
In such cases, it is possible to talk about cost-effective energy efficiency measures, that is, they identify the wrong habits and try to implement procedures to avoid them.

3. Clarify how and with what costs energy is transformed.

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[3] http://www.adene.pt/
[4] http://sgcie.publico.adene.pt/Paginas/default.aspx
[5] http://sgcie.publico.adene.pt/SGCIE/Paginas/PlanosRacionalizacao.aspx

Transforming energy is a crucial point for every energy analysis. It is important that all transformations are efficient because, overall conversion performance, is the product between the individual efficiencies.
Just think of a chain that is as strong as its weakest ring, so the overall system performance is lower than its lowest performance (multiplication between numbers between 0 and 1). On the other hand, it is good to remember that although the conversion efficiency of heat energy is 100%, it is not convenient in terms of energy because it is necessary to take into account the previous transformations that have allowed the energy to become electric energy and to get to that point of use, passing through production and transport.

4. Do a detailed survey of machines that consume more energy. Especially for those with a higher weight in terms of installed power, both electrical and thermal.

It is important to characterize every single machine and user in the internal network by paying more attention to the bigger the consumption that is almost always found by searching for machines with higher installed power.
It is good practice to look for inefficiencies in large boilers and / or large engines especially in internal combustion. Large machines allow higher efficiencies in percentages, on the other, they have the biggest losses in absolute terms ie in kWh, so energy. In fact, a large boiler can achieve excellent heat performance and, in parallel, the hot fluid distribution system may be inefficient with uncovered tubes or with inadequate insulation: large leakage can be attributed not directly to the boiler but To the distribution system. It is a good practice to pay more attention to systems with higher installed power inside the system considered to look for leaks where the probability is greater and where a very economical solution (eg piping isolation) can lead to significant results in terms of absolute energy savings.

5. Obtain load diagrams (consumption profile) (DDCs) of electrical installations considered as major electricity consumers.

For the devices identified in the previous paragraph it is also interesting to understand the load diagram. An example might be an enterprise involved in the cold chain that always needs ice to work or with great cold demand especially during working hours. The higher consumption will hypothetically be based on a classic two-spike load diagram, one around 10:30 in the morning and another around 15:00 in the afternoon: two peaks also for the electricity price of the grid. For the company, it may be interesting and convenient to think of cold production at night when the electricity tariff is lower and accumulate in special equipment such as high insulation tanks. You may also think of using smaller size machines since at night I have no peaks and can work on a constant load for a duration of up to 12 hours.
But it is not about using less energy (in fact if you consider thermal losses you have a greater total use) but only to economize your business.

6. Determine the energy efficiency of thermal energy generators by using direct or indirect methods.

In this step, we have to calculate the performance of devices dedicated to the exclusive production of thermal energy, such as boilers.
For small applications, it might make sense of an electric heater but usually you use larger size and cost equipment such as gas boilers or other fuels. You want to calculate the efficiency that is the ratio between the energy supplied by the boiler and the input energy in the boiler, necessary to produce the heat. There are two methods to calculate this efficiency, called direct and indirect. In the direct method, all incoming and outgoing flows are measured, their temperature and a first-rate balance.
For the calculation, according to regulations, refer to:

- UNI EN 297: 2007: Central heating boilers fueled with gaseous fuels. Type B boilers equipped with an atmospheric burner with a rated thermal input of less than or equal to 70 kW.
- UNI EN 483: 2004: Central heating boilers powered by gaseous fuels - Type C boilers with a rated thermal input not exceeding 70 kW.
- UNI EN 656: 2002: Gas-fired central heating boilers - Type B boilers with rated thermal output greater than 70 kW but not exceeding 300 kW.
- UNI EN 304: 1994 + A1: 2000: Heating boilers. Test rules for boilers with combustion fuel oil burners.
- UNI EN 26: 2007: Gas appliances for the instant production of hot water for sanitary purposes, equipped with atmospheric burner.
- UNI EN 625: 1996: Gas boilers for central heating. Specific requirements for the hot water heating function of combined boilers with rated thermal flow not exceeding 70 kW.

7. Check the status of power transmission and distribution systems (cables and panels, including piping, see section 3).

As already mentioned, the distribution of thermal and electrical flows in the company system is not always very efficient because of the already degraded insulation or due to inadequate electrical installation with too small or low quality cable sections.

8. Check if the equipment that controls and adjusts the conversion and the transmission of the energy works properly.

The state of the system controlling the different systems must be perfect: it is the central system that delivers adjustments and loads, depending on the feedback it receives from the individual measuring devices.
If this organ works badly there will be some imbalances of the general system that can only go worse. It is therefore vital to keep the control system 100% operational; Not only that, also the most of conversion and use devices have of internal diagnostics that can monitor their status and report any anomalies. It is a good idea to check the good condition of all these devices to find why and which component is not working properly.

9. Perform mass and energy balances for the main equipment using heat energy.

The advantage and utility to perform mass balance is to find any leaks along the ducts. In any case, a loss of mass can be associated with a loss of energy, but not always a loss of energy can be associated with a mass loss.
For example, to a loss along a hot water or gas pipeline is associated a loss of relative energy respectively to thermal energy and unused LHV and/or compressor pressure if the circuit was pressurized. The same does not happen in the case of unsuitable tube isolation, there is a dissipation of thermal energy along the duct and hence a lower useful temperature (in the case of heating) or higher (if cooling is required) for the user.
If you think to a simple heater, in case of insufficient insulation losses, you need to provide a warmer fluid to achieve the same beneficial effect in the same conditions or, if it is not possible, you will have a lower temperature in the room.
To do these simulations, you can use specific software such as Simulink (Matlab tool) or EES, both with implemented fluid properties.

10. Determine the specific energy consumption during the analysis period to compare with monthly and annual average values to identify some possible seasonal variations.

For engineers, data analysis is important to understand qualitatively whether energy is used effectively or not. It is a good idea to check the monthly consumption of the different devices, to compare them with the average monthly values of previous years, trying to figure out if they are varied and, if so, why. It is crucial to broaden the vision and try to locate a factory geographically, taking into account the monthly average temperatures and comparing it with those of the month under review, looking for gradients of the year and comparing with the average for that location to look for any inconsistencies and/or anomalies.
From a thermal point of view, the correspondence is straightforward if only the heating part is considered, but if we consider the electrical part as well, we do not have the same correlation, so we rely more on the historical consumption data in kWh.

11. Determine the energy intensity IE (kgep / VAB [€]), the specific energy consumption CEE (kgep / unit) and the carbon intensity IC (tCO2e / toe).

The energy consumption of a company is related to its economic activity. The ratio of total gross energy consumption expressed in kg of equivalent oil and the added value produced by it is defined as energy intensity and is a raw and aggregate indicator of the energy efficiency of a company's economy. As a ratio, the lower the energy intensity, the more (in theory) the energy efficiency increases. Specific energy consumption is the ratio between total gross energy consumption expressed in kg of equivalent oil and the number of products produced by the company. Even then, it is preferred to have a low value that implies the use of "little" energy for a single product. The carbon intensity is defined as the ratio between the tons of CO_2 equivalent generated by energy consumption and the equivalent tons of oil consumed for production. Even in this case it is better to have a low value, which means emitting a low amount of CO_2 equivalent per ton of equivalent oil or energy consumed, which means that energy uses are effective. The energy authority also recommends that these indices be calculated globally, and individually allocate to each business sector in the case of a multi-product enterprise to have greater sensitivity and to understand where to focus. The amount of energy consumption during the reference year (the reference year, is the year before the date of the energy audit) determines the target to achieve. Depending on the annual energy consumption value for the reference year, prENs should set targets for energy intensity and specific energy consumption that should decrease by at least 6% in eight years, in the case of plants with an intensive energy consumption equal to or Higher than 1000 toe / year, or 4% in eight years for all other implants. It should also ensure at least the maintenance of historical carbon-intensity values in both situations.

$$Enery\ Intensity\ (IE) = \frac{Total\ Energy\ Consumption\ (tep)}{Valor\ Acrescentado\ Bruto\ (€)}$$

$$Carbon\ Intensity\ (IC) = \frac{Total\ Equivalent\ Emissions\ \ (kgCO_{2eq})}{Total\ Energy\ Consumption\ (tep)}$$

$$Specific\ Energy\ Consumption\ (CEE) = \frac{Total\ Energy\ Consumption\ (tep)}{Production}$$

12. Identify and quantify the possible areas where energy efficiency is possible due to the different situations examined / lack of solutions used.

Find where the inefficiencies are and try to quantify them is very difficult analytically and requires detailed research and meticulous collection of data. Often, it is not possible to find such measurements exactly, often because auditors do not have time or receive sufficient rewards to justify such a work so, most of the times, they rely them on experience and observation.

13. Identify operations that achieve greater energy efficiency and / or reduced energy bills and relative technical and economic feasibility.

As previously mentioned, it is good to distinguish between saving and efficiency and therefore the ultimate goal is always to pursue lower energy consumption to achieve the same results without sacrificing anything in terms of comfort and performance.

14. Define the guidelines for achieving or improving operational energy management.

You want to understand the general energy situation. Often they have wrong habits that cause excessive energy consumption as already reported. At this stage, you try to propose corrective measures such as how to use them or how to install or replace machines or equipment.

15. Identify solutions with a depreciation period of less than or equal to 3 years (CIE companies with a power consumption <1000 toe / year)

16. Identify solutions with a depreciation period of less than or equal to 5 years (CIE companies with an energy consumption of ≥ 1000 toe / year) are better placed to invest in medium-term returns.

4.4 Relationship between stakeholders

It should be noted that there must be a relationship between the company and the responsible auditor that involves mutual respect and the exchange of ideas and opinions in a clear way. The audit will serve the company to profit, so there should be maximum collaboration between all involved parties in order to facilitate the process and to get the best possible results.
As an auditor, in addition to the objectives of effective control, he has to find solutions that could fit to the specifics of society, establish an open and easy dialogue and should understand their constraints.

The company should have figures referring to the energy branch to facilitate the auditor's work and someone who can provide all the data revision. Both of them need to create a communicative environment and facilitate the auditor's work to achieve the goals.

In the industrial area, a central theme throughout this dissertation, energy audits are fundamental steps to increase competitiveness and efficiency.

Thus, it is possible to improve production with less consumption and therefore less environmental impact, which results is an added value for businesses in the economic field or company's reputation when it is approaching to the market.

4.5 Invoices

4.5.1 Electricity

Petratex purchases electricity from IBERDROLA[6]'s supplier and distributor.
The electricity bills of this company are constituted according to the regulatory scheme in force in Portugal, which states that:

Termo de energia	PONTA	35.027 kWh x 0,061177 €/kWh		2.142,85 €
	CHEIA	110.772 kWh x 0,057146 €/kWh		6.330,18 €
	VAZIO	24.841 kWh x 0,048748 €/kWh		1.210,95 €
	S/VAZIO	13.877 kWh x 0,041999 €/kWh		582,82 €
Total dos termos de energia			**10.266,79 €**	
Termo de redes de energia	PONTA	35.027 kWh x 0,0473 €/kWh		1.656,78 €
	CHEIA	110.772 kWh x 0,0409 €/kWh		4.530,57 €
	VAZIO	24.841 kWh x 0,0225 €/kWh		558,92 €
	S/VAZIO	13.877 kWh x 0,0217 €/kWh		301,13 €
Total dos termos de redes de energia			**7.047,41 €**	
Termo de redes de potência	PTCON	736 kW x 29 dias x 0,032 €/kWh dia		708,06 €
	PTHPT	368 kW x 29 dias x 0,2263 €/kWh dia		2.419,73 €
Total dos termos de redes de potência			**3.127,79 €**	
Termo de energia reactiva	Forn V	59 kVArh x 0,0208 €/kVArh		1,23 €
	Cons FV	(tg 0,3 - 0,4) 1.296 kVArh x 0,009141 €/kVArh		11,85 €
	Cons FV	(tg 0,4 - 0,5) 327 kVArh x 0,0277 €/kVArh		9,06 €
	Cons FV	(tg > 0,5) 261 kVArh x 0,0831 €/kVArh		21,69 €
Total dos termos de energia reactiva			**43,83 €**	
Imposto especial de consumo de electricidade	184.517 kWh x 0,001 €/kWh			184,52 €
IVA	23% s/20.670,34€			4.754,18 €
Contribução Audio Visual	1 mês x 2,65€/mês			2,65 €
IVA Contribução Audio Visual	6% s/2,65€			0,16 €
VALOR TOTAL DE FATURA			**25.427,33 €**	

Figure 5.2.1 - Fac simile electic bill from Iberdrola

The different time slots have the same logic as the Italian ones but do not find direct correspondence for each. In fact, PONTA is the peak period, CHEIA is the intermediate period, VAZIO is the low demand period and SUPER VAZIO corresponds to the night band according to the table[7] provided by Iberdrola, which is shown below:

[6] https://www.iberdrola.pt/02sicb/corporativa/iberdrola

[7] https://www.iberdrola.pt/02sicb/corporativa/iberdrola/sobre-nos/mercado-electrico/regulamento-legislacao/tarifas-acceso-horarios

Ciclo semanal para todos os fornecimentos em Portugal Continental			
Período de hora legal de Inverno		**Período de hora legal de Verão**	
De segunda-feira a sexta-feira		**De segunda-feira a sexta-feira**	
Ponta:	09.30/12.00 h 18.30/21.00 h	Ponta:	09.15/12.15 h
Cheias:	07.00/09.30 h 12.00/18.30 h 21.00/24.00 h	Cheias:	07.00/09.15 h 12.15/24.00 h
Vazio normal:	00.00/02.00 h 06.00/07.00 h	Vazio normal:	00.00/02.00 h 06.00/07.00 h
Super vazio:	02.00/06.00 h	Super vazio:	02.00/06.00 h
Sábado		**Sábado**	
Cheias:	09.30/13.00 h 18.30/22.00 h	Cheias:	09.00/14.00 h 20.00/22.00 h
Vazio normal:	00.00/02.00 h 06.00/09.30 h 13.00/18.30 h 22.00/24.00 h	Vazio normal:	00.00/02.00 h 06.00/09.00 h 14.00/20.00 h 22.00/24.00 h
Super vazio:	02.00/06.00 h	Super vazio:	02.00/06.00 h
Domingo		**Domingo**	
Vazio normal:	00.00/02.00 h 06.00/24.00 h	Vazio normal:	00.00/02.00 h 06.00/24.00 h
Super vazio:	02.00/06.00 h	Super vazio:	02.00/06.00 h

Figure 5.2.2 – hourly rate divided for winter and summer period

The various terms of the invoice for the use of electricity are explained [3]. Similarly, to Italian invoices, the first item of *energia facturada* corresponds to the actual consumption of electricity as kWh, multiplied by the unit price € / kWh, providing the total cost for the energy consumed in €.

The second point, *termo de recles de energia* corresponds to the commitment of the lines in the various time slots. Also in this case, the logic of charging sees a unit price per hourly time that multiplies the kWh used in the respective band and then provides the total price for the use of energy.

The *term recles de potencia* is divided into *PTCON* or contracted power ie the available power stipulated in the contract and therefore the power for which the supplier undertakes to produce for the company, and the *PTHPT* ie the tariff to occupy the power lines at peak times, due to the fact that the manufacturer is committed to providing power to this company instead of others, using existing lines to transport energy.

In fact, *PTCON* is the result of measurements by means the transformer (from medium voltage to low voltage) that supplies the factory. If it exceeds that contracted consumption for more than 15 minutes, it clicks to the next level and the contracted power increases.

With regard to reactive energy, it is useful remind that is important to increase or improve the cosφ power factor, ie the cosine of the angle between the voltage and the current of a given load, in order to reduce, the total power absorbed and accounted and the value of the current, circulating in the plant.

The purpose to improve power factor correction is to reduce energy losses and reduce reactive power absorption by machinery and existing lines in an industrial site.
Improving power factor in plants has become important since the electricity provider has imposed contractual clauses through the tariff measures that oblige the user to improve the cosφ in his plant, otherwise he has to pays a penalty. Installing correct dimensioned condenser stack in parallel of all industrial electrical equipment could be the easiest way in order to improve performances and has one of the lowest payback time: generally, repayable within a few months.

In circuits with particular users such as filament lamps, electric boilers, certain types of ovens, the apparent power absorbed is all active power. In circuits with equipment having windings such as motors, welders, fluorescent lamps, transformers, a portion of the power absorbed is used to excite the magnetic circuits and is therefore not used as active power, but as reactive power.

For these reasons, the invoice is divided into reactive power supplied and consumed and that energy is not billed during "*ponta*" and "*cheia*" periods as the system allows the network to self-regulate. it is based on the fact that for a reactive energy absorption / input there will be the possibility to distribute such load / surplus of reactive power to other connected consumers that make flater the reactive power demand.

This is possible in these two-time slots as most users are connected, but it is not possible in the "*vazio*" and "*super vazio*" bands where users are few and the company's cosφ can affect stability and the quality of the electrical system of the network. For this reason, in the time slots with less demand, the reactive energy is billed at different prices both for the input and for the consumed one.
In the case of reactive power input during low demand periods, it makes it difficult to power the electricity in the desired direction from the grid, limiting it and increasing transportation losses; vice versa for the request, which would oblige the supplier to "change the quality of energy" that it distributes on the network.

In the penultimate voice there is a tax in € / kWh related to the total consumption while the last one contributes to the TV service that is compulsory to pay in the electricity bill, (a kind of Italian "canone Rai") which is not bound to possession of TV itself but to the electric line since the connection to the network involves both electricity and TV.

4.5.2 Load diagram

You can also measure the load diagrams of the company's electrical power consumption to understand the typical trend of the load curve seen by energy producers. The following items are monitored:

Active power, measured in kW and defined as the algebraic sum of the active powers of the individual phases and corresponds to the power actually used by the loads, that is:

$$P = P_1 + P_2 + P_3 + \ldots + P_n$$

Reactive power, measured in kvar (ie reactive volt amperes) and defined as the algebraic sum of the active powers of the individual phases and corresponding to the fraction of power stored in the magnetic circuits which is, however, necessary for the conversion of electric energy:

$$Q = Q_1 + Q_2 + Q_3 + \ldots + Q_n$$

It distinguishes itself in inductive and capacitive reactive power depending on whether the current vector is in advance or delayed with respect to phase voltage. Inductive power is usually associated to electric motors mainly and of many user equipment, it is therefore tried to compensate it with capacitive power through capacitors banks for parallel load correction. Only during night and weekends there is capacitive power, due to the absence of inductive loads.
Apparent power, measured in kVA and defined as the square root of the sum of the squares of active and reactive three-phase powers:

$$P_A = \sqrt{P^2 + Q^2}$$

4.5.3 Lighting system

It is also important to do a census of lighting devices, daily working hours and specific consumption for each category and area to have a map and an idea of how the lighting system works and how it is handled. That kind of operational procedure could be done by an internal responsible or the auditor should go there and check it.

The renewal of the lighting system has many positive aspects both from the technical and the economic point of view. In fact, it allows for a relatively fast return of the invested capital as it does not require invasive technical changes as it replaces incandescent, neon or other.

LED technology's greater advantage is that by its nature allows to not dissipate energy in the form of radiation heat to transform nearly all of the electricity they absorb into light beam, that is, the desired effect [13].

Figure 4.5.3.1 shows how a LED lamp can replace a classic incandescent light for domestic use and with the same lumens, that is, brightness, that allows savings for more than 80% of energy and thus have lower operating costs to respect with the same hours amount.

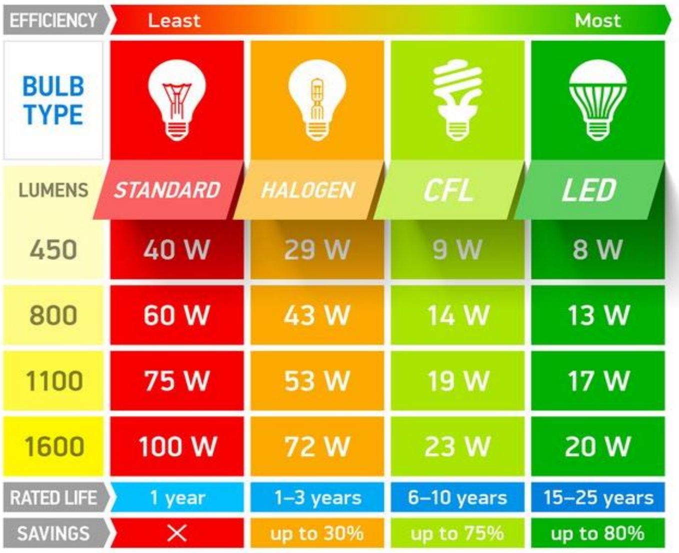


Figure 4.5.3.1 - Different lighting technologies comparison

4.5.4 Natural gas

A fac-simile of gas-bill is also given, referring to the one sent by the supplier Galp Gas[8] to understand how it is composed and to what the various entries correspond[9].

Periodo de Fornecimento		Descicao	Quantidade	Preco unitario [€]	Valor sem IVA [€]	IVA [%]
Inicio	Fim					
XX/YY/ZZ	XX+/YY+/ZZ+	Termo fixo	17,00 dias	6,7827	115,31	23
XX/YY/ZZ	XX+/YY+/ZZ+	Termo Energia	78.821,00 kWh	0,045938	3.620,88	23
XX/YY/ZZ	XX+/YY+/ZZ+	ISP - Energia Gas Natural	78.821,00 kWh	0,002124	167,42	23
XX/YY/ZZ	XX+/YY+/ZZ+	Taxa de Ocupcao do Subsolo do municipio PACOS DE FERREIRA				

TOTAL DO DOCUMENTO S/IVA [€]	3.903,60
TOTAL DE IVA [€]	897,828184
OUTROS CREDITOS/DEBITOS [€]	0
VALOR A PAGAR [€]	**4.801,43**

Figure 4.5.4.1 - Fac simile Galp gas bill

"*Termo Fixo*" is a fee that you have to pay to have gas available and depends on how many days you use the service, "*termo energia*" is the equivalent in kWh of real consumption and "*ISP- energia gas natural*" is a tax on all petroleum products that, after handing over to the authority its energy certification will disappear as a cost, so it can increase the savings immediately after the audit.

[8] http://www.energia-galp.com/eletricidade-gasnatural/?p1=P001&p2=galp%20gas&gclid=CMmWtdW0ydICFYU_GwodfQUIVA

[9] They also use EDP Gas as natural gas supplier for the canteen : http://www.casatotal-edp.com/?tsource=google-srch_ggl_marca_comercial_0&campaign=c&adgroup=36962527595&creative=edp%20g%C3%A1s%20comercial&google_network=g&adposition=1t1&gclid=CPur3_zAydICFdU_GwodjN8FaA

Then there is the invoice without IVA, the total value of the tax on that account, and then the total value. The gas meter's measurements and the conversion factor from m³ to kWh are also attached, which will then be the ones that will actually be paid.

Nùmero do Contador	Leitura actual [m3] REAL	Leitura anterior [m3]	Consumo [m3]	Fator de Conv. para[kWh/m3]	Consumo a Facturar [kWh]
XXXX-XXXXXX	341648	335236	6412	11,64583903	74673,11986

4.5.5 Calculate steam boiler's efficiency

Generally speaking, you can express the performance of a steam generator in a direct and indirect way. Refer to Figure 5.4.5 to better understand the proposed formulas:

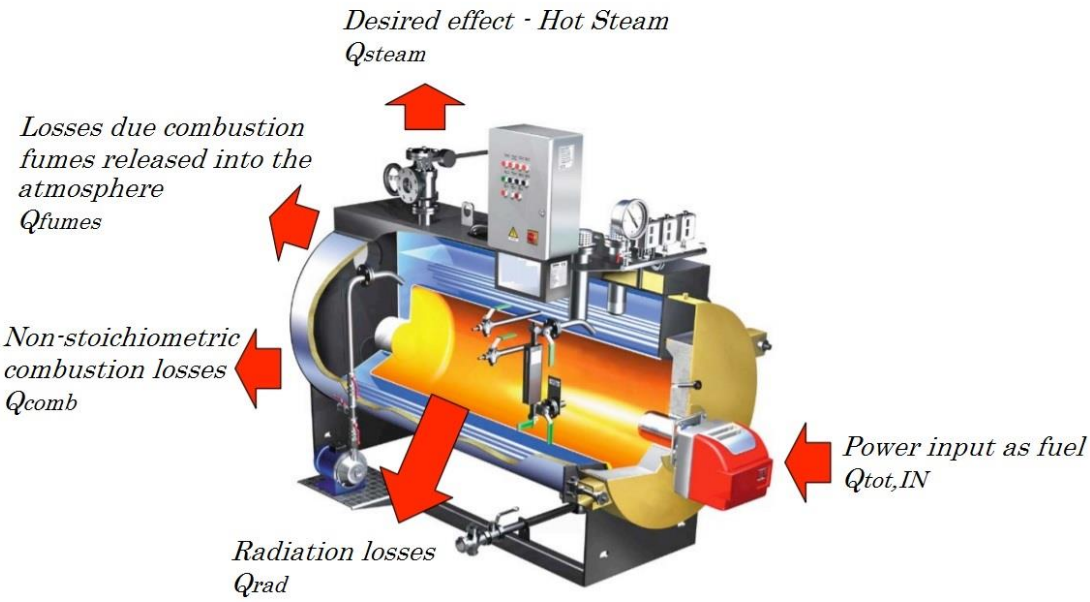


Figure 4.5.5.1 – Steam boiler's energy input/output

$$\eta_{direct} = \frac{Thermal\ power\ received\ from\ steam}{Thermal\ power\ total\ input} = \frac{Q_{steam}}{Q_{tot,IN}}$$

$$\eta_{indirect} = \frac{Thermal\ power\ total\ input - \text{Thermal power total losses}}{Thermal\ power\ total\ input}$$

$$= 1 - \frac{Thermal\ power\ total\ losses}{Thermal\ power\ total\ input}$$

$$= 1 - \frac{Q_{fumes} + Q_{comb} + Q_{rad}}{Q_{tot,IN}}$$

Between the two proposed expressions, the use of indirect efficiency is convenient, in fact it could be affected from a smaller error with respect to the other. If we suppose that the used measuring instruments have a 1% error, and that the amount of heat acquired by steam is usually around 90% compared to that total supplied, the formula for direct calculation could lead to a consistent mistake.

Instead, the indirect efficiency is expressed as a function of the lost thermal power, which, as said, is about 10% of the total supplied heat, if the measuring instrument has 1% of error it will affect only 10% of the value, so it will affect in a much lower rate, that allow to achieving a more reliable result.

Not all of the available energy in the fuel is exchanged with the operating fluid but is often released to the environment as smoke's sensible-heat losses (and even latent if you do not have a condensing boiler) and it is the primary cause of the decreasing of efficiency. These losses are strictly related to the air flow the generator uses and the fume's properties at the exhaust (temperature and humidity). The thermal flow of the fumes in the atmosphere is thus calculated in the hypothesis of ideal gas:

$$Q_{fumes} = m_{fumes} \cdot c_{p,fumes} \cdot \left(T_{OUT,fumes} - T_{environment}\right)$$

Figure 4.5.5.2 – Gas analyzers

It should be noted that combustion fumes are not a single homogeneous gas but a mixture of gases and therefore both the specific heat and the various thermodynamic properties of the fumes are to be considered as an average made on the total composition. The average fumes' thermodynamic properties can be weighed by percentages of composition for a typical combustion (for the type of fuel used) parameterized according to the excess air ratio used, or directly measured by using of special revelation sensors.

The mass of the fumes is the sum of the mass (or mass flow depending on what is considered) of the fuel plus the relative combustion air used in the combustion chamber, ie:

$$m_{fumes} = m_{fuel} + m_{air}$$

It is, however, simpler for calculation purposes, to express thermal losses in combustion fumes as a percentage of the energy present in the fuel through the empirical equation:

$$Q_{fumes}[\%] = K_s \cdot \frac{(T_{fumes} - T_{environment})}{CO_2}$$

K_s is the constant of Hassenstein which is the function of the CO_2 content in the fumes and the type of fuel and hence the percentage of CO_2 in the volume of the fumes:

	Combustibile			
CO_2	Metano	Gasolio	O.C.	Carbone
4	0,418	0,523	0,543	0,683
5	0,427	0,530	0,550	0,684
6	0,437	0,536	0,556	0,685
7	0,447	0,543	0,563	0,686
8	0,457	0,550	0,570	0,687
9	0,466	0,557	0,576	0,688
10	0,476	0,564	0,583	0,689
11	0,486	0,571	0,590	0,690
12		0,578	0,596	0,691
13		0,585	0,603	0,692
14		0,592	0,610	0,693
15				0,694
16				0,695

Figure 4.5.5.3 – Hassenstein's constant as a function of fuel and CO2 concentration

It should be noted that the leaks in the fumes depend directly on their exhaust temperature as the outside temperature of the environment changes in a limited and certainly unmanageable range. The main causes for which the exhaust fumes temperature is too high, compared to the designed temperature due to internal inefficiency, they are mainly:

- Water-side heat exchange surfaces are dirty due to the presence of limestone or on the smoke side there are some combustion residues that make it dirty. In these cases, the solution is "just" cleaning the exchange surfaces.

There is also the possibility to have a flame with incorrect geometry without good regularity due to dirt nozzles, even in this case a good and careful maintenance can allow to maintain high performance.

- Incorrect coupling between burner and boiler such as burner over sized compared to volumes available in the boiler as the combustion chamber. In this case, you may think of installing nozzles of different sizes in order to best exploit any thermal load conditions and / or install turbulators to increase turbulence and improve exchange conditions.

If the exhaust fumes temperature can't be reduced for example in diathermic oil boilers which always require high temperatures, you can use the hot flow in the fumes to preheat the combustion air, increasing combustion efficiency or in any case trying to pair compatible fluxes relying on thermal/energy levels.

A too low temperature of fumes is likely to cause the condensation of corrosive gases that are dissolved in the exhaust gases. If you want to avoid such problems, it is advisable to use stainless steel instead of carbon steel. The sulfur traces present in the fuel burn out in SO_2. This, in presence of particular catalysts, oxidates to SO_3 which, in the presence of water vapor, can condense and form sulfuric acid.

Heat exchange by irradiation depends directly on the boiler's exchange surface and surface's temperature, as well as from the environment's temperature in which it is located and by the convective thermal coefficient that occurs in the environment that depends on air velocity and much more but for simplicity you can write:

$$Q_{\text{rad}} = S_{ext} \cdot h_{conv} \cdot (T_{surface} - T_{environment})$$

Measuring the temperature of the surrounding environment, however, is complicated. It would be even better to talk about the radiant average temperature needed to evaluate the radiation exchange component and, as already mentioned, the air velocity for convective effects. Even in this case it is possible to express the irradiated thermal power and dispersed from the boiler body in percentage terms. According to the regulations, it is possible to find out how much the irradiation losses are in percentage terms, knowing the potential of the plant, the load factor and therefore the power demanded at that moment.

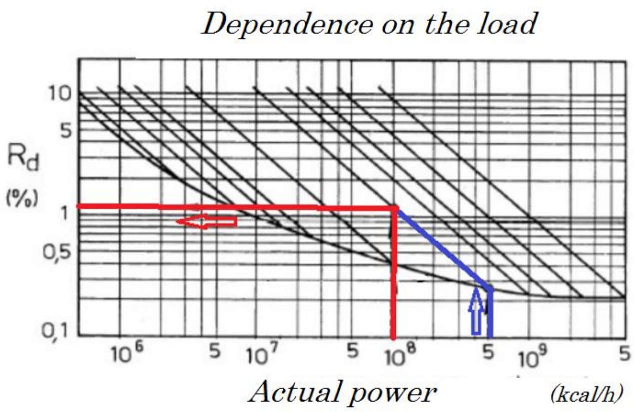


Figure 4.5.5.4 - Influence of load according to the plant's potential and irradiation losses

To find the percentage irradiation losses (Rd%) you start upwards from the blue line at the abscissa that indicates the potentials of the implant then on the oblique extension you are looking for the meeting point with the ascissa corresponding to the load of that time and by crossing with the ordinates you get the percentage loss. The more the working conditions approach the nominal load and the less the losses affect the energy balance, while vice versa, the more different they are from the nominal load and the more impact they have on the losses, in percentage.

Natural Resources Canada, on the other hand, proposes a graph that is used in a similar way. You start from the abscissa where the plant's potential is located and then proceed to find the curve corresponding to the load factor used. This load factor x is defined as the ratio between the work power in the various situations and the nominal value. Even in this case, it is easy to notice that as the workload approaches to the nominal potential, the percentage irradiation losses decrease as mentioned above.

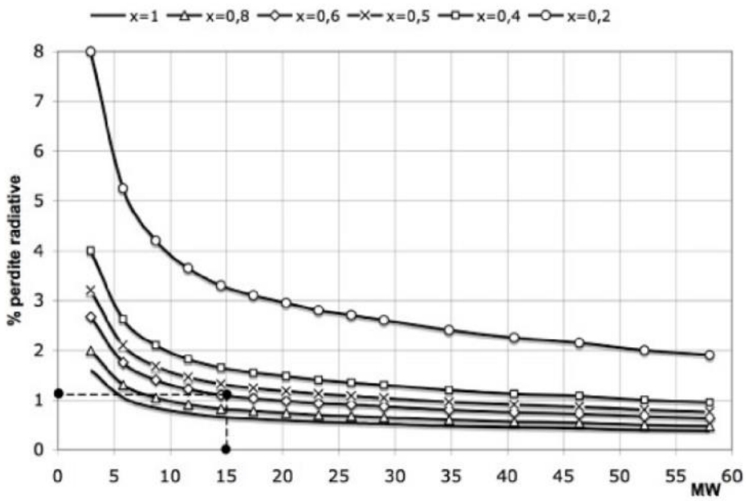


Figure 4.5.5.5 – Graph to find radiative losses %

There is another way to determine the percentage q3% irradiation losses according to UNI10348. There are some empirical equation that allow you to evaluate the efficiency by correlation depending on the nominal plant's power (Pn) , the technology used and the boiler's maintenance.

Generator's state	q_3 (%)
Great, high performance	$1{,}72 - 0{,}44 \cdot \log P_n$
Great	$3{,}45 - 0{,}88 \cdot \log P_n$
Obsolete, on average insulated	$6{,}90 - 1{,}76 \cdot \log P_n$
Obsolete, badly insulated	$8{,}63 - 2{,}20 \cdot \log P_n$
Obsolete, not insulated	$10{,}35 - 2{,}64 \cdot \log P_n$

Figure 4.5.5.6 - Table UNI 10348

There are a combustion losses when there is less combustion air (and therefore oxygen) available to the burner than necessary for complete oxidation, i.e. less than the stoichiometry, a part of the carbon in the fuel does not participate to the combustion.

Incomplete combustion is detectable when there is CO and particulate carbon in the fumes (for liquid and solid fuels). If the combustion air is not increased, to allow to all the fuel to react, a portion of energy is dissipated in the form of hot CO (which would be able to undergo further combustion) and/or unburnt particles.

In particular, the LHV of CO (carbon monoxide) is 10.05MJ / kg versus 44.4MJ / kg of diesel and 46.1MJ / kg of natural gas, so it means that if there isn't a complete oxidation of fuels, it is not fully exploited, so there is still energy contained therein, polluting more than necessary and thus increasing all the costs involved in the process.

In order to quantify losses for unburned fuel, a fume analysis is needed with a percentage of the gases forming the fumes and using the following formula to obtain the percentage of losses:

$$Q_{comb}[\%] = K_c \cdot \frac{CO}{CO_2 + CO}$$

- CO and CO_2 are the volume-based percentage of carbon monoxide and carbon dioxide in fumes (very different from molar and weight)

- Kc is a constant depending on the type of fuel:

	METHANE	**DIESEL**	**COAL**
K_c	37.9	50.5	59

For all that said so far, the optimum values of the operating parameters of a boiler are:

	METHANE	**DIESEL**
FUMES' TEMPERATURE [°C]	100-130	140-160
CO_2 [%VOL]	9.7-10.5	12-14
O_2 [%VOL]	1.1-3	1.1-4
EXCESS AIR [%]	5-20	5-25
$CO_{2,MAX}$ [%VOL]	11.5	15

For the calculation of air index you can use the following graph :

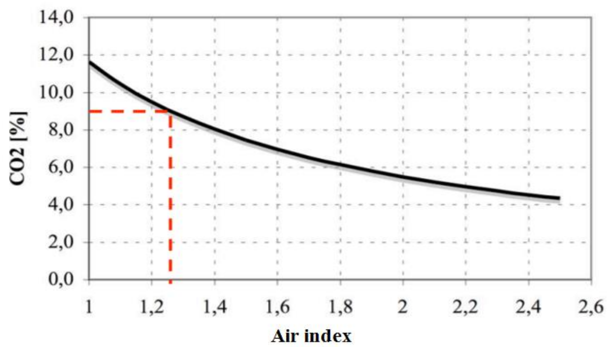


Figure 4.5.5.7 - Relationship between CO_2 in fumes and air index

Another way to calculate the boiler's efficiency in a very easy and fast way, taking account the variables that affect combustion the most: T_{fumes}, T_{air}, $CO_{2\%}$.

$$\eta_{boiler} = 100 - K_1 \left(\frac{T_{fumes} - T_{air}}{\%CO_{2\,fumes}} \right) - K_2$$

K_1 and K_2 are coefficients normally supplied by the boiler manufacturer and represent respectively: K_1 = Calculation weight (usually 0.61) and K_2 = Fixed boiler losses (usually 3%).

4.5.6 Biomass

Biomass is an industry term to get energy burning wood, and other organic matter. Burning biomass releases carbon emissions, around a quarter higher than burning coal, but has been classified as a "renewable" energy source in the EU and UN legal frameworks, because trees can regrow. It has become popular among coal power stations, which switch from coal to biomass to comply with the law. Biomass more often refers to plants or plant-based materials that are not used for food or feed, and are specifically called lignocellulosic biomass. As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.

According to Portuguese law in the specific case of Energy Intensity and Specific Energy Consumption, only 50% of the energy resulting from endogenous waste and other renewable fuels should be considered.

4.5.7 Fuels

Then fuel consumption for more traditional fuels such as diesel and gasoline for the company's fleet must be added. With the appropriate conversions, you can start from the consumed liters and through the density and energy density you get the total energy value for the fuels in toe.
In this case the energy conversion is only possible using average values of specific energy but more in deep calculations are useless.

4.6 VAB calculation

VAB (*Valor Acrescentado Bruto*) [4], [5], [23] is the gross value added created thanks to the company's production. this index is calculated in accordance with portuguese law as:

VAB=

+	Vendas (SNC 71)	+	Sales of materials (SNC 71)
+	Prestações de serviços (SNC 72)	+	Incoming from services provided (SNC 72)
+	Proveitos suplementares (SNC 781)	+	Additional income (SNC 781)
+	Trabalhos para a própria empresa (SNC 74)	+	Work for your own business (SNC 74)
-	Custo das mercadorias vendidas e das matérias consumidas (SNC 61)	-	Cost of sales and consumables (SNC 61)
-	Fornecimentos e serviços externos (SNC 62)	-	External supplies and services (SNC 62)
-	Outros custos e perdas operacionais (SNC 688)	-	Other operating costs (SNC 688)

The VAB will be used later in computing some indexes that show the company's performances. Clearly, the higher the VAB is, the better will be for the company if the conditions remain the same.

When VAB is needed to calculate the already mentioned indicators, it is usually as a denominator of indices (such as the most famous EI ie energy intensity), so if the VAB is increasing it will make the indices decrease.

4.7 Environmental impact

4.7.1 Reference units: toe and $CO_{2,\ equivalent}$

After analyzing and organizing data on energy needs in the various forms that the company needs, it is important to understand how to convert consumptions and how much these consumptions contribute to the pollution according to respectively tep and tons of $CO_{2,\ eq}$.

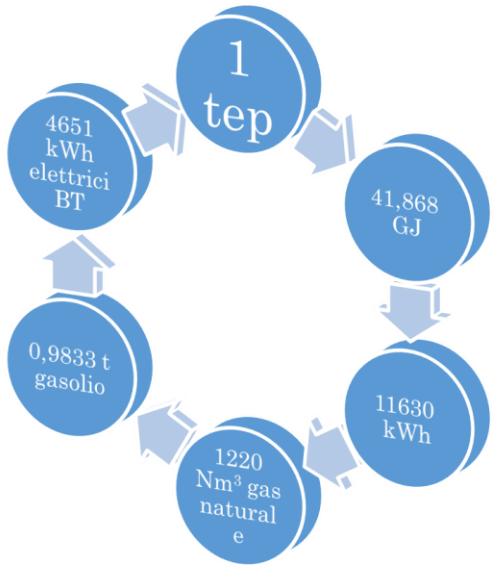


Figure 4.7.1.1 – Energy equivalences

The energy equivalents shown in the figure are considered fixed and standard, so it means that 1 ton of equivalent oil indicates the potentially released energy from the complete combustion of one ton of oil. Without specifying exactly what type of oil it is, with what degree of purity, what is the source, that is why an average reference is done to the heating value of oil and is defined as the TOE as a universal reference, conventionally fixed by IEA (International Energy Agency) [26] in 41.86 GJ, from this hypothesis then the other equivalences proposed in the scheme are obtained.

Another interesting observation is that 1tep = 11630kWh = 4651kWh electric, and this is because it is assumed that a generic ton of oil (true or equivalent) used to produce electricity must be transformed, assuming a global generation and transportation efficiency around 40 %; indeed:

$$\eta_{tot} = \frac{electric\ energy}{Energy\ needed\ to\ produce\ and\ transport\ it} = \frac{4651\ \mathrm{kWh}_{el}}{11630\ kWh} = 40\%$$

The conversion factor provided by the Portuguese authority [6], which sets its 0.000215 toe/kWh_{el}, is based on similar considerations.

Lastly, a table to converting the most common energy measurement units from the official ENEA site is added:

CONVERSION ENERGY FACTOR						
	J	kWh	kcal	Btu	tec	tep
J	1	2,777x10^{-7}	2,388x10^{-4}	9,478x10^{-4}	3,412x10^{-11}	2,388x10^{-11}
kWh	3,600x10^{6}	1	8,600x10^{2}	3,412x10^{3}	1,228 x10^{-4}	8,598x10^{-5}
kcal	4,186x10^{3}	1,162 x10^{-3}	1	3,967	1,428 x10^{-7}	9,998x10^{-8}
Btu	1,055 x10^{3}	2,930 x10^{-4}	2,520 x10^{-1}	1	3,599 x10^{-8}	2,519 x10^{-8}
tec	3,098 x10^{10}	8,606 x10^{3}	7,401 x10^{6}	2,937 x10^{7}	1	7,4x10^{-1}
tep	4,186 x10^{10}	1,163 x10^{4}	1x10^{7}	3,968 x10^{7}	1,351	1

Figure 4.7.1.2 - http://www.enea.it/it/comunicare-la-ricerca/le-parole-dellenergia/unita-di-misura/fattori-di-conversione [11]

For $CO_{2,eq}$ emission, literature often refers to the equivalence between the power to contribute to the greenhouse effect of different gases. We're talking about the well-known GWP or Global Warming Potential. However, we want to estimate how much of the greenhouse effect is due to energy consumption and therefore try to attribute a certain amount of emissions to the desired energy unit.

The applied equivalences are:

$$1kWh_{electric} = 0{,}47 \cdot 10^{-3}\ t\mathrm{CO_{2eq}}$$

$$1kWh_{electric} = 0{,}215 \cdot 10^{-3}\ \mathrm{tep}$$

$$1tep_{electric} = 2{,}1867\ t\mathrm{CO_{2eq}}$$

Furthermore, the table proposed by the Portuguese authorities in Despacho No 17313/2008 setting out the energy equivalents for conversion between fuel units and toe and the standard estimate of the emissions to be attributed to the single fuel is shown.

Combustível	PCI (MJ/kg)	PCI (tep/t)	FE (kgCO_2e/GJ)	FE (kgCO_2e/tep)
Antracite	26,7	0,638	98,2	4111,4
Betume / Alcatrão	40,2	0,96	80,6	3374,6
Biogasolina e Biodiesel	27	0,645	0	0,0
Briquetes de lignite	20	0,478	101,1	4232,9
Briquetes de turfa	16 — 16,8	0,382 — 0,401	105,9	4433,8
Carvão betuminoso	25,8	0,616	94,5	3956,5
Carvão sub-betuminoso	18,9	0,451	96,0	4019,3
Carvão vegetal	29,5	0,705	0	0,0
Combustível para motor (gasolina)	44 — 45	1,051 — 1,075	69,2	2897,3
Coque de Carvão	28,2	0,674	94,5	3956,5
Coque de forno / lignite ou gás	28,2 — 28,5	0,674 — 0,681	107	4479,9
Coque de Petróleo	31 — 32,5	0,740 — 0,776	97,5	4082,1
Etano	46,4	1,108	61,6	2579,1
Fuelóleo pesado	40 — 40,4	0,955 — 0,965	77,3	3236,4
Fuelóleo	41,2	0,984	77,3	3236,4
Gás de Alto Forno	2,5	0,060	259,4	10860,6
Gás de coqueria e de fábricas de Gás	38,7	0,924	44,7	1871,5
Gás de forno de aceария a oxigénio	7,1	0,170	171,8	7192,9
Gás de petróleo liquefeito	46 — 47,3	1,099 — 1,130	63,0	2637,7
Gás de Refinaria	49,5	1,182	51,3	2147,8
Gás natural (superior a 93 % de metano)	47,2 — 48	1,127 — 1,146	56,1	2348,8
Gás natural liquefeito	44,2 — 45,2	1,056 — 1,080	64,1	2683,7
Gás natural (1)	45,1	1,077	64,1	2683,7
Gases de aterro/ lamas de depuração e outros biogases	50,4	1,204	0	0,0
Gasóleo / Diesel	42,3 — 43,3	1,010 — 1,034	74,0	3098,2
Hulha	17,2 — 30,7	0,411 — 0,733	97,5	4082,1
Lignite castanha	5,6 — 10,5	0,134 — 0,251	101,1	4232,9
Lignite negra	10,0 — 21	0,239 — 0,502	101,1	4232,9
Lubrificantes, ceras parafínicas e outros produtos Petrolíferos	40,2	0,960	73,3	3068,9
Madeira / resíduos de Madeira	13,8 — 15,6	0,330 — 0,373	0	0,0
Matérias-primas para refinaria	43	1,027	73,3	3068,9
Metano	50	1,194	54,9	2298,6
Monóxido de Carbono	10,1	0,241	155,2	6497,9
Nafta química / Condensados de gasolina	44,5	1,063	73,3	3068,9
Óleo de xisto	38,1	0,910	73,3	3068,9
Óleos usados	40,2	0,960	73,3	3068,9
Orimulsão	27,5	0,657	76,9	3219,6
Outra biomassa primária sólida	11,6	0,277	0	0,0
Outros biocombustíveis Líquidos	27,4	0,654	0	0,0
Peletes / briquetes de madeira	16,8	0,401	0	0,0
Petróleo Bruto	42,3	1,01	73,3	3068,9
Querosene	43,8	1,046	71,8	3006,1
Resíduos Industriais	7,4 — 10,7	0,177 — 0,256	142,9	5982,9
Turfa	7,8 — 13,8	0,186 — 0,330	105,9	4433,8
Xisto betuminoso	8 — 9	0,191 — 0,215	106,6	4463,1

Figure 4.7.1.3 - Lower Heating Value and Emission Factors for different Fuels

In the table above, the LHV (MJ / kg) is the lower heating value of the fuel expressed in MJ per kilogram (kg), LHV (TOE/t) is the lower heating value of the fuel expressed in tons of equivalent oil (TOE) per ton (t), FE (kgCO_{2e} / GJ) is the emission factor of greenhouse gas (CO_2) expressed in kilograms of CO2 equivalents on energy released by fuel in GJ, and FE (kgCO_{2e} / toe) is the Greenhouse gas emissions factor expressed in kilograms of CO_2 equivalent for the energy released by one ton of fuel oil equivalent (toe).

For other solid, liquid or gaseous primary fuels not explicitly covered in the previous table, the following expression may be used to transform the lower heating value (LHV) of the fuel from MJ/kg or to toe/t:

$$PCI\left[\frac{toe}{t}\right] = \frac{PCI\left[\frac{MJ}{kg}\right]}{41868\left[\frac{MJ*t}{toe*kg}\right]}$$

This expression considers the thermodynamic conversion used by the International Energy Agency (1 toe = 41 868 MJ). For the purposes of carbon dioxide accounting for the greenhouse gas problem for other solid, liquid and gaseous primary fuels not explicitly mentioned in the table and not comparable with others, reference values of the emission factor that you should use (FE) are respectively 96, 73 and 59 kgCO2eq / GJ .

For electricity, conversion considers the average electrical output (ηelectric) of thermoelectric power plants using fossil fuels. Consequently:

$$Electric\ energy\ \left[\frac{toe}{kWh}\right] = \frac{\eta_{electric}}{86 * 10^{-6}}$$

For the purposes of this Order and in accordance with Annex II to Directive 2006/32 / EC, the value of the electric efficiency is 0,4, so that 1kWh = 215 * 10-6 toe. For the purpose of carbon dioxide emission calculation for greenhouse gas emissions, the emission factor associated with the consumption of electricity is deemed to be 0.47 kgCO2e / kWh in accordance with the provisions of Decree No 63/2008 of 21 January, 1st Series.

For steam, the conversion factor estimates that the average thermal efficiency (η_{termic}) of boilers currently used to generate steam is given by:

$$Steam's\ energy\ \left[\frac{tep}{t}\right] = \frac{Steam's\ specific\ enthalpy\ \left[\frac{MJ}{kg}\right]}{\eta_{thermic} * 41{,}868}$$

For the purpose of calculating carbon emissions for the release of greenhouse gases, the associated emission factor for steam production can be considered as:

$$\text{Emission factor for steam consumption}\ \left[\frac{\text{kgCO}_{2eq}}{\text{GJ}}\right] = \frac{65{,}05}{\eta_{thermic}}$$

As a result of the order, the η_thermic value for the vapor generation boiler is equal to 0.9, so for 1 GJ of consumed steam, 72.3 $kgCO_{2e}$ are emitted.
The carbon content is the amount of carbon per unit of energy of a given fuel. In 1996 GLs only proposed specific fuels and their respective carbon value, called "carbon emission factor", then revised in the 2006 GLs. There were also added some values for fuels not directly mentioned in the GLs Of 1996.

Since the carbon content can vary considerably for some fuels, GLS introduced values ranges in 2006, that is, providing for each fuel a default, a lower and higher tolerance limit. CO_2 emissions are calculated using IPCC values.

A summary of the carbon content values in the two sets of guidelines is shown in the table below comparing the changes between the 1996 and 2006 GLSs between -13.7% (refinery gas) and + 7.3% (Blast Gas), although for many fuels the variation is minimal or zero. Such systematic changes are reflected in different estimates of CO_2 emissions.

Fuel Type	*1996 Guidelines*	*2006 Guidelines***	Percent Change
Anthracite	26.8	26.8	0.0%
Coking Coal	25.8	25.8	0.0%
Other Bituminous Coal	25.8	25.8	0.0%
Sub-Bituminous Coal	26.2	26.2	0.0%
Lignite	27.6	27.6	0.0%
Patent Fuel	25.8	26.6	+3.1%
Coke oven coke	29.5	29.2	-1.0%
Gas Coke	29.5	29.2	-1.0%
Coal Tar	..	22.0	x
BKB	25.8	26.6	+3.1%
Gas Works Gas	..	12.1	x
Coke Oven Gas	13.0	12.1	-6.9%
Blast Furnace Gas	66.0	70.8	+7.3%
Other recovered gases	..	49.6	x
Peat	28.9	28.9	0.0%
Oil shale	29.1	29.1	0.0%
Natural Gas	15.3	15.3	0.0%
Crude Oil	20.0	20.0	0.0%
Natural Gas Liquids	17.2	17.5	+1.7%
Refinery Feedstocks	20.0	20.0	0.0%
Orimulsion	22.0	21.0	-4.5%
Refinery Gas	18.2	15.7	-13.7%
Ethane	16.8	16.8	0.0%
Liquefied petroleum gases (LPG)	17.2	17.2	0.0%
Motor Gasoline excl. bio		18.9	0.0%
Aviation Gasoline	18.9	19.1	+1.1%
Gasoline type jet fuel		19.1	+1.1%
Kerosene type jet fuel excl. bio	19.5	19.5	0.0%
Other Kerosene	19.6	19.6	0.0%
Gas/Diesel Oil excl. bio	20.2	20.2	0.0%
Fuel Oil	21.1	21.1	0.0%
Naphtha	20.0	20.0	0.0%
Lubricants	20.0	20.0	0.0%
Bitumen	22.0	22.0	0.0%
Petroleum Coke	27.5	26.6	-3.3%
Non-specified oil products		20.0	0.0%
Other hydrocarbons	20.0		
White Spirit & SBP		20.0	0.0%
Paraffin Waxes		20.0	0.0%
Industrial Waste	..	39.0	x
Municipal Waste (non-renewable)	..	25.0	x

Figure 4.7.1.3 - https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustion_Highlights_2016.pdf

5. PETRATEX'S DATA ANALYSIS

5.1 Data analyzers

It has been highlighted in the previous chapter how it is necessary to do many measurements and compare them with utility invoices to verify the correspondence and measuring which equipment is more (or less) energy consumer within the company's energy system.

Thanks to Circutor's[10] tools you can measure electrical power flows without having to disconnect or install new components in the network, only by installing devices that, thanks to the built-in SD memory, can measure a large amount of quality-related data of electrical quantities. There is a new tool proposed by the same manufacturer, which is very similar to the ability of measurements, but is also able to access the internet by connecting to a router, allowing remote monitoring and recording of data captured in dedicated cloud.

You also need a program called Power Vision Plus[11] to read such measurements, which allows you to open these data and query them by means of special filters that allow you to create the desired graphics such as active, reactive and apparent absorption power, the various harmonics components, frequency, cosφ between phasors and more.

Figure 5.1.1 – Measurement equipment used CIR-e⁺

[10] http://circutor.com/en
[11] http://circutor.com/en/products/measurement-and-control/energy-management-software/powervision-series-detail

Parameters measured

Parameter	Symbol (unit)	L1	L2	L3	LIII	Max / Min
Voltage	V	•	•	•		•
Current	A	•	•	•		•
Frequency	Hz	•				•
Active power	W	•	•	•	•	•
Reactive power (L and C)	varL, varC	•	•	•	•	•
Apparent power	V · A	•	•	•	•	•
Power factor	FP	•	•	•	•	•
Active energy	W·h				•	•
Reactive energy (L and C)	var·hL,var·hC				•	•
Apparent energy	VA·h				•	
Harmonic decomposition U, I (50)		•	•	•		
THD (%) U, I	% THD	•	•	•		
MD (Max. demand) - Active power	W (MD)				•	•
MD (Max. demand) - Apparent power	VA (MD)				•	•
Fundamental U, I		•	•	•		
WA flicker	WA	•	•	•		
PST flicker	Pst	•	•	•	•	•

Figure 5.1.2 - Measurements taken

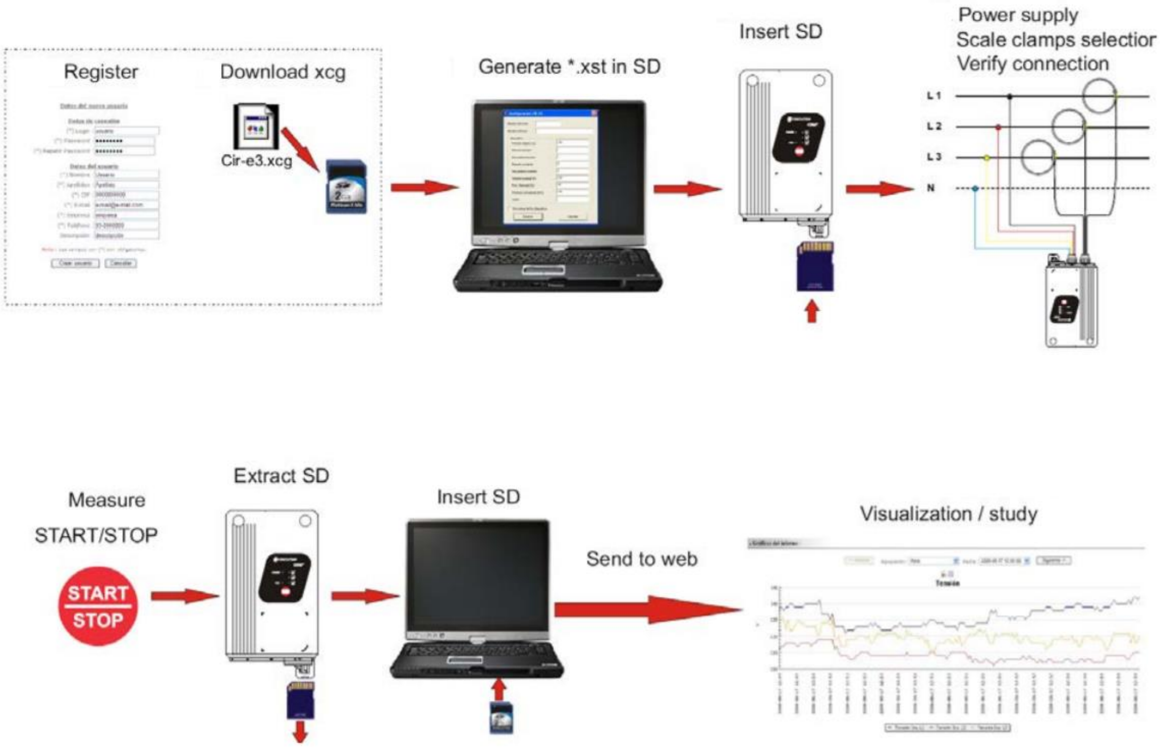


Figure 5.1.3 - How to use CIR-e⁺

The following energy sensors have been installed, called ANEN[12]:

	Start date	End date	Description
ANEN1	21/10/2016	27/10/2016	Accounting office
ANEN2	21/10/2016	27/10/2016	Speedo Line
ANEN4	21/10/2016	27/10/2016	Ironing
ANEN5	21/10/2016	27/10/2016	Sample line
ANEN7	21/10/2016	27/10/2016	Manifacturing
ANEN3	11/10/2016	27/10/2016	Trasformer 1
ANEN6	11/10/2016	27/10/2016	Trasformer 2

Figure 5.1.2 – Energy analyzers' point of measurement

The total scheme of Petratex's electrical system is attached at the end of the report. Only the main measurements (power and energy) and their position are highlighted, so as to understand the arguments that will be proposed.

The network is powered in medium voltage from the Iberdrola service provider through two identical transformers (whose datasheets are in the figure below), providing electricity to the company, and where ANEN 3 and ANEN 6 have been installed to measure the total power supply input (energy) and verify that it is comparable and as far as possible equal to what the supplier declares.

The verification aspect is important because the supplier measures the power of the service before the transformer and therefore still in medium voltage, while the meters are in low voltage, it is thus possible to determine the losses in the transformers and possibly challenge the supply and charging to the service provider if processing performance is too low. In fact, the supplier charges the individual customer, known as the big consumer in medium voltage, transformation costs and their losses.

The measurements made and the comparison with the data provided by the supplier are the following for a sample-day continuous active energy monitoring day, which are proposed at the end of the discussion:

[12] ANalyzer of ENergy

Consumos Horarios de Energia Activa (kWh) 11/10/2016

Hora	IBERDROLA	ANEN 3	ANEN 6	Total	Difference	Error %
0:00	76	38,9	36	74,9	1,1	1,447368
1:00	78	41	37	78	0	0
2:00	76	40,2	36,8	77	-1	1,315789
3:00	78	41	36,7	77,7	0,3	0,384615
4:00	98	53,9	48,7	102,6	-4,6	4,693878
5:00	284	158,3	148,7	307	-23	8,098592
6:00	343	186,8	175	361,8	-18,8	5,48105
7:00	358	199,1	188,2	387,3	-29,3	8,184358
8:00	582	316,2	301,5	617,7	-35,7	6,134021
9:00	640	342,8	326,4	669,2	-29,2	4,5625
10:00	625	336,7	320,6	657,3	-32,3	5,168
11:00	638	341,3	325	666,3	-28,3	4,435737
12:00	551	295,8	279,6	575,4	-24,4	4,428312
13:00	582	314,3	299	613,3	-31,3	5,378007
14:00	618	331,5	316	647,5	-29,5	4,773463
15:00	588	315,6	301,1	616,7	-28,7	4,880952
16:00	593	318,6	303,7	622,3	-29,3	4,940978
17:00	471	252,9	238,2	491,1	-20,1	4,267516
18:00	362	194,7	182,5	377,2	-15,2	4,198895
19:00	313	167,6	158	325,6	-12,6	4,025559
20:00	230	122,3	113,4	235,7	-5,7	2,478261
21:00	181	96,7	89	185,7	-4,7	2,596685
22:00	122	64,2	57,5	121,7	0,3	0,245902
23:00	86	45,9	40,8	86,7	-0,7	0,813953

Figure 5.1.3 – Difference between measurements and consumption datas

In the table below, the IBERDROLA column represents the amount declared by the supplier, the ANEN measurements and their sum in TOTAL as there are two transformers that feed the company and the DIFFERENCE column that is the Difference between declared and measured values. The last column instead specifies the percentage error for the measurement being made.

So, you get a general relative percentage error of 3.87% which, overall, is acceptable. See below the total results of 11/10/2016. See also the graph of active energy measured compared with those given by Iberdrola.

	IBERDROLA	ANEN 3	ANEN 6	TOTAL	DIFFERENCE	ERROR%
TOTAL	8573	4616,3	4359,4	8975,7	-402,7	4,697305

Figure 5.1.4 – Total difference between measurements and consumption datas

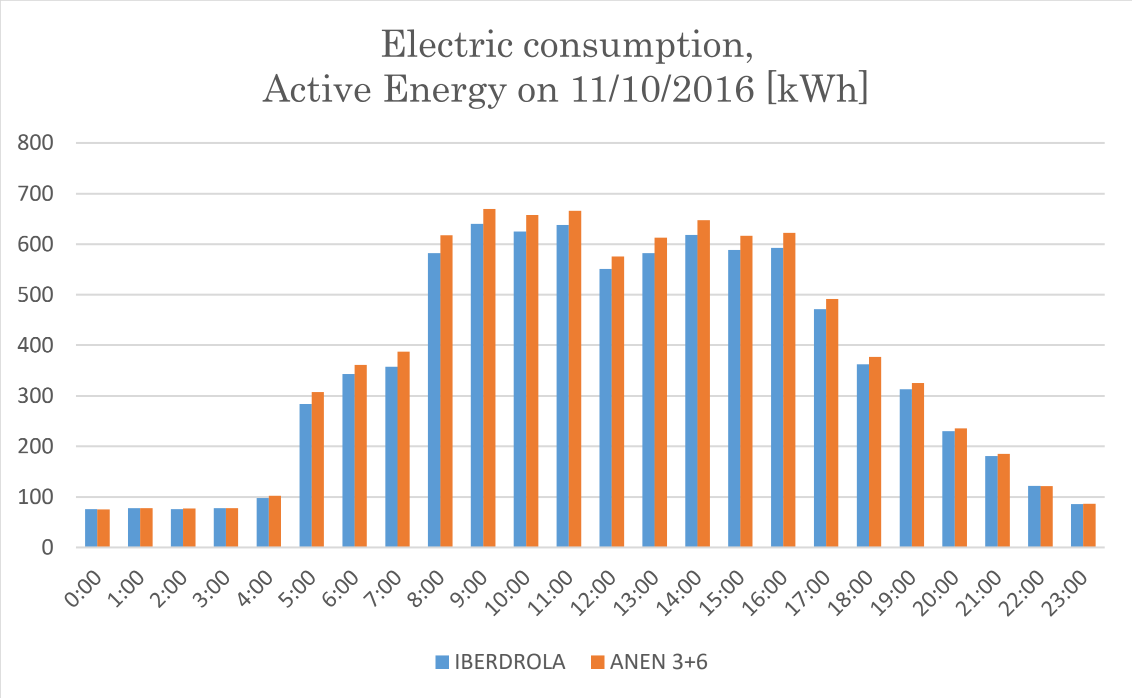


Figure 5.1.5 – Monthly comparison between measurements and consumption datas

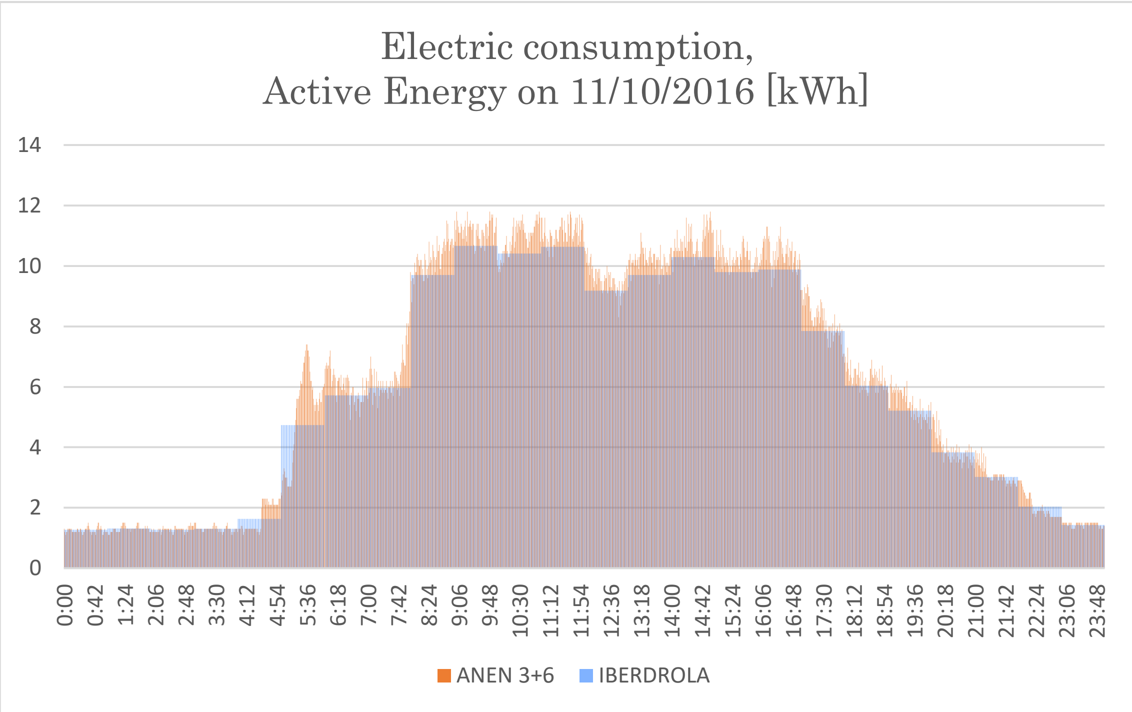


Figure 5.1.6 – Daily comparison between measurements and consumption datas

From the careful observation of the data there are some questions that require a somewhat more refined investigation.

- Why is there a difference between the active energy billed by the supplier and the one measured? Why the difference column is negative for almost all values?
- Why is there a relative error more than double from the time zone between 4:00 and 5:00 (up to 8:00)?

The supplier gives us measurement of energy and power divided into periods respectively of 1 hour and 15 minutes. Considering the part of the active energy, the supplier has advantages to get us pay more energy than he provides us but it seems that Petratex uses more energy than it actually pays. The measurement system used in this case, described above, allows to obtain values with a very high acquisition frequency, providing output values minute by minute for all measurements.

The strangest thing is that we measured a greater value than the energy input giving by Iberdrola, after transformers and their losses. Obviously, there is no energy generation in transformers, but only losses that should reduce the output energy value, but that does not happen.

The reasons for this may be attributable to Iberdrola's data, which are not very detailed and it could be possible that the supplier has "scaled" the values with a "standard efficiency" of the transformer, but the measurements made seem to be too conservative, in user's advantage, that is quite unprobable.

The disadvantage is that with the data available we cannot calculate the energy losses associated with the transformers. other equipment should be installed before and after the transformers to be able to calculate the actual losses.

Considering that the electric machines in question are the property of the service provider, but the costs of the losses are entirely on the customer you could make a request for replacement or you might think of modifying the service contract in favor of the client if you could calculate such transformation losses.

5.2 Electricity

After receiving all the electricity bills from the company, it is for the 2015 and 2016 that the following consumption is organized, divided by hourly and monthly intervals and finally the relative percentage on the total.

2015

Eletricidade																	
Meses	Consumo de Energia (kWh)					(kVAr)	Custo da energia (€)				Custo da energia (€)					TOTAL	(€/ kWh)
	HSV	HV	Hponta	Hcheia	Total	REA	HSV	HV	HP	HC	Pcontatada	PHP	Fixo redes	Imposto	Reactiva		
jan	12.001	19.742	29.981	74.410	**136.134**	894	527,90 €	984,95 €	1.911,46 €	4.321,68 €	569,46 €	2.172,06 €	4.722,44 €	164,96 €	27,02 €	15.401,93 €	0,1131
fev	17.272	25.773	43.481	106.838	**193.364**	531	759,76 €	1.285,87 €	2.772,13 €	6.205,04 €	678,97 €	2.739,22 €	6.747,03 €	196,01 €	14,75 €	21.398,78 €	0,1107
mar	13.764	20.422	37.201	89.694	**161.081**	317	605,45 €	1.018,89 €	2.371,75 €	5.209,34 €	613,27 €	2.434,28 €	5.654,86 €	163,73 €	4,81 €	18.076,38 €	0,1122
abr	10.973	18.121	27.328	86.699	**143.121**	654	482,68 €	904,09 €	1.742,30 €	5.035,39 €	678,97 €	3.193,25 €	4.985,29 €	145,77 €	15,84 €	17.183,58 €	0,1201
mai	10.388	16.837	31.606	104.328	**163.159**	1.447	456,95 €	840,03 €	2.015,04 €	6.059,27 €	657,07 €	3.517,28 €	5.779,39 €	165,81 €	30,36 €	19.521,20 €	0,1196
jun	9.270	16.647	34.951	119.918	**180.786**	628	407,77 €	830,55 €	2.228,30 €	6.964,72 €	687,68 €	3.836,50 €	6.475,02 €	183,44 €	20,31 €	21.634,29 €	0,1197
jul	10.982	16.331	33.534	121.810	**182.657**	778	483,08 €	814,79 €	2.137,96 €	7.074,60 €	665,50 €	3.918,45 €	6.512,19 €	185,31 €	23,89 €	21.815,77 €	0,1194
ago	7.473	10.928	18.725	67.218	**104.344**	6.757	328,72 €	545,22 €	1.193,81 €	3.903,95 €	687,68 €	1.966,07 €	3.670,57 €	106,99 €	377,95 €	12.780,96 €	0,1225
set	10.424	17.193	31.437	109.839	**168.893**	2.399	458,53 €	857,79 €	2.004,27 €	6.379,34 €	687,68 €	3.450,80 €	5.984,62 €	171,54 €	124,79 €	20.119,36 €	0,1191
out	12.662	21.140	33.972	121.478	**189.252**	621	556,98 €	1.054,72 €	2.165,88 €	7.055,32 €	665,50 €	3.664,30 €	6.690,90 €	191,90 €	15,18 €	22.060,68 €	0,1166
nov	19.710	28.249	55.353	138.066	**241.378**	784	867,00 €	1.409,40 €	3.529,03 €	8.018,74 €	687,68 €	3.487,09 €	8.527,11 €	244,03 €	9,61 €	26.779,69 €	0,1109
dez	18.468	30.617	47.303	119.736	**216.124**	1.264	812,37 €	1.527,54 €	3.015,80 €	6.954,15 €	809,39 €	3.416,93 €	7.518,00 €	218,77 €	20,16 €	24.293,11 €	0,1124
Total	153.387	242.000	424.872	1.260.034	2.080.293	17.074	6.747,19 €	12.073,84 €	27.087,73 €	73.181,54 €	8.088,85 €	37.796,23 €	73.267,42 €	2.138,26 €	684,67 €	241.065,73 €	
Média	12.782	20.167	35.406	105.003	173.358	1.423	562,27 €	1.006,15 €	2.257,31 €	6.098,46 €	674,07 €	3.149,69 €	6.105,62 €	178,19 €	57,06 €	20.088,81 €	0,1159
%	7,37%	11,63%	20,42%	60,57%	100,00%	0,82%	2,80%	5,01%	11,24%	30,36%	3,36%	15,68%	30,39%	0,89%	0,28%	CO2e (kg)	977737,9

Figure 5.2.1 – 2015 bills

2016

Eletricidade																	
Meses	Consumo de Energia (kWh)					(kVAr)	Custo da energia (€)				Custo da energia (€)					TOTAL	(€/ kWh)
	HSV	HV	HP	HC	Total	REA	HSV	HV	HP	HC	PC	PHP	Fixo	Imposto	Reactiva		
jan	15.354	25.738	35.312	105.763	**182.167**	792	644,85 €	1.254,68 €	2.160,28 €	6.043,93 €	658,63 €	2.400,26 €	6.886,30 €	184,82 €	16,37 €	20.250,12 €	0,1112
fev	16.146	26.043	44.480	136.944	**223.613**	2.079	678,12 €	1.269,54 €	2.721,15 €	7.825,80 €	756,90 €	2.713,38 €	8.641,25 €	226,26 €	37,39 €	24.869,79 €	0,1112
mar	13.877	24.841	35.027	110.772	**184.517**	1.943	582,82 €	1.210,95 €	2.142,85 €	6.330,18 €	708,06 €	2.419,73 €	7.047,40 €	187,17 €	43,83 €	20.672,99 €	0,1120
abr	13.696	23.883	34.867	115.065	**187.511**	2.114	575,22 €	1.164,25 €	2.133,06 €	6.575,50 €	756,90 €	3.882,55 €	7.152,50 €	190,16 €	47,90 €	22.478,04 €	0,1199
mai	10.596	21.288	37.649	121.093	**190.626**	696	443,89 €	1.037,75 €	2.303,25 €	6.919,98 €	732,48 €	4.057,11 €	7.394,19 €	193,25 €	27,99 €	23.109,89 €	0,1212
jun	11.297	20.218	34.299	108.570	**174.384**	1.404	474,46 €	985,59 €	2.098,31 €	6.204,34 €	756,90 €	4.010,30 €	6.720,27 €	177,03 €	68,54 €	21.495,74 €	0,1233
jul	15.927	25.791	46.161	142.749	**230.628**	571	668,92 €	1.257,26 €	2.823,99 €	8.157,53 €	799,68 €	4.748,29 €	8.891,70 €	233,48 €	19,92 €	27.600,77 €	0,1197
ago	9.734	16.791	30.761	94.019	**151.305**	3.000	408,82 €	818,53 €	1.881,87 €	5.372,81 €	846,18 €	3.269,69 €	5.852,23 €	154,16 €	127,40 €	18.731,69 €	0,1238
set	9.300	16.496	29.809	29.809	**85.414**	1.995	390,59 €	804,15 €	1.823,63 €	4.947,13 €	846,18 €	3.319,36 €	5.488,94 €	145,20 €	86,36 €	17.851,54 €	0,2090
out	13.868	20.701	37.802	118.416	**190.787**	605	582,44 €	1.009,13 €	6.767,00 €	2.312,61 €	818,88 €	4.073,60 €	7.391,80 €	193,81 €	21,93 €	23.171,20 €	0,1215
nov	18.666	27.836	33.329	128.817	**208.648**	729	783,95 €	1.356,95 €	2.038,97 €	7.361,38 €	846,18 €	2.314,98 €	7.876,44 €	211,67 €	19,09 €	22.809,61 €	0,1093
dez	20.714	32.740	29.644	116.736	**199.834**	765	869,53 €	1.596,01 €	1.813,53 €	6.671,00 €	818,88 €	2.118,44 €	7.362,80 €	202,85 €	15,02 €	21.468,06 €	0,1074
Total	169.175	282.366	429.140	1.328.753	2.209.434	16.693	7.103,61 €	13.764,79 €	30.707,89 €	74.722,19 €	9.345,85 €	39.327,69 €	86.705,82 €	2.299,86 €	531,74 €	264.509,44 €	
Média	14.098	23.531	35.762	110.729	184.120	1.391	591,97 €	1.147,07 €	2.558,99 €	6.226,85 €	778,82 €	3.277,31 €	7.225,49 €	191,66 €	44,31 €	22.042,45 €	0,1197
%	7,66%	12,78%	19,42%	60,14%	100,00%	0,76%	2,69%	5,20%	11,61%	28,25%	3,53%	14,87%	32,78%	0,87%	0,20%	CO2e (kg)	1038434,0

Figure 5.2.2 – 2016 bills

It is also interesting to see how the composition is divided into the different time zones, both in terms of power consumption in kWh and energy costs for the year 2015.

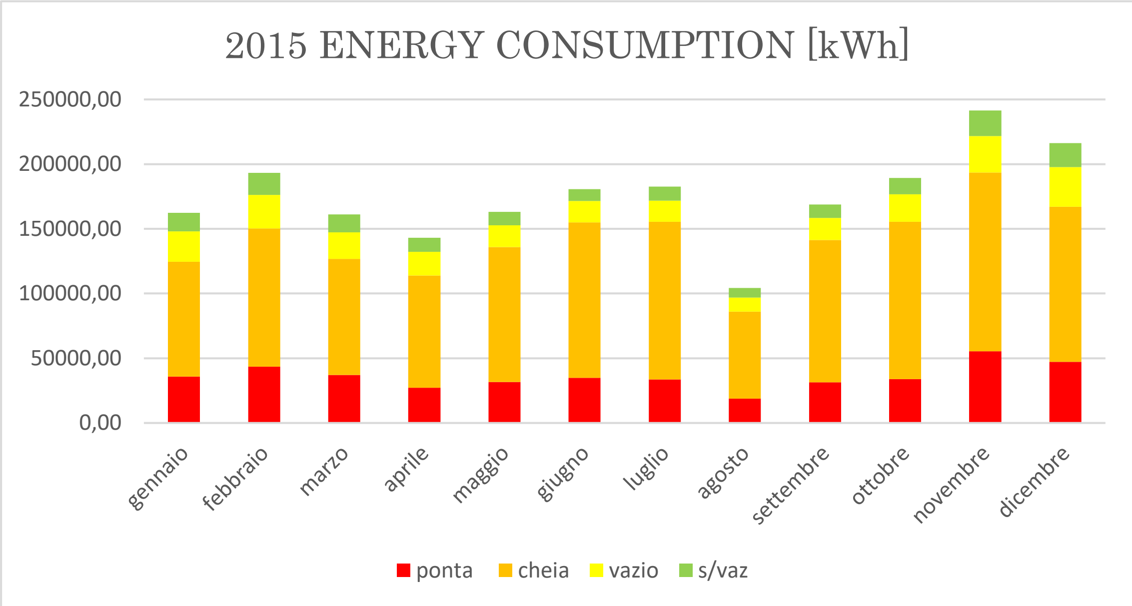


Figure 5.2.3 - kWh per time slots 2015

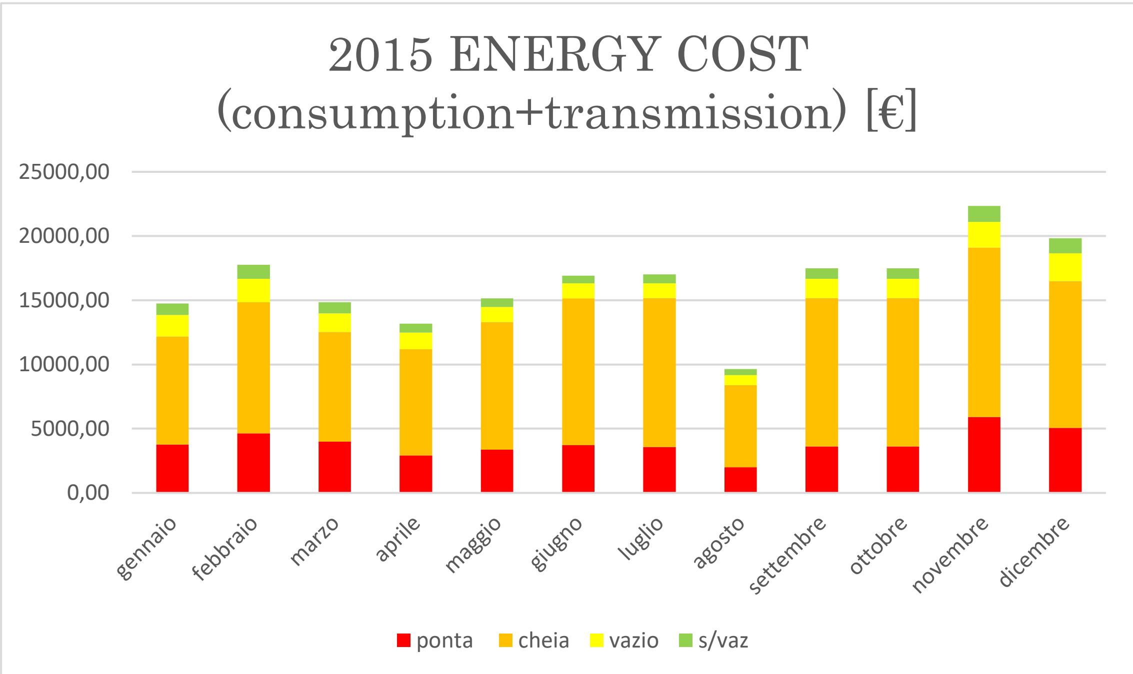


Figure 5.2.4 - € per time slots 2015

Graphs 5.2.3 and 5.2.4 show a trend of consumption quite typical for such companies. Greater consumption in the winter months, though little, and a collapse of consumption during august which is the classic month when the plant closed for a couple of weeks.

Another factor to pay attention is how the reactive power in august is very large compared to the other months because many machineries remain connected to plants' grid and there is not enough correction of the power factor, thus increasing the costs for reactive power. Compared to the absolute values of the bills the reactive power part is a minimum amount but, with regard to reactive power costs, it is almost 7 times higher than the average in other months. In fact, the capacitors that usually balance the reactive power do not come into operation if under a certain threshold, so, a prolonged non-operation will lead to costs above.

Companies are then usually interested in understanding how much they pay for a kWh of energy at the end. We add all monthly costs (electrical) and divide by the number of days of the months and do a monthly general average for the cost of kWh. More in-depth analysis is done when the company explicitly requests it, otherwise, the procedure described above is usually followed, as shows the next graph 5.2.5 .

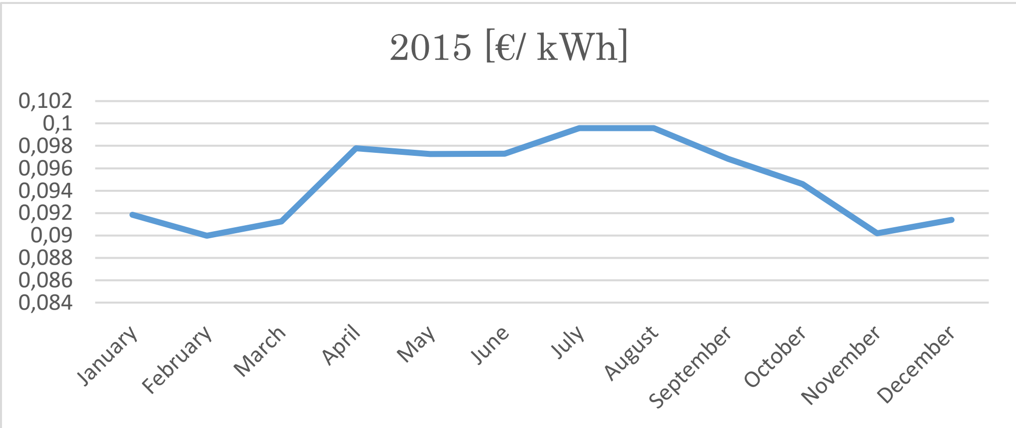


Figure 5.2.5 - €/kWh general in 2015

From Graph 5.2.5 compared to the consumption trend seen in Figure 5.2.3 above, it is interesting to note how the cost per kWh goes, which also considers fixed costs in addition to the cost of energy. The costs are bigger in the month of lower consumption and lower in months when the consumption is greater. The reason is easily understandable, as it is possible to split the total cost in the consumed kWh and the fixed costs weigh less in percentage, on each.
Always as far as 2015 is concerned:

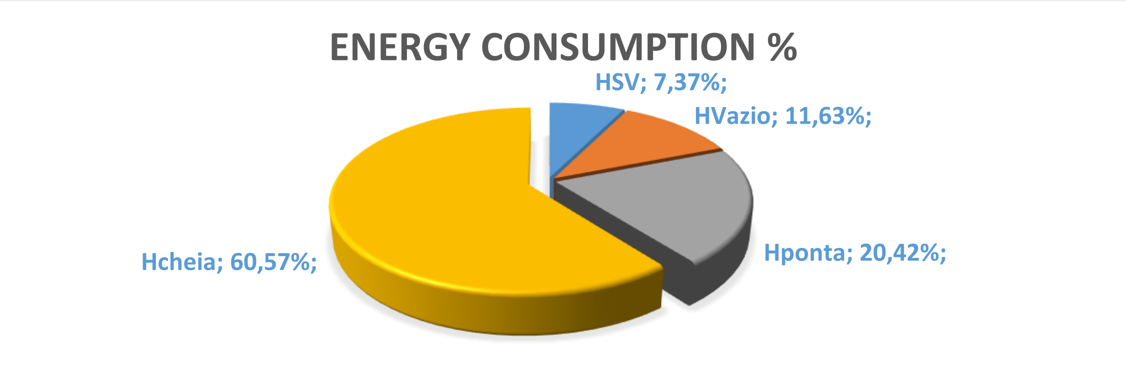


Figure 5.2.6 – Energy hourly division consumption in 2015

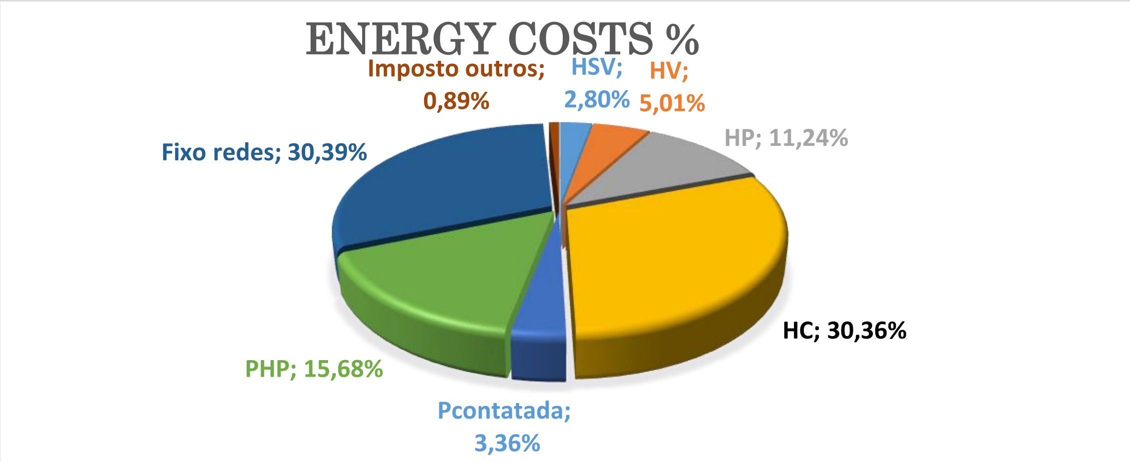


Figure 5.2.7 – Annual energy divided costs in 2015

Comparing the total electric consumption between 2015 and 2016, there is a general increase in electricity usage, which is approximately 9% as it's easy to see in the next graph.

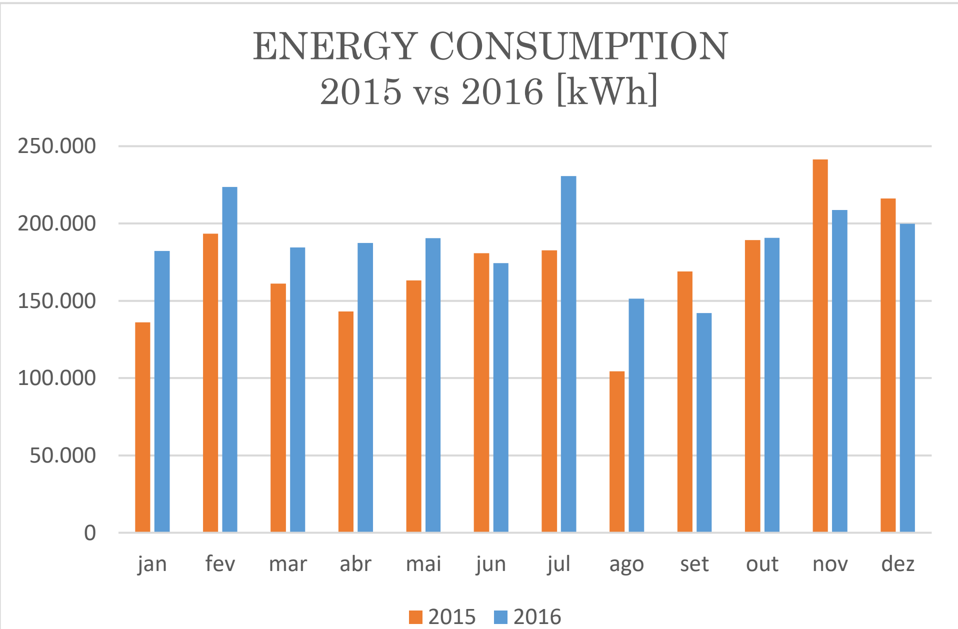


Figure 5.2.8 – Energy consumptions 2015 vs 2016

5.2.1 Thermal resistance for ironing, ANEN 4

As mentioned in the section on ironing in the production process, see how the ANEN 4 energy consumption measurement tool, highlights how the power consumption of this production unit is very high.

The causes are not difficult to detect: ironing plates are completely electric, a choice dictated by the ease of use and relative safety, but above all by the ability to precisely control the temperature. Also, considering that the time to reach the working temperature of these equipment is about 20/30 minutes, it is preferable to always leave in standby-mode the resistors that on the other hand means that they continue to consume electricity.

Analyzing the data obtained from the measurements, making it a daily average and looking for a percentage representing the total of the energy consumed, it's clear to see that the ironing department does about 25-30% of total electrical consumption, for an annual total of over 60,000 € / year.

If we estimate the coefficient of use of 80% during one day, defined as the ratio between hours of use and hours in which electricity is consumed in this line, and if we could raise this coefficient to 90% with a better management system, it would save around 6.000 €/year.

The company has added a computer system where each production process site has a dock to record the business activity and each employee has a tablet to be inserted into that dock, so that the department head has in real time the produced quantities. All the data are then stored, determining the productivity of each employee, the number of items produced per each production line and the production times.

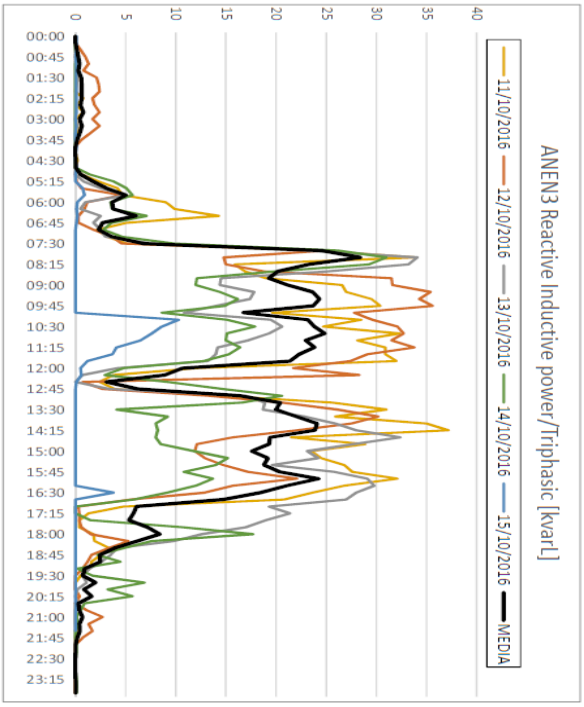
It would be interesting to try to implement a system that allows you to optimally coordinate the work time, thus obtaining a more rational use of the ironing stations and therefore of energy.

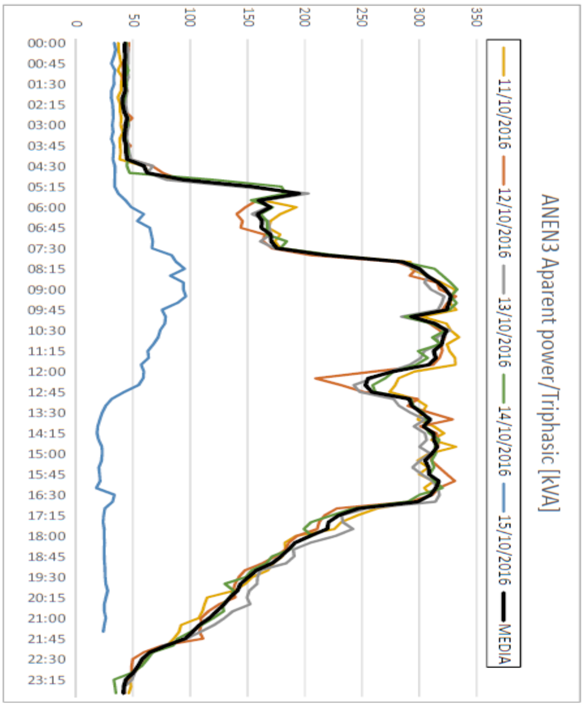
Figure 5.2.1.1 – Worker in ironing station

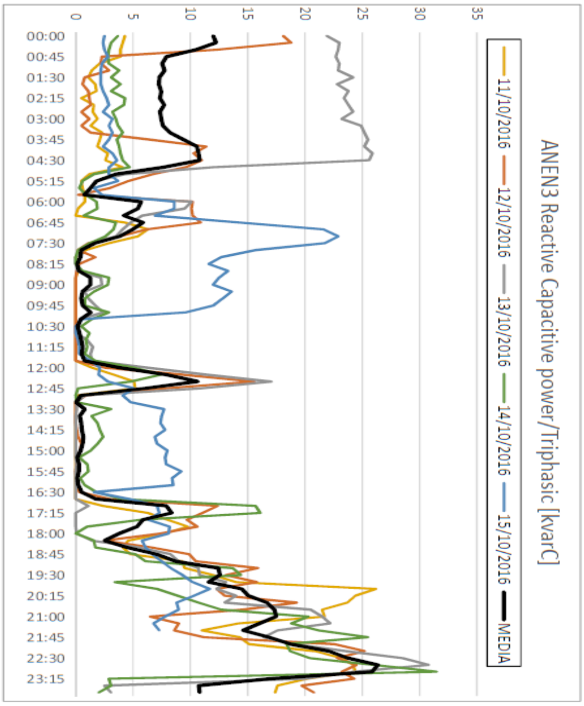
5.3 Load diagrams

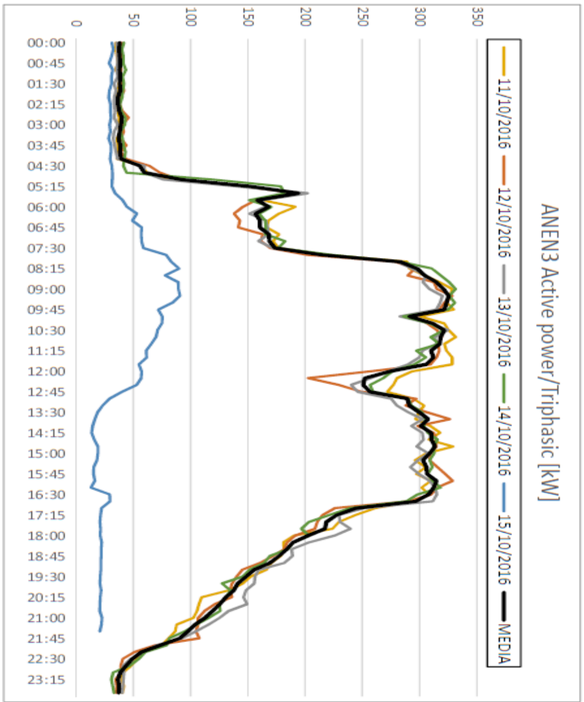
Below are the diagrams showing the trend for the ANEN 3 and ANEN6 measuring devices, that is, those that allow to calculate the total amount of electricity consumed by the company.

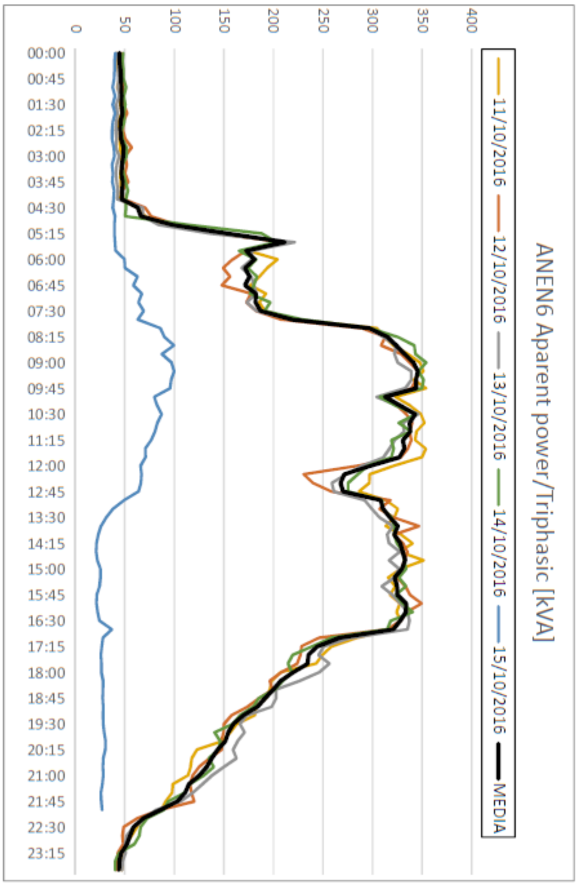
It is also interesting to see how the system behaves during weekends, where there is an increase in capacitive reactive power due to the absence of working devices that balance with inductive power.

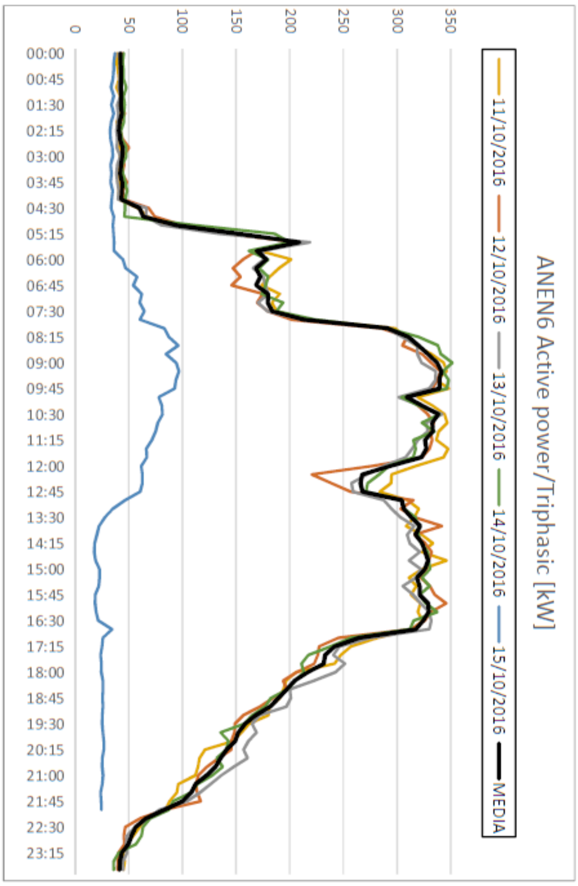


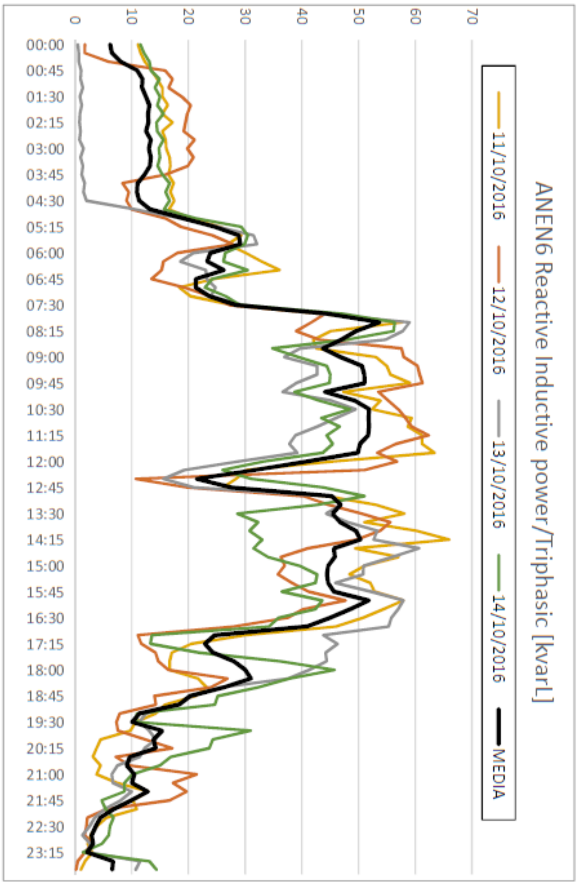


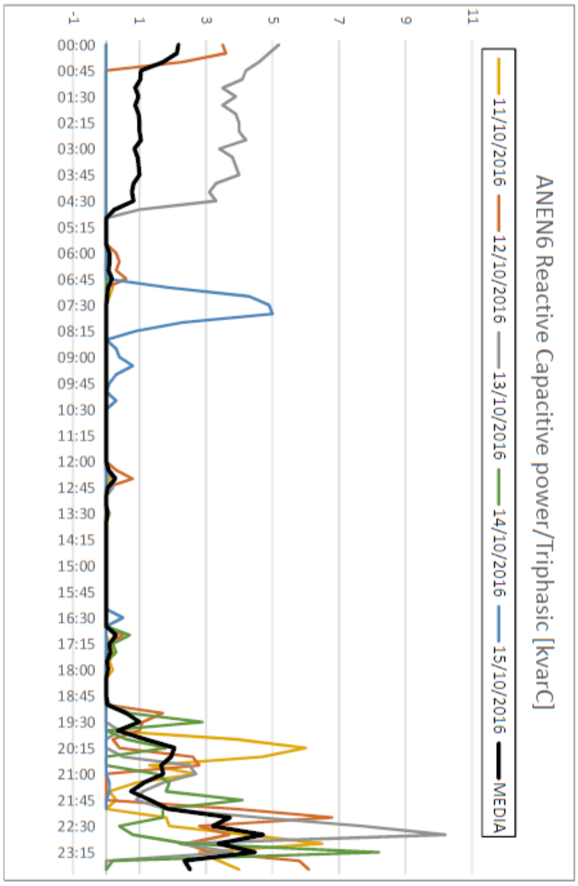





ANEN6 Aparent power/Triphasic [kVA]
11/10/2016
12/10/2016
13/10/2016
14/10/2016
15/10/2016
MEDIA


ANEN6 Active power/Triphasic [kW]
11/10/2016
12/10/2016
13/10/2016
14/10/2016
15/10/2016
MEDIA


ANEN6 Reactive Inductive power/Triphasic [kvarL]
11/10/2016
12/10/2016
13/10/2016
14/10/2016
MEDIA


ANEN6 Reactive Capacitive power/Triphasic [kvarC]
11/10/2016
12/10/2016
13/10/2016
14/10/2016
15/10/2016
MEDIA

5.4 Natural Gas

Here there are the monthly consumption for the canteen and the factory together:

2015

Gas Natural									
Meses	Consumo de Energia			Custo da Energia(€)				Total (€)	(€/kWh) no ISP
	Consumo (t)	Consumo (m^3)	Consumo (kWh)	Termo Fixo (€)	Termo Energia (€)	IVA (€)	ISP (€)		
jan	6,50	7.283,53	83.420,85	246,69 €	4.048,18 €	1.027,15 €	171,00 €	5.493,02 €	0,063797237
fev	6,63	7.251,40	85.017,48	217,86 €	4.523,00 €	1.131,68 €	179,49 €	6.052,03 €	0,06907459
mar	6,36	6.963,32	81.659,70	244,21 €	4.346,24 €	1.095,69 €	173,44 €	5.859,58 €	0,069632123
abr	6,53	7.150,73	83.834,70	233,37 €	4.422,43 €	1.111,79 €	178,07 €	5.945,66 €	0,068797205
mai	7,68	8.477,17	98.493,04	241,05 €	5.239,19 €	1.309,00 €	211,06 €	7.000,31 €	0,068931224
jun	7,49	8.263,28	96.055,19	233,19 €	5.104,21 €	1.274,92 €	205,74 €	6.818,06 €	0,06883871
jul	8,39	9.185,03	107.664,87	215,43 €	4.988,71 €	1.249,55 €	228,68 €	6.682,37 €	0,059942389
ago	5,23	5.728,86	67.150,23	215,39 €	2.510,94 €	659,86 €	142,63 €	3.528,81 €	0,050427041
set	7,99	8.744,19	102.500,47	208,44 €	4.745,39 €	1.189,46 €	217,71 €	6.361,00 €	0,059934282
out	12,51	13.690,22	160.481,00	215,40 €	7.401,70 €	1.831,02 €	343,86 €	9.791,98 €	0,058873753
nov	11,37	12.445,98	145.890,78	208,46 €	6.726,41 €	1.666,29 €	309,87 €	8.911,03 €	0,058956174
dez	9,95	10.894,62	127.711,22	215,40 €	5.893,97 €	1.467,54 €	271,25 €	7.848,15 €	0,059328417
	96,64	106.078,32	1.239.879,52	2.694,89 €	59.950,37 €	15.013,95 €	2.632,80 €	80.292,01 €	0,064757916

2016

Gas Natural									
Meses	Consumo de Energia			Custo da Energia(€)				Total (€)	(€/kWh) no ISP
	Consumo (t)	Consumo (m^3)	Consumo (kWh)	Termo Fixo (€)	Termo Energia (€)	Imp. e Taxas (€)	ISP (€)		
jan	10,07	10.969,72	129.177,00	202,92 €	5.576,84 €	1.400,90 €	311,09 €	7.491,75 €	0,055587732
fev	9,67	10.539,82	124.116,31	264,32 €	4.824,54 €	1.239,29 €	299,36 €	6.627,51 €	0,05098563
mar	10,33	11.253,60	132.530,59	798,14 €	4.449,40 €	1.280,46 €	319,66 €	6.847,66 €	0,049256567
abr	8,33	9.078,04	106.894,28	772,30 €	3.273,31 €	989,79 €	257,83 €	5.293,23 €	0,047106317
mai	8,12	8.844,14	104.122,86	797,89 €	3.179,12 €	972,48 €	251,15 €	5.200,64 €	0,047535135
jun	8,11	8.841,04	104.093,77	771,99 €	3.166,17 €	963,52 €	251,07 €	5.152,76 €	0,0470892
jul	9,22	10.047,17	118.301,10	623,72 €	3.406,36 €	992,55 €	285,34 €	5.307,96 €	0,042456279
ago	3,97	4.326,86	50.940,45	513,99 €	1.084,03 €	395,80 €	122,87 €	2.116,68 €	0,039140168
set	6,35	6.916,73	81.436,65	497,44 €	2.348,89 €	699,83 €	196,43 €	3.742,58 €	0,043544971
out	7,07	7.701,58	90.677,93	514,01 €	2.756,32 €	802,48 €	218,71 €	4.291,51 €	0,044915012
nov	9,59	10.449,89	123.049,11	598,33 €	3.731,98 €	1.064,23 €	296,80 €	5.691,34 €	0,043840585
dez	12,67	13.805,03	162.569,19	657,08 €	4.922,54 €	1.373,50 €	392,12 €	7.345,24 €	0,042770174
	103,50	112.773,62	1.327.909,25	7.012,13 €	42.719,49 €	12.174,83 €	3.202,43 €	65.108,88 €	0,049031119

Figura 5.4.1 - 2015 / 2016 natural gas bills

From a comparative graph between consumption in 2015 and 2016, and there is an increase, especially in the first months of 2016.

Such a significant increase, as well as the trend in consumption from August to December, can not only be related to the external temperature trend, but to the production program, especially because the steam is needed (around $1000kg_{steam}/h$) so, it's normal that during winter the consumption start increasing a bit.

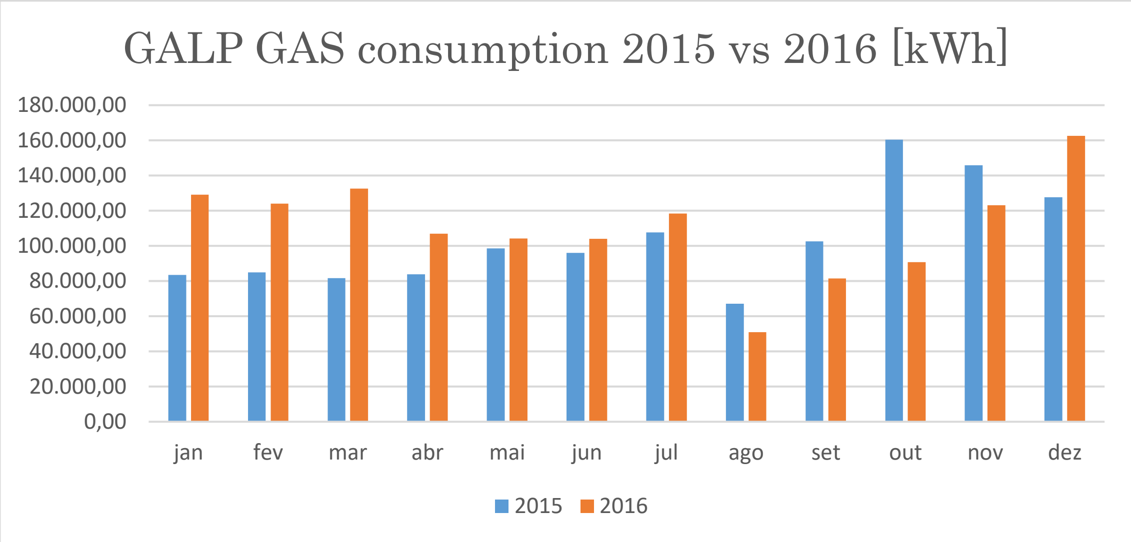


Figure 5.4.2 – Comparison between 2015 and 2016 or natural gas consumption

5.5 Biomass

The company decided to install a biomass boiler to burn residuals derived from the processing of almonds and olives to heat the water to feed the air heaters and the radiant floor heating system .for the quality control at 1st floor.

Figure 5.5.1 – Biomass, Biomass boiler's specifics, amonds and olive waste, biomass boiler

The boiler's power is 1.74MW that allow to warm up the water from the return temperature of the circuit up to about 80-85 ° C depending on the set-point required by the equipment. The Company's 2015 invoices for biomass purchase are:

Date	Costs [€]	Biomass [ton]
28/01/2015	6000	40
09/04/2015	174,97	0,975
09/10/2015	10800	80
15/10/2015	4051,35	30,01
21/11/2015	2027,6	14,8
Total	23053,9	165,785

Since biomass with its growth has absorbed CO_2 from the atmosphere, CO_2 input caused by biomass combustion is not counted, but you should take counts biomass as energy need as "Toe". In particular, SCGIE gives you 0.401 toe/ton as standard conversion factor for wood pellet biomass. Moreover, the energy-consumption obtained as biomass, always from SCGIE regulations, must be counted in half of his value because it is endogenous biomass. Then:

$$165.785 t_{biomass} * 0.401 \frac{toe}{t_{biomass}} * 0.5 = 66.48\, toe * 0.5 = 33.12\, toe$$

Used biomass are shells of almonds and olive kernels from local farms, it means far not more than 50 km radius area, with average properties as fuel comparable to:

Density: 360 Kg/m^3 (broken shells)
Density: 430 Kg/m^3 (grounded shells)
Energy Density: 1440-1720 KWh/m^3
Humidity: 5-10% (in weight)
Ash % in weight: 2-4
HHV (higher heating value): 4,6-4,8 kWh/Kg
LHV* (lower heating value): 4,4-4,6 kWh/Kg

The combustion fumes after exchanging heat with water are sent to a centrifugal filter to separate any particles in the fumes to limit the pollution effect. Captured and not emitted ashes and other particles are periodically collected and disposed by specialized firms.

Sometimes, the boiler has inadequate fuel input, ie pallet waste, other lumber with not proper suitable size, with nails or other impurities that contribute to first soiling the boiler, lowering its efficiency and increasing pollutant emissions. Here there is the fast way to calculate the boiler's efficiency:

$$\eta_{boiler} = 100 - K_1 \left(\frac{T_{fumes} - T_{air}}{\%CO_{2\,fumes}} \right) - K_2$$
$$= 100 - K_1 \left(\frac{112 - 15}{11.7} \right) - K_2$$
$$= 100 - 0.65 \left(\frac{112 - 15}{11.7} \right) - 5$$
$$= 90.05\%$$

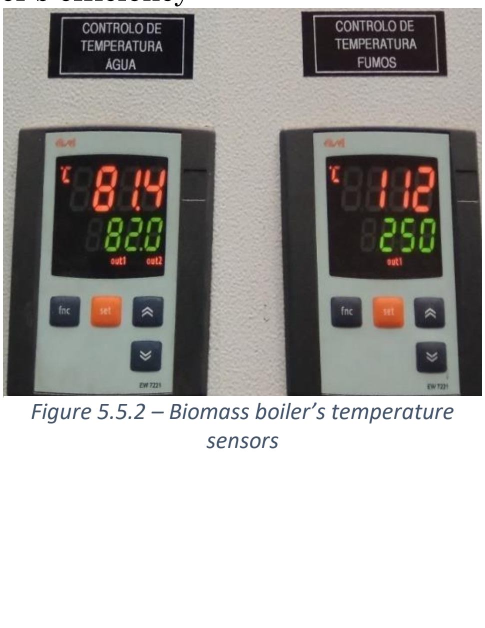


Figure 5.5.2 – Biomass boiler's temperature sensors

The obtained efficiency is quite good considering that K_1 was chosen slightly higher and to K_2 were added two points due to the unclear purity of the fuel material as biomass in order to have a conservative approach to the values, so for the simplifications introduced and the result obtained may be that actual efficiency will be about the calculated value.

If we want to try to calculate the efficiency in the other way, it's possible to calculate that:

Measuring the necessary values such as the presence of CO_2 and the temperature of the fumes, the percentage losses in fumes are obtained:

$$Q_{fumes}[\%] = K_s \cdot \frac{\left(T_{fumes} - T_{environment}\right)}{CO_2}$$
$$= 0.447 \cdot \frac{(112 - 15)}{11.7} = 4\%$$

In order to quantify losses for unburned fuel, an analysis of the fumes is needed with a percentage of the gases forming the fumes and using the following formula to obtain the percentage of losses:

$$Q_{comb}[\%] = K_c \cdot \frac{CO}{CO_2 + CO} = 59 \cdot \frac{1.2}{11.7 + 1.2} = 5\,\%$$

- CO and CO_2 are the volume-based percentage of carbon monoxide and carbon dioxide in fumes (very different from molar and weight).

- Kc is a constant depending on the type of fuel: in this case is biomass and you should use 59.

For the irradiance losses, we can consider that the external temperature of the boiler is not that high because it's well insulated so, we can consider in total 1.4% losses.

In the presented case, the results of the analysis is:

$$\eta_{indirect,\%} = 100 - \left(Q_{fumes\%} + Q_{comb\%} + Q_{rad\%}\right)$$
$$= 100 - (3.7 + 5 + 1.4) = 89.9\,\%$$

As you can see the difference is less than 1% between the two calculation methods.

5.6 Fuels

There is nothing to point out because fuel consumption is almost similar from 2015 to 2016.
About fuels for cars and trucks of the fleet we have that:

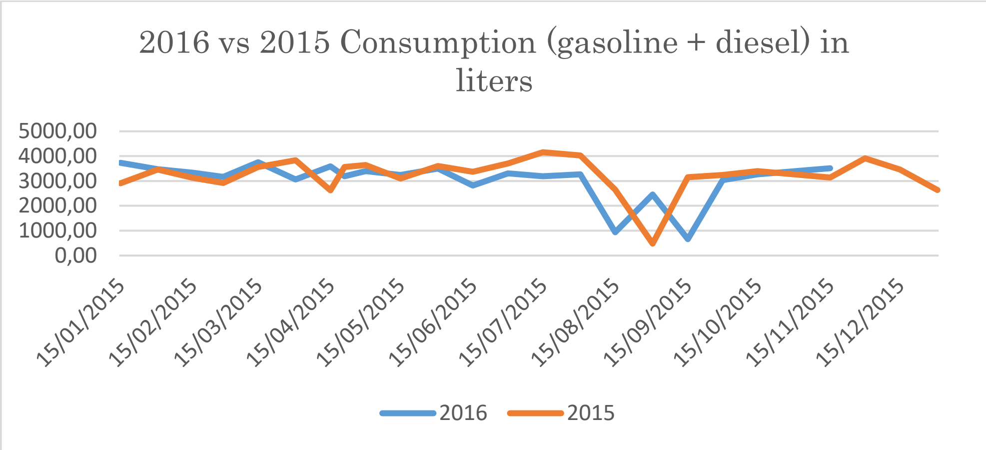


Figure5.6.1 - 2016 vs 2015 Consumption (gasoline + diesel) in liters

And the total consumptions for 2015 are:

Diesel [liters]	Gasoline Super [liters]
61.793,42	2.128,01

5.7 2015 and 2016 comparison

At this point you can easily get a comparison of consumed energy and costs in toe and €, respectively. The energy consumed for the most part is electricity followed by natural gas consumption. It's easy to notice that even if the natural gas consumption is increasing, the costs are not. This result is easily explained as the average natural gas costs have dropped from 2015 to 2016 as can be seen in the tables 5.4.1, from 0.065 €/kWh to 0.049 €/kWh.

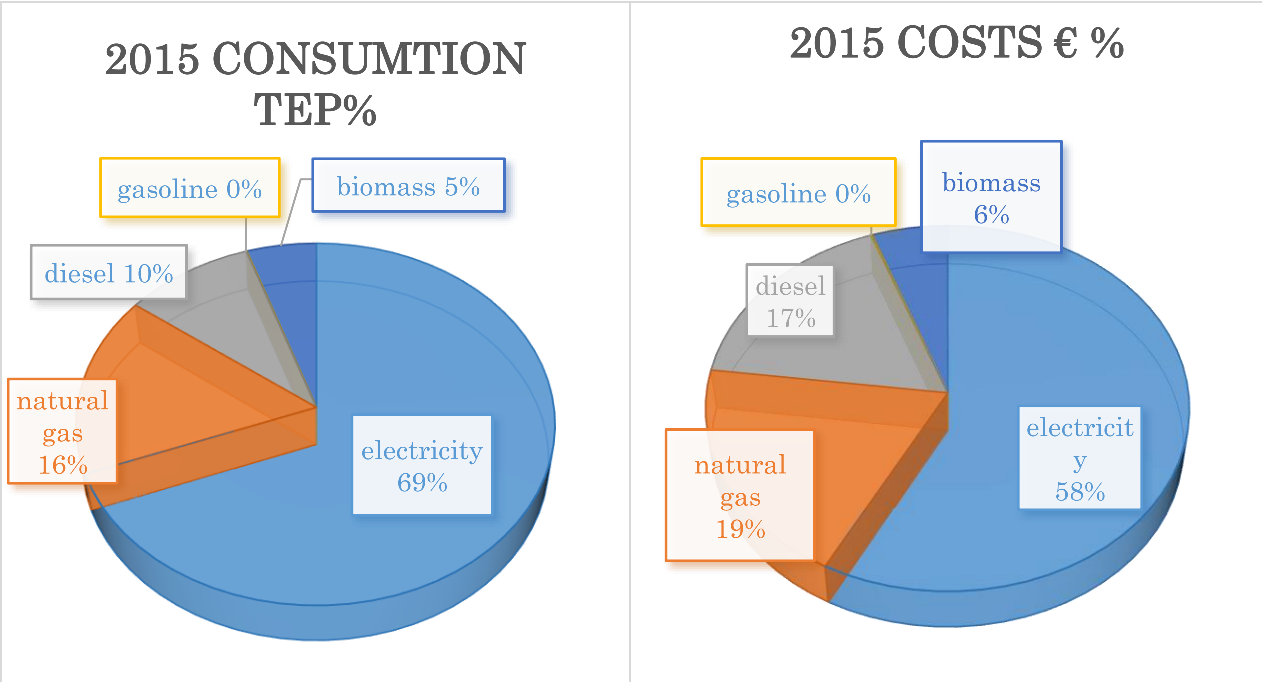


Figure 5.7.2 - Consumption and costs percentages in 2015

Keeping in mind the 2015 pie charts 5.7.2 where you can see the percentages of energy consumption used by the company at energy and cost levels, it is noted that:

- The largest consumption (in toe and €) is electricity, so there will be scope to improvements in electrical users.
- Natural gas is the second cause of consumption with 15% but in the cost chapter it increases his weight to 19%, it means that this kind of energy has a considerable specific cost. Conversely, for biomass, even if it is 10% in toe consumption, it reduces its weight to 6% on costs, which means it is economical. From these considerations one can develop an integration between the two gas and biomass boilers.
- The comparison of the same data is similar for 2016 so the considerations are only made for the reference year ie 2015.

Usually, we try to express data on energy transfers (but also materials or costs in a process) in the form of a flow diagram, called Sankey's diagram, in which the amplitude of the branches is proportional to the amount of the energy flow.
The purpose is to visually accentuate the larger flows transfers within a system, making the Sankey diagram useful to locate dominant energy flows in the total.

The proposed diagram shows the energy consumptions and uses of energy in the current case for 2015. Consumption subdivisions were made by installed meters

and extrapolated to actualized consumption to 2015, keeping the total of consumed energy.
In this case, losses in individual uses of energy are not evaluated, but only the total amount related to each of them.

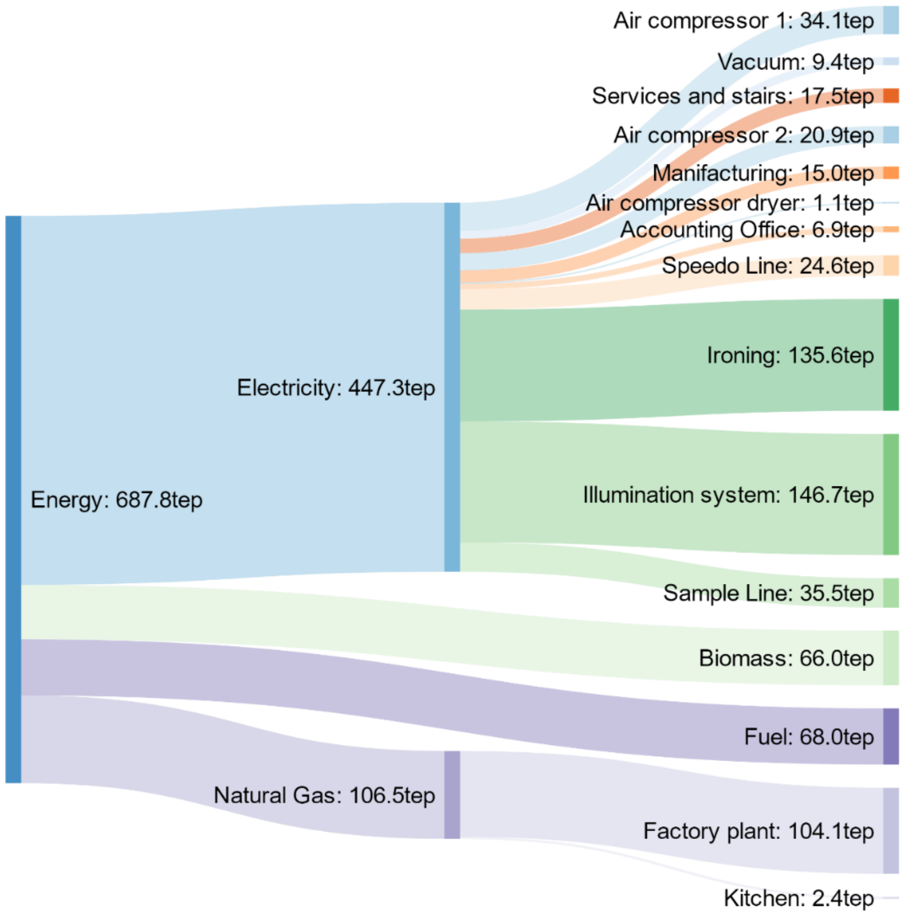


Figure 5.7.3 – Sankey's diagram

It is also interesting to compare the most important energy indicators already introduced in the checklist:

Production
m² Processed material
502588,0

Index	EI Energy Intensity [kgep/€]	33.6
	CI Carbon index [tCO2eq/toe]	2.34
	CEE Specific consumption [tep/unit]	1.33

It is to be considered that IE is calculated as the ratio between total energy consumption and VAB (gross income), therefore the improvements can apparently work in two directions: maintain the same energy consumption and increasing the VAB or maintaining the VAB constant and decreasing the energy needed to produce that value. Both ways actually include and imply improving energy efficiency in production.

5.8 Reference Year's Emissions

Energy consumption of different types has been reported to the equivalent units, specifically in toe, as described above.
We report and add monthly fuel consumption per month, getting the total energy consumption of the company.

It is a very compact and aggregated expression to quantify consumption, but is also significant, as the Portuguese energy authority distinguishes large and medium-sized consumer companies from a 500toe/year threshold.

In the case study, 2015 consumption was 613.3toe plus the contribution of the biomass of 66.48toe, that should be halved, for a total of 646.6toe, that increase for 2016 in 640 toe plus almost the same amount of biomass they reach a consumption around 673toe, which means that the company, for the Portuguese and European law is a big energy consumer because needs more than 500toe/year (and less than 1000toe).

In turn, the equivalents TOEs are converted into tons of equivalent CO_2 depending on the pollution source, ie it tries to quantify pollutant emissions in terms of impact on the equivalent greenhouse effect as shown in 5.8.2.

It comes at a total emission value that can / must be eliminated or better re-absorbed by natural processes of chlorophyllin photosynthesis or trees, a reason why the emissions from combustion of biomass are not counted.

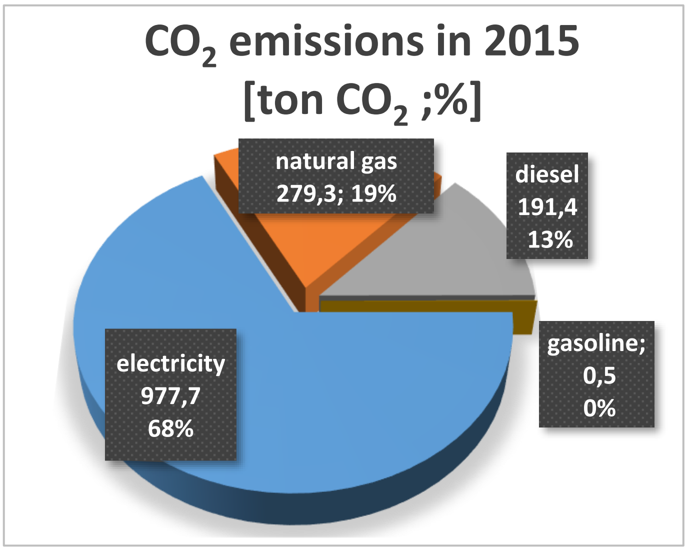


Figure 5.8.1 – Percentage of CO_2 emissions

Assuming to consider a plant that lives in a temperate climate, located in the city and hence an environment of higher environmental stress than a natural environment, we can think that the tree itself can absorb between 10 and 20 $kgCO_2$ / year, A growth cycle that, on average, reaches its maximum in a time range of 20 to 40 years.

	Consumos de Energia em tep						
	Meses	**Eletricidade**	**Gás Natural**	**Gasóleo**	**Gasolina Super**	**Total tep**	**Total CO2**
2015	jan	29,3	7,0	2,4	0,0	38,7	90,3
	fev	41,6	7,1	5,4	0,1	54,2	126,9
	mar	34,6	6,9	5,3	0,1	46,9	110,6
	abr	30,8	7,0	5,4	0,0	43,3	102,9
	mai	35,1	8,3	5,6	0,0	49,0	116,3
	jun	38,9	8,1	5,8	0,0	52,8	124,7
	jul	39,3	9,0	6,6	0,0	54,9	130,4
	ago	22,4	5,6	5,6	0,0	33,6	81,4
	set	36,3	8,6	3,0	0,0	48,0	111,9
	out	40,7	13,5	5,5	0,0	59,7	142,3
	nov	51,9	12,2	5,9	0,0	70,0	164,6
	dez	46,5	10,7	5,1	0,0	62,3	146,2
	Total Anual	447,3	104,1	61,8	0,2	613,3	1.448,4

	Consumos de Energia em tep						
	Meses	**Eletricidade**	**Gás Natural**	**Gasóleo**	**Gasolina Super**	**Total tep**	**Total CO2**
2016	jan	39,2	10,8	3,2	0,0	53,2	124,5
	fev	48,1	10,4	5,8	0,0	64,2	150,9
	mar	39,7	11,1	5,8	0,0	56,6	134,7
	abr	40,3	9,0	5,6	0,0	54,9	129,6
	mai	41,0	8,7	5,2	0,3	55,3	129,2
	jun	37,5	8,7	5,4	0,2	51,9	122,2
	jul	49,6	9,9	5,1	0,1	64,7	150,9
	ago	32,5	4,3	5,1	0,3	42,2	98,5
	set	18,4	6,8	2,6	0,3	28,0	66,4
	out	41,0	7,6	2,9	0,2	51,7	119,0
	nov	44,9	10,3	5,4	0,3	60,9	142,6
	dez	43,0	13,6	0,0	0,0	56,6	130,5
	Total Anual	475,0	111,5	52,1	1,7	640,3	1.499,0

Figure 5.8.2 – Toe and equivalent CO_2

It is possible to think about converting the weight of a biomass of a plant to the weight of carbon dioxide that it absorbed during its life. In fact, the weight of the carbon content is generally about 45-50% of the total of the dry biomass and then:

$$1\ g\ dry\ matter\ =\ 0{,}5\ g\ C\ =\ 1{,}83\ g\ CO_2$$

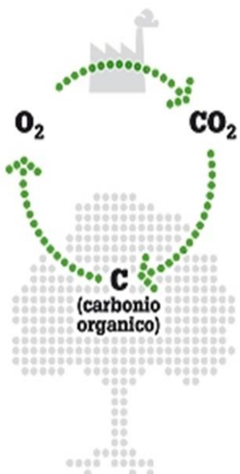


Figure 5.8.1 – Carbon and oxygen cycle

It should also be considered that the growth of biomass is not constant throughout a plant's life, but mainly depends on age. The relationship between biomass and age is very simplified as follows:

$$B\ =\ B_\infty\ \cdot\ (1\ -e^{-\alpha t}\ )$$

Where B is the plant biomass at time t, B_∞ and α are parameters that depend on the species, the climatic conditions and the fertility characteristics of the soil. In mathematical terms, B_∞ indicates the horizontal asymptote of the curve, that is, the maximum cumulable biomass, and α its slope in the origin.

It was estimated that in the reference year to re-absorb the 1448.4 tCO_2 emitted would serve 72420 trees that "work" for a year, considering what was said earlier and estimating that the "average" tree that was taken into account absorbs an amount of 0.02 tCO_2 / (tree * year).

Alternatively, another calculation for the number of trees needed to absorb all of the CO_2 can be made, and it is based on a sample-tree planted in wet tropics that absorbs an average of about 22 kg of carbon dioxide every 40 years and each tree absorbs 1 ton of CO_2 during his life.

It is also to be considered that as trees grow, they compete for resources and some may die or be destroyed and therefore not all will reach their full potential for carbon sequestration. The proposed calculation assumes that 5 trees are planted to ensure that at least one lives up to 40 years or that their combined seizure is equal to 1 ton. So you will need 7242 trees, an order of magnitude less compared to the previously found value, but with a much longer absorption time interval.

These calculations are only indicative as too many approximations have been made. For this kind of calculation, it makes more sense to think about the amount of CO_2 absorbed during the average life of a plant, which, of course, implies that to re-absorb the CO_2 emitted in a year from a factory you should wait many years to re-absorb it, ie those corresponding to the average life of plant.

Also in this case, it is an arbitrary and only theoretical parameter but it could give an idea of the surface that one should think covering of trees for the CO_2 capture due to any production or human activity.

5.9 VAB

As already explained, here is the VAB calculation for Petratex:

	VAB		
		€	+/-
2015	71	68.914.138,96	+
	72	1.644.572,40	+
	781	661.044,50	+
	74	0,00	+
	61	28.346.188,67	-
	62	22.994.725,57	-
	688	98.290,93	-
	Total VAB	**19.780.550,69**	

5.10 ISP, an instant economic savings

It has already been mentioned in the analysis of utilities as there is a voice in both gas and electricity invoices called ISP, acronym for Imposto Sobre Produtos Petrolíferos (tax on petroleum products). The ISP is the tax on energy and petroleum products and applies to all gas and diesel, as well as propane and butane gas, oil and LPG, which are for sale or for consumption.

In accordance with the Código dos Impostos Especiais de Consumo, ISP is applied on all petroleum and energy products, such as hydrocarbons, if consumed or sold to use as fuel and the idea for its introduction is inspired by the fact that the use of such energy sources will entail some environmental costs which that tax is purposed to face.

In Portugal, this excise tax has been introduced and, after careful energy auditing and certification with the relevant improvement solutions, is eliminated as a kind of incentive for the various parties to draw up measures for energy efficiency.

However, the law provides for situations where petroleum and energy products are exempt from ISPs. For example, no such petroleum tax is imposed on petroleum products consumed in the structures that produce them. Article 89 of the Código dos Impostos Especiais de Consumo also exempts ISP from the products used in the following situations:

- For different purposes than fuel or heating fuel;
- Aircraft use (except for private aviation recreation);
- Inland and coastal waterway transport (including fisheries and aquaculture);
- Use by the same entities for the production of electricity, heat or electricity and city gas;
- Products used in public transport and the transport of passengers and goods by rail.
- "Economically vulnerable" people and those who are benefiting from the social tariff.

You may also have the following incentives:

- Part of the sum for carrying out energy audits (up to 750 € for installation with a lower consumption of 1000TOE) by the existing energy efficiency fund.

- Economic aid for the purchase of equipment and monitoring systems through the existing energy efficiency fund for this purpose

- Exemption from the ISP tariffs for electricity and natural gas provided by DGAIEC

- Special consumption taxes authorized by the General Directorate of Customs.

In Petratex's case, the amount of ISP is made up from electricity's bills for € **2.138,20** and € **2.632,80** for Natural Gas for 2015, which become respectively € **2.300** and € **3.202** in 2016.

The total is € **4.771** in 2015 and € **5.502** in 2016, which, thanks to the energy audit carried out, will be spared since submission of the document to the authority, with the possibility of investing such resources in plant efficiency or improvements or simply considering spending avoided and therefore gains.

	ISP		
	Electricity [€]	**Natural gas [€]**	**Total [€]**
2015	2138,20	2632,80	**4771,00**
2016	2300,00	3202,00	**5502,00**

6. POSSIBLE SOLUTIONS

From utility bills and production process analysis, it appears that Petratex uses a lot of energy. It could be interesting to understand general aspects that come from dates observation.

Consumption is above all electrical and is an important part of the cost, but in terms of energy in kWh, gas consumption is also worthy of attention: respectively **2.080.293 kWh$_{el}$** versus **1.239.879kWh$_{gas}$** for a 241.066 € and 80.292 €.

The possible solutions proposed were made taking into account that:

- Electricity consumption of lighting devices is a slice corresponding to approximately ⅙ of energy requirements and only a small part is LED and therefore total consumption could be significantly improved by intervening on these devices.

- The electrical consumption of the part of the presses that always need a certain temperature and which are heated and maintained by electrical resistances. These consumptions are very large and if on the one hand, it is true that the use of electrical resistances it is possible to control the temperature instantaneously and heat up the press in a short time, on the other hand it is to be considered that, Joule effect to heat is a big waste in exergetic terms.

- For ventilation air heating, it is possible to think of air heat exchangers that don't reach very high temperatures, certainly comparable to the DHW temperatures. In these assumptions, an implementation involving the use of solar panels could be interesting especially in the months between the end of February and April and between September and early November, considering the temperatures at these latitudes and the frequency of days with large irradiation in such periods.

- A possible solution for steam production could be use a medium temperature evacuated tube solar collectors to reach higher temperatures without excessive penalties from the point of view of re-irradiation and convection losses. This solution is to be considered in the months between April and September in which gas consumption appears to be a "base" for the consumption profile and hence it would be possible to consider it as a reference value for the sizing of the plant and collectors' surface. At least, it could be interesting try to pre-heat the water with a solar collectors system.

- Solar heating systems for water, work with your current water heater or boiler to preheat water for any application that requires hot water. Hot water from solar heating systems for water can also be used to heat up and cool down offices and many other rooms. Active solar heating systems collect and absorb solar energy and use electric fans or pumps to transfer and distribute heat to all served rooms. This can dramatically reduce costs. Solar absorption cooling uses solar-heated water to drive an air conditioner. Solar desiccant cooling removes moisture from the air to decrease the relative humidity and helps to decrease temperature[18].

- Installations aimed to eliminate the use of boilers to become free from natural gas consumption are merely theoretical in this case. Usually long-term vision it is preferable but it has to be considered that the steam generator boiler has to be cushioned as cost and that to have complete self-sufficiency from the thermal energy point of view, it would be necessary to install many collectors. The over-installation, on the one hand, guarantees sufficient thermal input during the winter, but in the summer, there would be excessive heat production, a situation which shows the most weaknesses, first of all the return times of the invested capital and the fact that the required thermal energy in summer is less than in winter and in fact will not be exploited, also note the trend of consumption that fall in August. You might think to pair a solar thermal cooling absorbing machine during the summer.

6.1 Solar radiation

The basis of all the considerations in 6th chapter is a careful analysis of the solar irradiation available in the area considered.
To understand how any surface works with radiant energy it is good to define some geometric parameters and relative position between Sun and collector

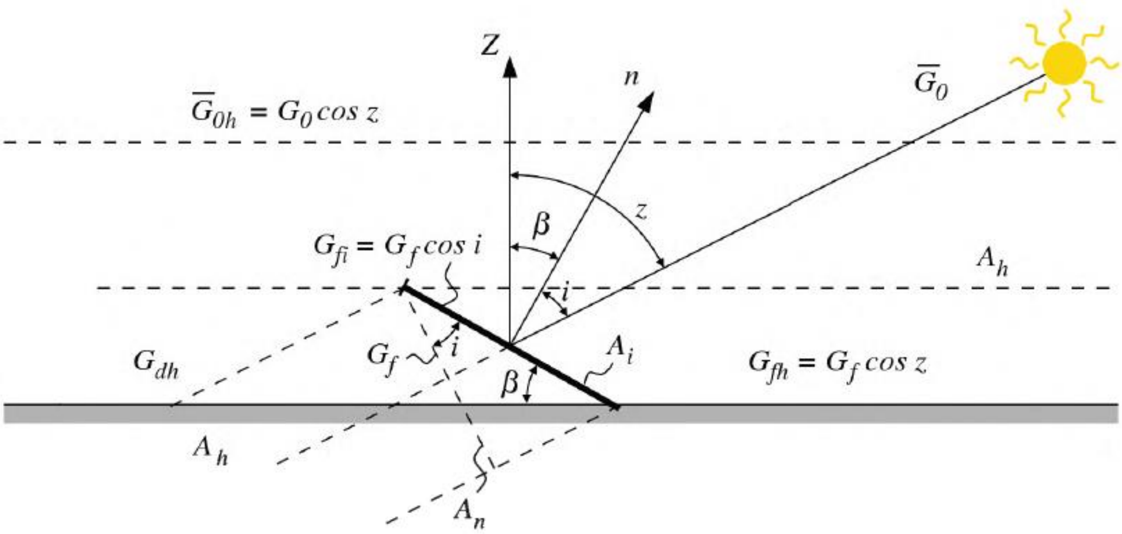


Figure 6.1.1 - Global Irradiance [W / m2] to the incident surfaces and on the soil facing the Sun or South

The capture surface is inclined with a β angle, oriented towards the south and with area A_i and n is the perpendicular to this surface. The angle that forms the perpendicular to the surface (n) with the perpendicular to the ground, assumed horizontal, called z, will be the inclination angle of the collector, for geometric construction. Figure 6.1.1 shows how the angle of incidence of solar rays on the surface, summed up at the inclination angle β, gives the z angle, called Azimuth.

Think of solar radiation as a beam of parallel rays with incidence angle i on the surface Ai, they will be the same that would affect the surface A perpendicular to the rays, constructed as the projection of the Ai surface in the direction of incidence of radiation. Then:
$A_n = A_i * \cos i$

In the same way, if I consider the same beam of rays, with the same angle of inclination as compared to the Ai surface, they will be equivalent to the incident radiation to a horizontal surface, constructed as the surface Ai projection to the ground. Then:
$A_i = A_h * \cos \beta$

The solar irradiance, defined as power on surface units G_0 [W / m2] coming from the Sun on the capturing area A_i, it will depend on the angle of incidence with which it reaches this surface and so, from the surface inclination angle and from the time of day considered. Virtually, starting from the irradiance G_0 to reach the irradiance of the inclined surface and what comes to its A_n and A_h projections above, with the similar meaning of the subscripts, it will be that:

$G_{0i} * A_i = G_0 * A_n = G_{0h} * A_h$
$G_{0i} = G_0 * \cos i$
$G_{0h} = G_0 * \cos z$

The global incident irradiance on a generic inclined surface Ai, is the function of the angle of incidence of the sun's rays, and will be a very important parameter in choosing the positioning of solar collectors to maximize the captured energy.
Greater inclination than 10° compared to latitude favors winter performance without penalizing too much on summer's performances while, on the other hand,

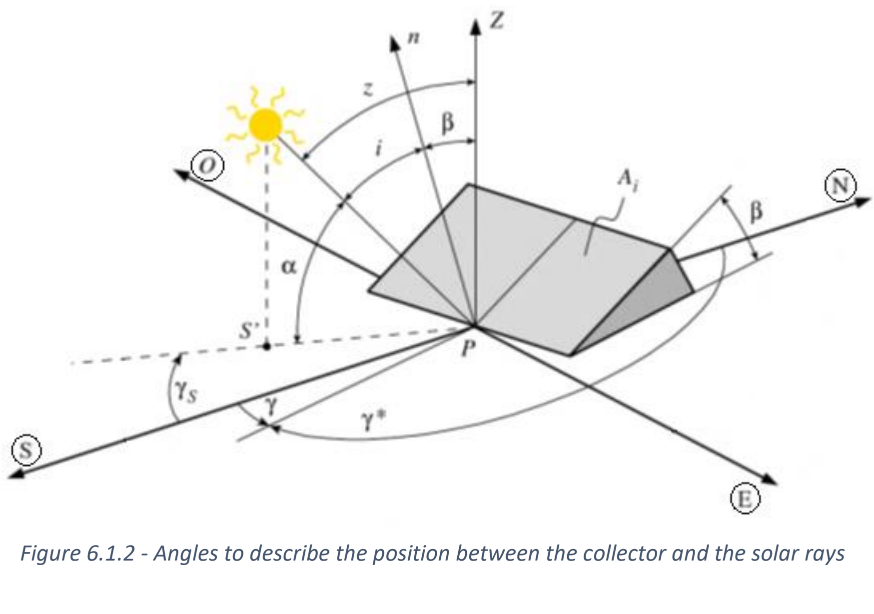


Figure 6.1.2 - Angles to describe the position between the collector and the solar rays

a lower inclination than 10° compare to latitude will favors summer performance without penalizing too much the winter's one.
Horizontal surfaces have a good summer performance but not that much on winter, at the other end, vertical walls have discrete winter performance but quite bad on summer.

From yearly and seasonal radiation energy analyzes, the annual radius curve is relatively flat and, consequently, the small angular displacements from the maximum (which by ratio of the direct irradiance components is for $\beta = \varphi = 40°$) do not overly penalize the annual energy yield.
All inclinations below latitude improve summer energy yield, while only higher inclinations in latitude (no more than 35 degrees) improve winter performance.

It should be remembered that these considerations concern only the direct components of the irradiation while the flat, thermal and photovoltaic solar panels are capable of absorbing much of the diffuse radiation that is detected in fact, the covering glass is transparent to the radiation arriving on the surface Incidence angle below the reflection limit, typically between 70° and 80°.

For a fixed surface with a latitude-like inclination ($\beta = \varphi = 40°$), the influence of azimuth variations on the optimal value ($\gamma = 0$) is illustrated in the following figures [9]:

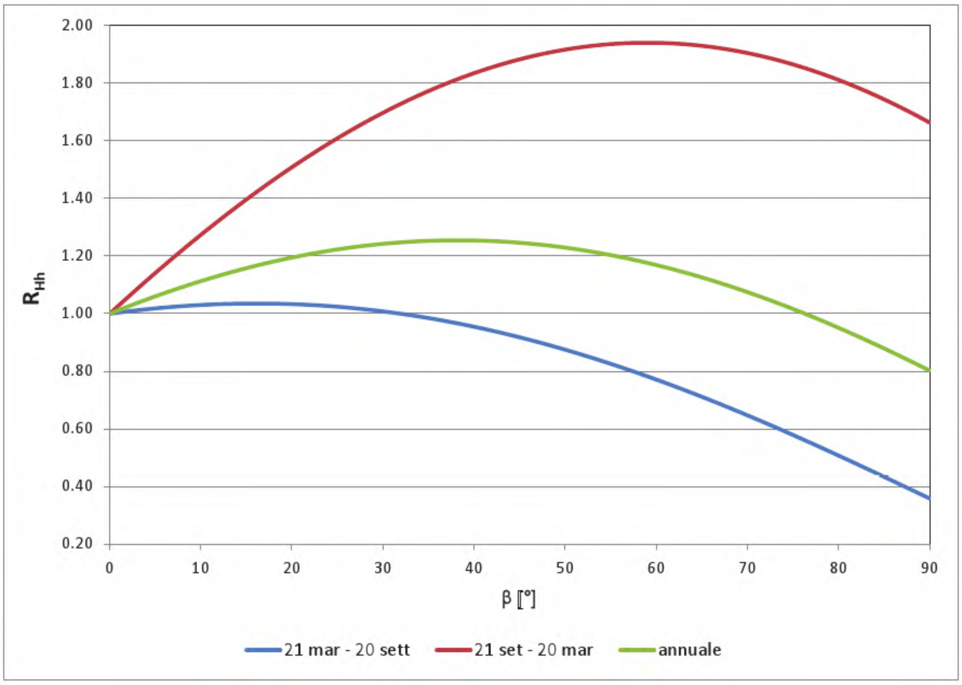


Figure 6.1.3 - Influence of inclination variation on a seasonal and annual basis for a south oriented fixed collector $\gamma = 0$ at the latitude of $\varphi = 40$ °

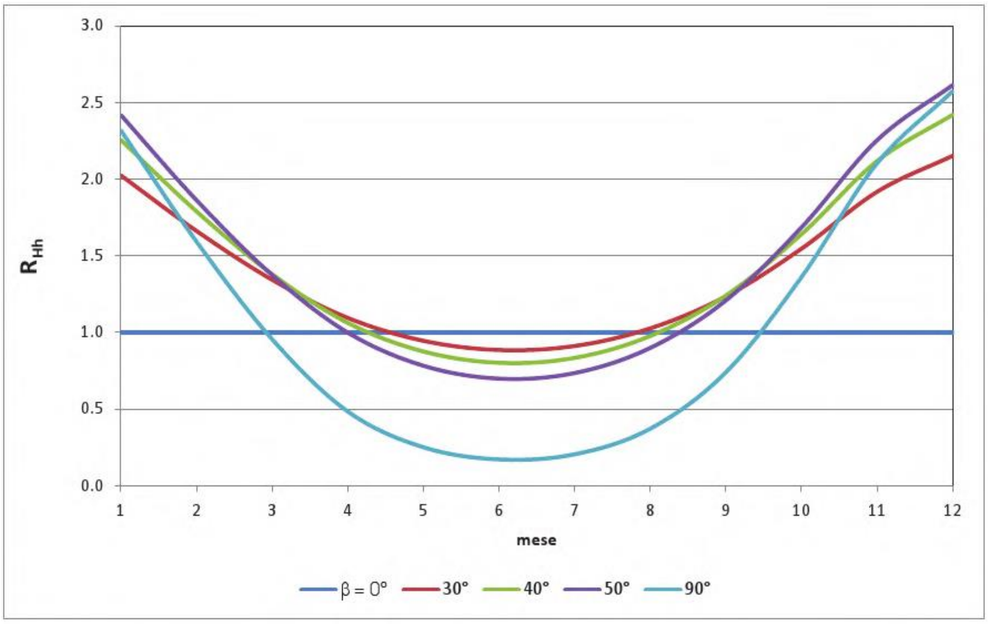


Figure 6.1.4 - Influence of the inclination variation on a monthly basis for a fixed orientation collector south γ = 0 at the latitude of φ = 40 °

Azimuth variations contained within the 15th of module will penalize energy yield to a very limited extent. While, it increases considerably if you move to the south-east and south-west orientations (azimuth of module 45°) and accentuates further, especially in the winter, if you move to east or west orientation (azimuth module 90°).

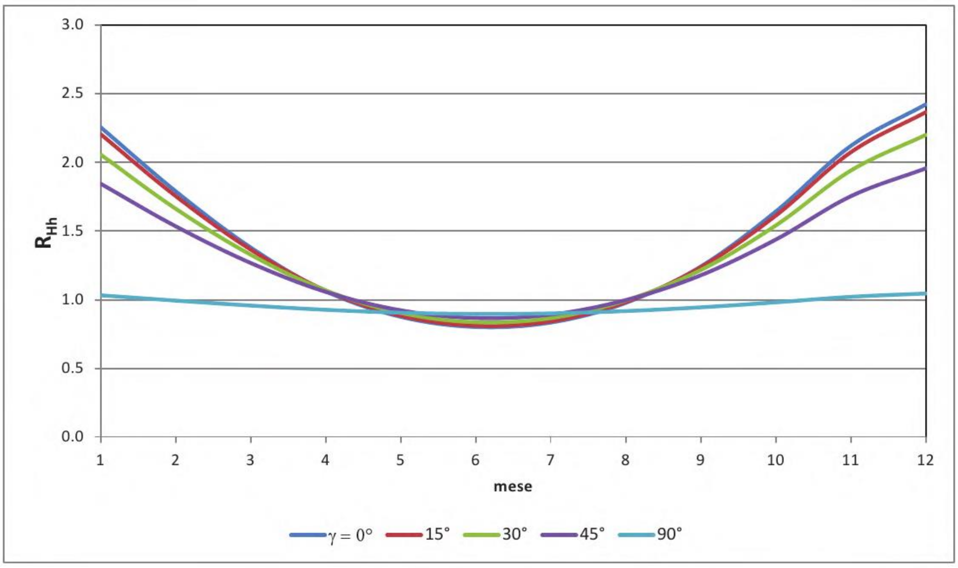


Figure 6.1.5 - Influence of azimut variation on southern orientation (γ = 0 °) on the irradiation of an fixed 40 °inclined surface

6.1.1 Solar irradiance available

This is done with the help of GIS data provided by the online PVGIS software, which allows to synthesize all the concepts just exposed and provides measured data exactly to the desired coordinates.
The data to be used in inputs concerning Petratex are:

- Position:
  - $41° \, 18'17'' \, Nord$
  - $8° \, 21'49'' \, Ovest$
  - $323 \, m \, o.s.l.$
- Optimum tilt angle (β_{opt}) given form software **I_{opt}=35°**

Mese	H_h	H_{opt}	DNI	I_{opt}	D/G	T_D	T_{24h}	N_{DD}
Gen	1840	3130	2800	64	0.47	9.1	7.1	254
Feb	2900	4420	4040	57	0.40	9.2	7.1	213
Mar	4300	5440	4650	44	0.43	12.5	10.2	130
Apr	5130	5560	5070	27	0.40	15.0	12.9	131
Mag	6250	6070	6010	16	0.36	17.5	15.4	41
Giu	7080	6500	7260	6	0.31	20.2	18.3	4
Lug	7280	6880	7970	11	0.26	23.2	21.0	0
Ago	6580	6900	7680	23	0.26	23.3	20.8	2
Set	5120	6300	6490	39	0.28	21.8	19.2	29
Ott	3360	4740	4180	52	0.41	17.8	15.4	97
Nov	2130	3510	3150	62	0.44	12.4	10.2	230
Dic	1640	2940	2680	66	0.47	10.0	7.6	258
Anno	4480	5200	5170	35	0.34	16.0	13.8	1389

Figure 6.1.1.1 – Petratex's irradiation data

With:

- **H_h** irradiation on horizontal surface [Wh/(m^2 * day)]
- **H_{opt}** irradiation on the surface with optimal tilt inclination [Wh/(m^2 * day)]
- **DNI** perpendicular direct irradiation [Wh/(m^2 * day)]
- **I_{opt}** optimum tilt angle [°]
- **D/G** diffuse and global irradiation ratio [-]
- **T_D** average temperature during daylight[°C]
- **T_{24h}** average temperature during the whole day (24h) [°C]
- **N_{DD}** number of degree days (-)

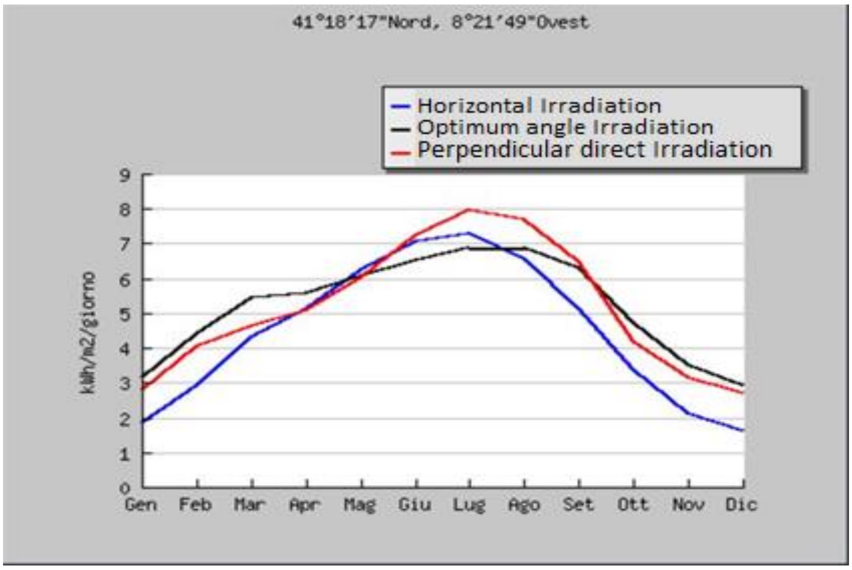


Figura 6.1.1.2 - Available irradiation comparison

Figure 6.1.1.2 suggests a comparison of the irradiation available on the site where Petratex is located. It is noted that the optimum inclination that maximizes the energy coming through the radiation is 35 °, ie about 6 ° less than the latitude to which the collector is located. This inclination allows you to capture more energy during the winter without faring too much on summer behavior, as already mentioned.

In order to make a comparison and realize the good potential for solar available irradiation in Portugal, there is a comparison with a color map with Italy.

Average daily temperatures are also a key point in energy analysis and the figure below shows that Portugal has more uniform and higher temperature than Italy, mainly due to its location close to the Ocean and geomorphological conformation.

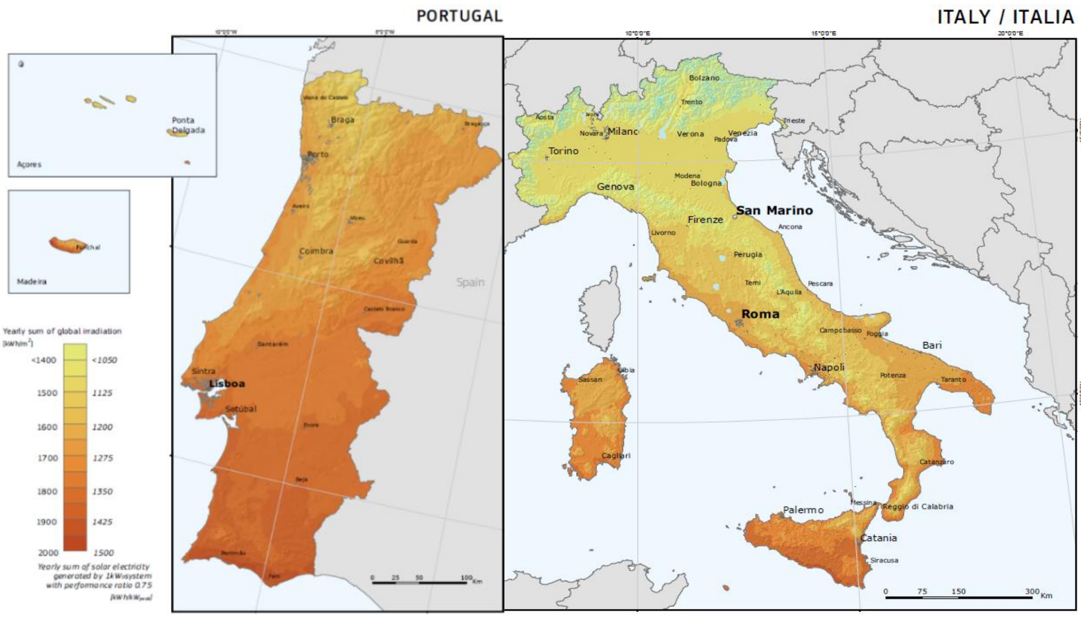


Figure 6.1.1.3 – Solar irradiance available in Portugal and in Italy

A calculation is proposed to find out if solar technology can be interesting or not. First of all, you do not want to distort the system in its operation, we want to preheat the water that is going to the boiler up to the maximum temperature that the solar panel allows to obtain, and then continue the process in the steam generator.

From the available literature, it has been found that the annual specific producibility for a solar thermal collector in the district of Porto is about 2000kWh / year. Consider the already proposed consumption tables, such as the price per kWh supplied with natural gas for 2016 of 0.05 € / kWh, and that the steam generator works with 75% efficiency. This means that:

$$Savings\left[\frac{€}{year * collector}\right] = \frac{2000\left[\frac{kWh}{year * collector}\right] * 0.05\left[\frac{€}{kWh_{natural\ gas}}\right]}{0.75\ [efficiency]} = 133\left[\frac{€}{year * collector}\right]$$

Assuming to install the plant at a total cost including collector, installation and various service organs such as expansion vessel, valves and controls for a specific amount of 1100 € / collector, the simple payback time is around 8 years and a half.

$$Payback\ time = \frac{1100\left[\frac{€}{collector}\right]}{133\left[\frac{€_{saving}}{year * collector}\right]} = 8.5\ [years]$$

The proposed values for productivity are, however, optimistic, and in any case the return time is long enough for everything, if everything always works with good reliability. In addition, the steam boiler use profile begins around 7 am, a time when it is difficult to produce enough hot water even with well-designed flat glass collectors.

6.2 Photovoltaic existing plants

The photovoltaic system that is seen above the building produces electricity that is completely sold to the grid. The plant has an installed power of 250 kWp but does not count in the audit because the energy is not consumed but entirely sold.

To understand the sense to installing such a plant without consuming, only selling to the grid, you should considering when this installation took place, ie when there was a chance to benefit from state and European incentives for photovoltaic production. The choice was for polycrystalline silicon panel technology, not the best for efficiency, but this solution would have made it easier to return in investment costs.

- PVGIS estimates of solar electricity generation
- Location: 41°18'17" North, 8°21'49" West, Elevation: 323 m a.s.l.,
- Solar radiation database used: PVGIS-classic
- Nominal power of the PV system: 250.0 kW (crystalline silicon)

- Estimated losses due to temperature and low irradiance: 10.6% (using local ambient temperature)
- Estimated loss due to angular reflectance effects: 2.9%
- Other losses (cables, inverter etc.): 14.0%
- Combined PV system losses: 25.3%

	Fixed system: inclination=34 deg., orientation=0 deg.			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	655.00	20300	3.31	103
Feb	724.00	20300	3.70	103
Mar	1000.00	31100	5.27	163
Apr	986.00	29600	5.31	159
May	1090.00	33800	5.94	184
Jun	1170.00	35200	6.47	194
Jul	1160.00	36000	6.47	201
Aug	1200.00	37200	6.69	207
Sep	1060.00	31800	5.82	175
Oct	855.00	26500	4.55	141
Nov	626.00	18800	3.22	96.6
Dec	505.00	15700	2.56	79.4
Year	921.00	28000	4.95	151
Total for year		336000		1810

- **E_d**: Average daily electricity production from the given system (kWh)
- **E_m**: Average monthly electricity production from the given system (kWh)
- **H_d**: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
- **H_m**: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Petratex then participates in the production of energy from renewable sources through PV for 346MWh / year of average equivalent to about 68toe / year, considering the prospectus given by Adene with conversion unit 0.000215toe / kWh_{el}.
The potential for installing a solar system, as well as being interesting from the point of view of boiling water boiler for steam production, is interesting for its productivity thanks to the irradiation that exists in that area as already shown.

Figure 6.2.1 – Petratex

6.3 Replacement lighting system

Below there are the current consumption and prospect with the new lighting system to compare total consumption and calculate a simple payback time considering an electricity cost of 0.12 €/kWh which is in line with the average price during 2016.

EXISTING:

Place	Lamps' model	N° lamps	Unit Consumption [W]	Working hours	Electric consumption [kWh/year]	Annual electric costs [€]
Ironing	cor 84	300	50	8h-18h	37500	4500
New household	cor 84	120	60	8h-18h	18000	2160
Manifacturing	cor 84	140	100	8h-18h	35000	4200
Household	cor 84	210	60	8h-22h	44100	5292
Garage / technical zones	cor 84	100	80	8h-18h	20000	2400
Offices	cor 84	84	80	8h-20h	20160	2419,2
1floor offices / Labs	cor 84	280	80	8h-20h	67200	8064
Courtyard	cor 84	180	100	From Sat to Mon	44928	5391,36
Outdoor	150 W	14	150	Only night time	7665	919,8
TOTAL					**294553**	**35346,4**

REPLACEMENT [17],[20]:

Place	Lamps' model	N° lamps	Unit Consumption [W]	Unit's cost [€]	Electric consumption [kWh/year]	Annual electric costs [€/year]	Annual energy savings [kWh/year]
Ironing	LED	300	20	10	15000	30000	3600
New household	LED	120	20	12	6000	16500	1980
Manifacturing	LED	140	20	20	7000	28000	3360
Household	LED	210	25	12	18375	36750	4410
Garage / technical zones	LED	100	20	16	5000	20000	2400
Offices	LED	84	30	16	7560	11340	1360,8
1floor offices / Labs	LED	280	30	16	25200	46200	5544
Courtyard	LED	180	20	20	8985,6	29203,2	3504,38
Outdoor	LED	14	60	30	3066	2520	302,4
TOTAL					**96186,6**	**220.513**	**26.462**

It's clear how savings are really interesting and with a simple payback time calculation it will take less than a year to recover the investment of € 24.000:

$$Payback\ time[years] = \frac{investment\ [€]}{annual\ saving\ \left[\frac{€}{year}\right]}$$

$$= \frac{\sum(units_{replaced} * cost_{unit}[€])}{annual\ energy\ saving\ \left[\frac{kWh}{anno}\right] * energy\ cost\ [€]}$$

$$= \frac{\sum(units_{replaced} * cost_{unit}[€])}{(unit\ cons._{ANTE}\ [kW] - unit\ cons._{POST}\ [kW]) * working\ hours\ \left[\frac{h}{year}\right] * energy\ cost\ [€]}$$

$$= \frac{24000[€]}{26462\left[\frac{€}{year}\right]} \cong 1\ year$$

For the conversion of energy savings, you can save more than 45 toe/year, ie 6.7% of total toe consumption, falling within the normative target of a performance improvement of at least 4% in eight years, for this type of a company with an annual consumption of more than 500 toe.

Figure 6.3.1 - Existing lighting system

6.4 Biomass and natural gas boiler integration

Once you understand the system and operating logic, and you check the power consumption and performance, you wonder how to use all the systems already here in the best way.

In particular, they have a biomass boiler working with an efficiency more than 90% used only to heat water for sanitary and low temperature heating purposes for aerothermal heaters when it could be integrated with the steam generator, composing together as a single integrated heating system.

The current situation is shown schematic 6.4.1 and the one proposed for the integration of the two systems 6.4.2.

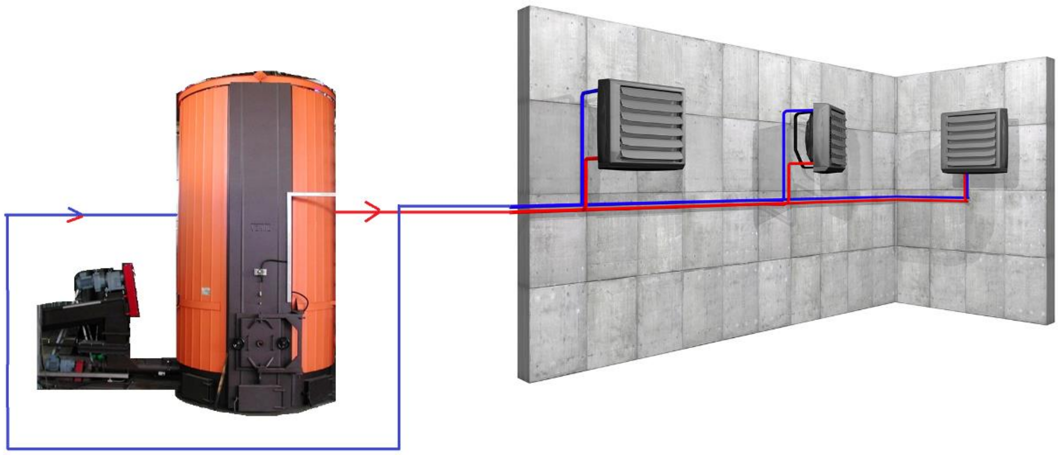


Figure 6.4.1 - Current situation. Biomass boiler works only for heaters

A mathematical model in EES has thus developed, which allows to simulate the functioning of the system in the new configuration, ie by making the biomass boiler system works as a preheater for the steam generator. This solution is energy-efficient since the biomass boiler works with higher efficiency, but also because the fuel is less valuable and less expensive than natural gas, thus increasing the possible final saving, that's the most interesting parameter for a company.

In addition, there is a small difference in the energy required by the pump due to the thermal expansion of the water entering a higher temperature (preheated).
The data used in the model are those obtained so far by calculation and measurements over a one-year time span:

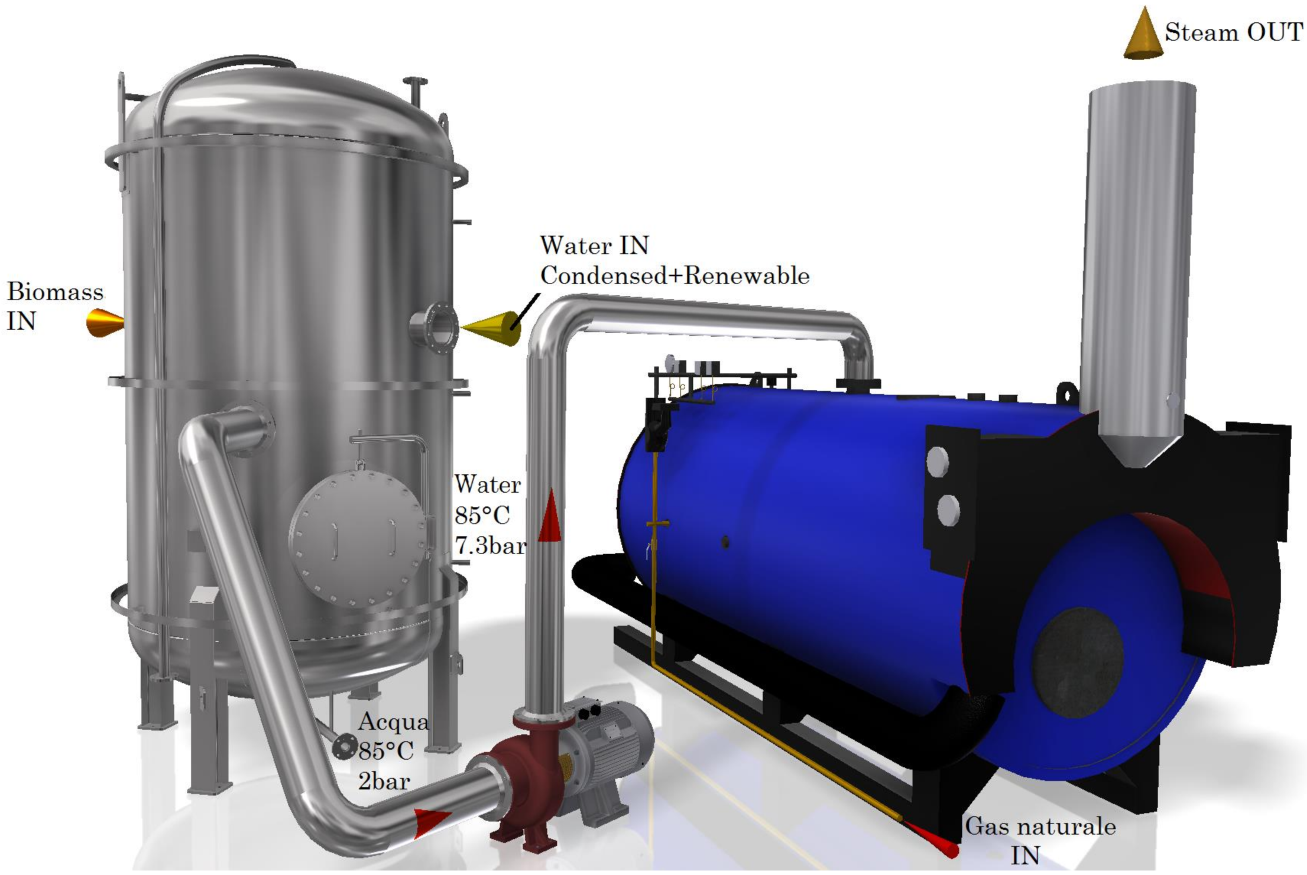


Figure 6.4.2 - Proposed solution with integrated system with biomass boiler and steam generator

"Bilanci di massa"
m_rinn=450000 [kg]
m_cond=600000 [kg]

"Temperature"
T_in_water_cond=35 [°C]
T_in_water_rinn=15 [°C]
T_out_bio=85[°C]

"Pressione"
p_low=2 [bar]
p_high=7,3 [bar]

"Rendimenti"
eta_comb_BIO=0,90
eta_comb_GV=0,72
prezzo_el=0,12 [€/kWh]
prezzo_gas=830,73 [€/ton]
prezzo_bio=139,06 [€/ton]

The results of the simulation are positive and there is a 7,737 tons of gas savings versus 17,332 tons of additional biomass.

But as the biomass price of 139 € / ton versus 830 € / ton of natural gas, the preheating system could allow the company to save more than 4000 € / year and would therefore make this solution convenient and relatively simple to build.

Furthermore another parameter has to be checked : if the preheating capacity of the boiler is compatible with the new mass flow needed for the steam generation.

Unit Settings: SI C bar kJ mass deg

$\delta_{h,pompa1}$ = 0,4882 [kJ/kg]	$\delta_{h,pompa2}$ = 0,4162 [kJ/kg]	$\eta_{comb,BIO}$ = 0,9 [-]
$\eta_{comb,GV}$ = 0,72 [-]	$H_{comb,bio}$ = 2,574E+08 [kJ]	$H_{comb,gas1}$ = 2,868E+09 [kJ]
$H_{comb,gas2}$ = 2,611E+09 [kJ]	$h_{in,bio}$ = 110,9 [kJ/kg]	$h_{in,gv1}$ = 111,4 [kJ/kg]
$h_{in,gv2}$ = 356,4 [kJ/kg]	$h_{out,bio}$ = 356 [kJ/kg]	$h_{out,gv}$ = 2843 [kJ/kg]
$LHV_{biomass}$ = 16500 [kJ/kg]	LHV_{gas} = 46187 [kJ/kg]	m_{bio} = 17332 [$kg_{biomass}$]
m_{cond} = 600000,00 [kg]	m_{gas1} = 86238 [kg]	m_{gas2} = 78501 [kg]
m_{rinn} = 450000 [kg]	m_{water} = 1,050E+06 [kg]	$prezzo_{bio}$ = 139,1 [€/ton]
$prezzo_{el}$ = 0,12 [€/kWh]	$prezzo_{gas}$ = 830,7 [€/ton]	p_{high} = 7,3 [bar]
p_{low} = 2 [bar]	$RISPARMIO_{kg,gas}$ = 7737 [kg_{gas}]	$RISPARMIO_{POMPA}$ = 2,517 [€]
$risparmio_{spec,pompa}$ = 0,07192 [kJ/kg]	$RISPARMIO_{€}$ = 4017 [€]	$T_{in,water,cond}$ = 35 [°C]
$T_{in,water,rinn}$ = 15 [°C]	t_{mix} = 26,43 [°C]	$t_{out,bio}$ = 85 [°C]

The net savings is around € 4000 per year and it means a simple payback time less than two years considering we don't have to install new machinery, and not much should be purchased but they should only modify the feeding lines, and the main costs will be about labor and material.

In this solution, net savings in terms of natural gas are 7737kg ie 7toe/year which correspond to 1.2% of energy requirements and although not much in terms of energy consumption reduction, total efficiency is increased and costs decreased as already mentioned above.

Moreover, the question of emissions is quite controversial because, on the one hand, it is true that gas combustion is less polluting than combustion of biomass in terms of CO_2, particulate matter and other carcinogenic substances, but it is also true that CO_2 emissions from biomass has previously been absorbed by the biomass itself, so the total CO_2 balance going back to zero while the gas combustion increases carbon dioxide.

6.5 Boiler's substitution

The gas boiler used in the plant is quite old without the most recent technology neither the best performance. Such obsolescence is manifested mainly in the burner and in the thermal insulation of the cast iron body.
To estimate the overall boiler efficiency as the ratio between the steam energy and the total energy input as fuel mass multiplied per its heating value, you should know all these parameters. As already said there are many ways to estimate that efficiency.

Figure 6.5.1 – Steam generator and thermal pictures

Measuring the necessary values such as the presence of CO_2 and the temperature of the fumes, the percentage losses in the fumes are obtained:

$$Q_{fumes}[\%] = K_s \cdot \frac{(T_{fumes} - T_{environment})}{CO_2}$$
$$= 0.447 \cdot \frac{(170 - 20)}{7} = 10\%$$

In order to quantify losses for unburned fuel, an analysis of the fumes is needed with a percentage of the gases forming the fumes and using the following formula to obtain the percentage of losses:

$$Q_{comb}[\%] = K_c \cdot \frac{CO}{CO_2 \cdot CO} = 37.9 \cdot \frac{1.3}{7 + 1.3} = 5.9\%$$

- CO and CO_2 are the volume-based percentage of carbon monoxide and carbon dioxide in fumes (very different from molar and weight)

- Kc is a constant depending on the type of fuel: in this case is natural gas and you should use 37.9

In the present case, the results of the analysis:

$$\eta_{indirect,\%} = 100 - (Q_{fumes\%} + Q_{comb\%} + Q_{rad\%})$$
$$= 100 - (10 + 5.9 + 3) = \mathbf{81.1}\%$$

Another way to calculate the boiler's efficiency in a very easy and fast way, taking account the variables that affect combustion the most: T_{fumes}, T_{air}, $CO_{2\%}$.

$$\eta_{boiler} = 100 - K_1\left(\frac{T_{fumes} - T_{air}}{\%CO_{2\,fumes}}\right) - K_2$$
$$= 100 - 0.7\left(\frac{170 - 20}{7}\right) - 4 = \mathbf{81}\%$$

It is immediate to see how the results are very similar despite the different calculation methods, even if in the second case it's less complex.

The boiler is a fairly dated system, considering that the datasheet reports 1999 as the installation year so, it can be assumed to replace that steam generating system with a new generation one with all the energy efficiency solutions: controlled Combustion, fluid-dynamic control of air and smoke, adequate insulation and integrated economizer that allow total efficiency of over 90%.

Assuming that substitution allows a total improvement of 10% in boiler efficiency and taking into account that gas demand for the steam boiler is 95% of gas consumption, you have that:

Year	Tot Consumption [kWh]	Boiler Consumption [kWh]	Boiler efficiency	Tot Costs [€]	Unit cost [€/kWh]	SAVINGS [€]
2015	1.239.879,52	1.177.885,54	0,81	80.292	0,065	
2016	1.327.909,25	1.261.513,79	0,81	65.109	0,049	
REPLACED	1.181.985,16	1.122.885,90	**0,91**	57.917	0,049	**7191**

Assuming an investment cost of 35K € and dividing by the annual savings, the simple payback time to replace the boiler is around 5 years.

$$Payback\ time[years] = \frac{investment\ [€]}{annual\ saving\ \left[\frac{€}{year}\right]}$$
$$= \frac{35'000\ [€]}{7'200\left[\frac{€}{year}\right]} = \mathbf{4.85}\ [years]$$

About energy savings, according to consumption for the year 2016, the difference is 145'924kWh of natural gas, ie about **12.6 toe/year** that become even more if we compare the reference year 2015.

6.5 Solar collector System

Considering what we already saw about Solar radiation in this site, and considering that the condensed water flow rate it's about 5500 liters/day and its temperature it's around the environment's temperature, it's possible to calculate how much energy it'll be possible to save if the system could pre-heat the water until 80°C, not a critical temperature for solar collectors.

The water that is processed by the steam generator is the sum of the return water of the condensate circuit and of the water of the renewal network at almost the same temperature because the condensed water has the time to reach the thermal equilibrium with the environment. It has been introduced M_{ratio} that represent the ratio between the really used steam for working purpose and the total produced steam by the steam generator. So, it is:

	Flowrate [liters/day]
$\dot{m}$ condensed water	5500
$\dot{m}$ renew water	1000

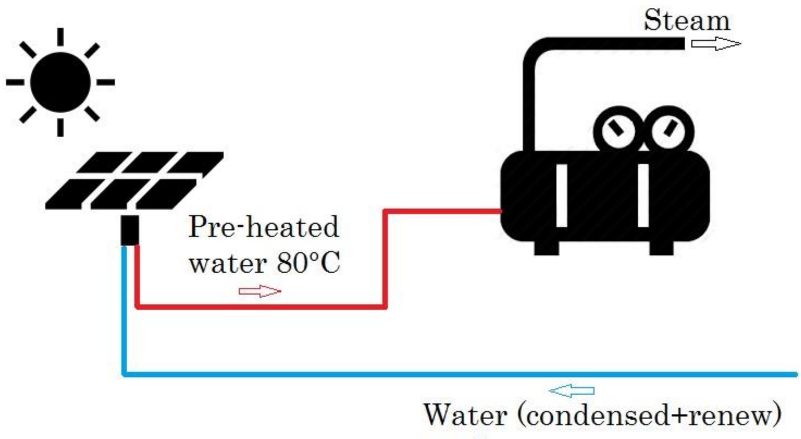


Figure 6.5.1 – Solar collectors and steam generator scheme

With EES Engineering Equation Solver it's possible to calculate the Enthalpy in different thermodynamic states and then calculate the energy savings, and the related economic savings.

```
p_atm=1[bar]

"TEMPERATURES"
t_network=14
 t_condensate=t_network+1
t_IN=(t_network* m_tot*(1-M_ratio)+ t_condensate*m_condensate)/m_tot
t_solar=80 [°C]

"DAILY"
"MASS"
m_condensate=5500 [kg]
M_ratio=0,85 "The used steam is about 15% of the total steam production"
m_tot=m_condensate/M_ratio

"ENTHALPY"
h_W_IN=enthalpy(Water;T=t_IN;P=p_atm)
h_W_SOLAR=enthalpy(Water;T=t_solar;P=p_atm)

 "ENERGY SAVINGS without boiler efficiency"
Daily_energyKJ_saving=(h_W_SOLAR-h_W_IN)*m_tot
Daily_energyKWH_saving=Daily_energyKJ_saving/3600

 "ENERGY SAVINGS with boiler efficiency"
eta_boiler=0,81
Daily_energyKWH_saving_boiler=Daily_energyKWH_saving/eta_boiler

"€ SAVINGS"
 price_€perkWh_gas_nat=0,05
Daily_€_saving= price_€perkWh_gas_nat*Daily_energyKWH_saving_boiler

"YEAR 250 [working days/YEAR] "
workingdays_per_year=250
YEAR_€_saving=Daily_€_saving*workingdays_per_year
YEAR_TEP_saving=Daily_energyKWH_saving_boiler*workingdays_per_year*1,077*0,000077942
```

The results are:

Unit Settings: SI C bar kJ mass deg

$Daily_{energyKJ,saving}$ = 1,764E+06 [kJ]	$Daily_{energyKWH,saving}$ = 489,9 [kWh]	$Daily_{energyKWH,saving,boiler}$ = 604,9 [kWh]
$Daily_{€,saving}$ = 30,24 [$]	η_{boiler} = 0,81 [-]	$h_{W,IN}$ = 62,38 [kJ/kg]
$h_{W,SOLAR}$ = 335 [kJ/kg]	$m_{condensate}$ = 5500 [kg]	M_{ratio} = 0,85 [-]
m_{tot} = 6471 [kg]	$price_{€perkWh,gas,nat}$ = 0,05 [$/kWh]	$t_{condensate}$ = 15 [°C]
t_{IN} = 14,85 [°C]	$t_{network}$ = 14 [°C]	t_{solar} = 80 [°C]
$workingdays_{per,year}$ = 250 [-]	**$YEAR_{TEP,saving}$ = 12,69** [tep]	**$YEAR_{€,saving}$ = 7561** [€]

It's showed how it could be possible to save more than **7500€/year** and more than **12.5tep** (from natural gas) so it means we can save around 2% of the total energy consumption. A very good result considering that the costs won't be that huge, 20.000€ and the payback time will be less than 3 years.

6.6 Solution's final recap

At the end, it' a good thing to do a recap about the suggested and studied solutions, as:

Solution	Investment [€]	Money Savings [€/year]	Energy Savings [tep/year]	Payback time [years]
Replacement lighting system	21.200	21.400	40	1
Biomass and steam generator integration	8.000	4000	7	2
Boiler's substitution	35.000	7200	12,6	4,9
Solar collector system	20.000	7500	12,5	2,7

Figure 6.6.1 – Comparison between different purposed solutions.

It' clear how the replacement of lighting system it's the most interesting, with the highest energy savings per year compared to others solutions. It' important to understand that the savings in energy are not all the same, in fact if you are able to save the same amount of thermal energy or electricity (it depends mostly on temperature, but in general it's like this), the second one will be bigger if you report the savings to primary energy, i.e. in toe.

More in deep it will be more correct to consider exergy than energy, in fact the exergy considers the temperature of the thermal energy and the primary energy to produce, distribute and use electricity.

7. CONCLUSION

There has been a review of what and how an energy audit should be carried out and there is a very interesting example of an audit for a leading industry in its manufacturing sector: Petratex.

The energy audit comes from a European law obligation but never as now, it has become an instrument that transforms itself into capital saving opportunity for company and thus becomes directly a competitive advantage when considered with farsightedness and wisdom.

The problem that afflicts most of the companies and common sense, is that there is no real sensibility to improving energy performance to preserve the environment. The only point where most companies (and people) focus on, is money, and not the safeguard of their environment, thinking that the two things are disconnected or at least too far apart.

In reality, however, is the opposite, and not only the market is rewarding virtuous companies from the point of view of energy performance as they spend less than others on the energy side but they can avoid costs related to emissions and have the opportunity to sell their emission-quote, achieving double benefits.

Not to mention that some companies in general are starting to prefer to be supplied from the most virtuous ones without necessarily putting the price as the only decision parameter, as they may need to state that their product requires less than a specific amount of $kgCO_2$ for their production.

In the studied case, there would be many different possibilities of application especially for the steam generation from a solar thermal source through the use of collectors with evacuated tubular technology which allow to have medium temperature fluids for the steam production without needing conventional fossil fuels.

It should also be considered that Petratex works in a very industrialized area, especially with regard to the furniture sector, with which it could divide a big size co-generator for the production of electricity and heat.

Petratex has also implemented a production line control system by giving a tablet to every worker in which work time and productivity are recorded. That kind of system could be very interesting and could be a useful way for a detailed production monitoring and energy management.

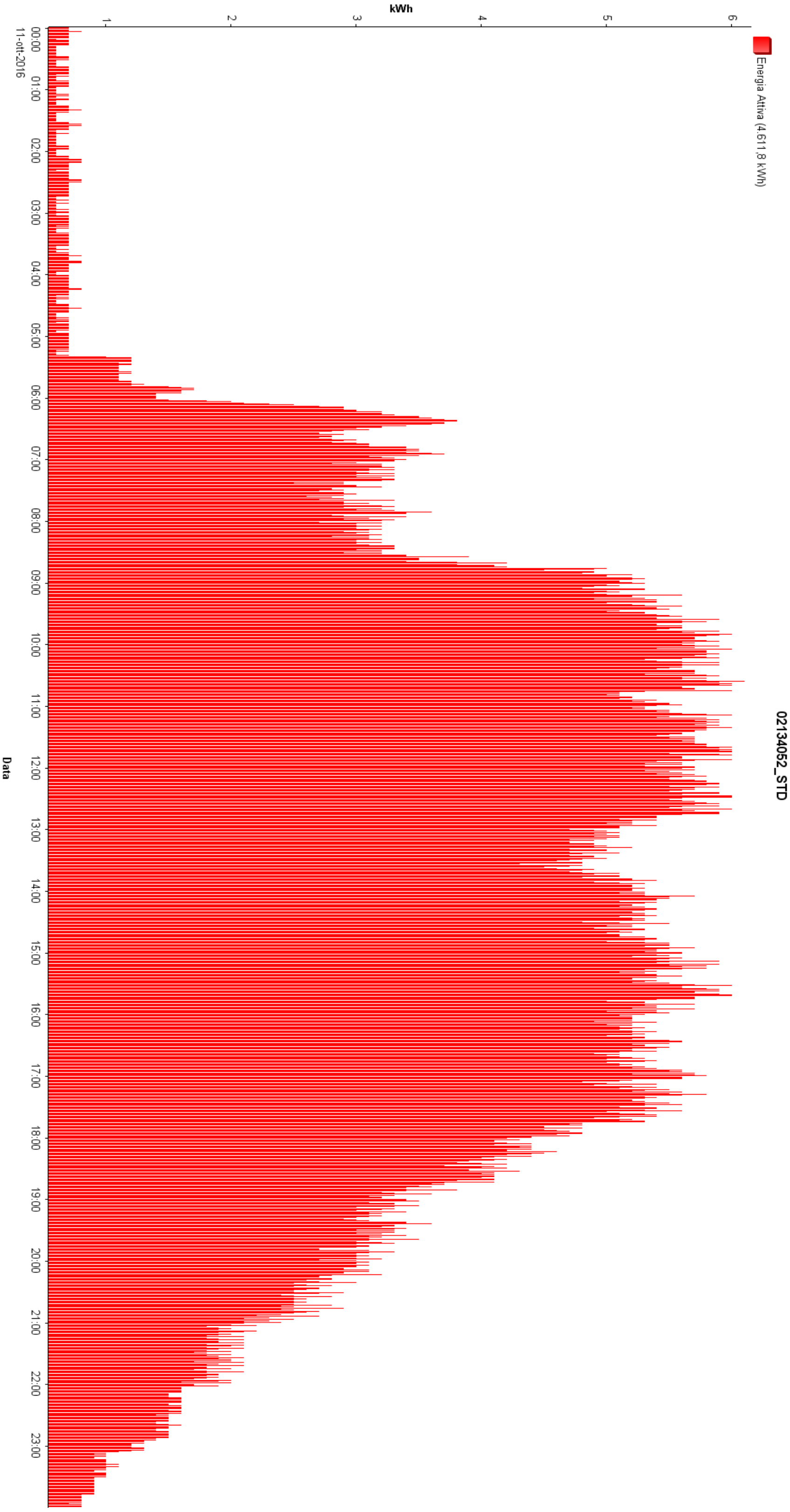
In fact, it has already been pointed out that there are often periods when ironing resistors are in standby, consuming energy even if they are not working.
If you can optimize your time and know exactly when do you need steam and / or irons in working temperature, you might avoid the standby phase and their energy consumptions that would directly become energy-saving and therefore economical savings.

If, with the right will and conscience, technical difficulties can be overcome in some way, however, what worries most, is the lack of will and awareness in the potential of the audit tool.

Also the measurement and consumptions monitoring allows you to understand the variations of energy requirement during the year and allows you to link them, to external or internal factors, in cause-effect relationships so, you know which parameters you should monitor and what are the conditions that most affect the performance of the business.

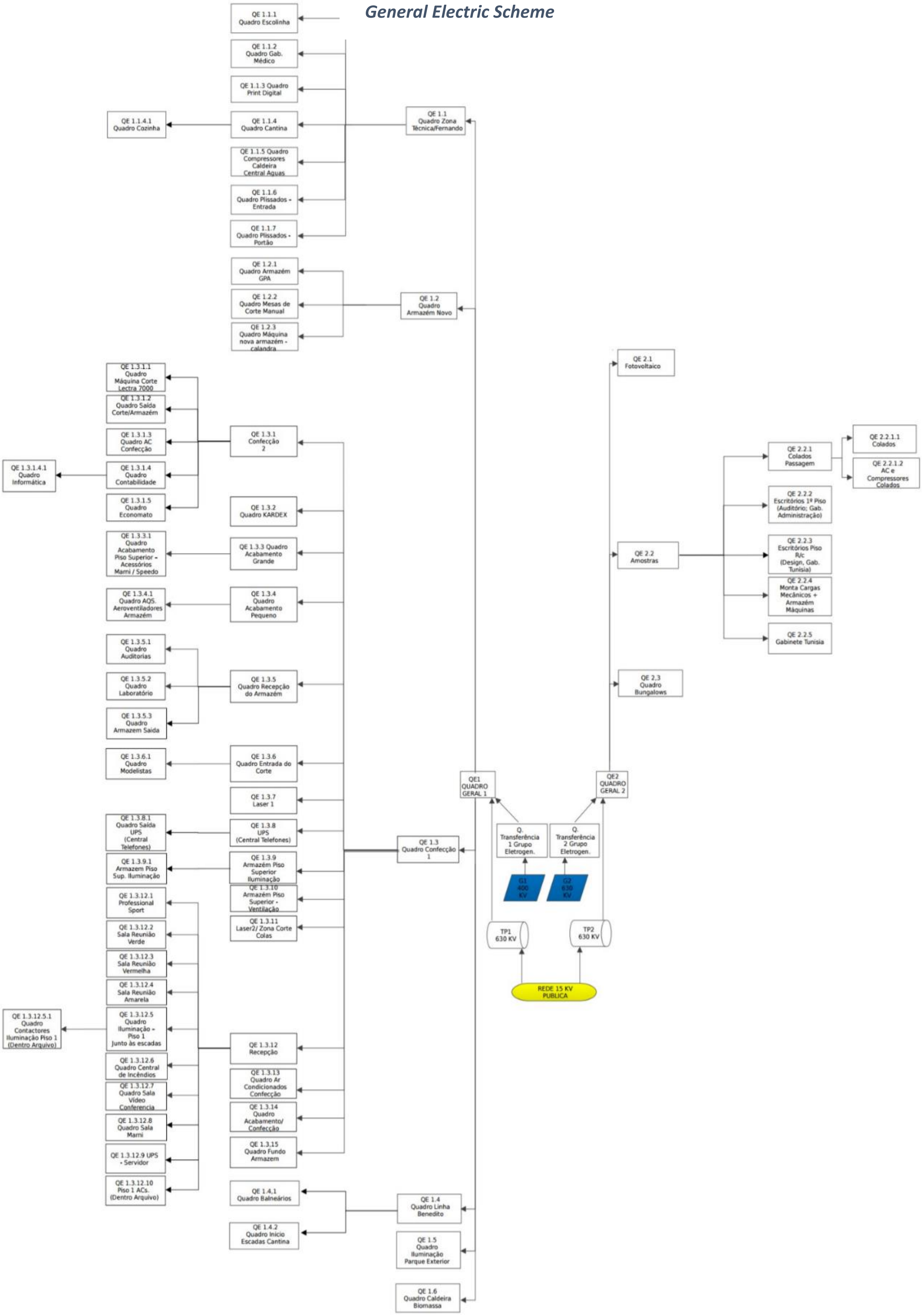
Today, more than ever, "the datas", understood as information, are crucial if you know how to analyze and use them. Being able to constantly measure, control and regulate your own consumption and production can be a determining factor for the optimization of the production process and the use of raw materials and above all energy that enable you to produce with less environment impact. Therefore, the focus is once again efficiency and not savings, even if the first implicates the other in a long-time perspective.

8. ANNEX AND PICTURES



Energy consumption daily diagram

General Electric Scheme



" mass balance"

m_rinn=450000 [kg]

m_water=m_rinn+m_cond

m_cond=600000

"pressions"

p_low=2 [bar]

p_high=7,3 [bar]

"temperature"

T_in_water_cond=35 [°C]

T_in_water_rinn=15 [°C]

t_mix=(m_rinn*T_in_water_rinn+m_cond*T_in_water_cond)/m_water

t_out_bio=85[°C]

"efficiency"

eta_comb_BIO=0,90

eta_comb_GV=0,72

"LHV"

LHV_biomass=16500 [kJ/kg]

LHV_gas=46187 [kJ/kg]

"1 whitout pre heating"

"2 with pre heating"

h_in_bio=Enthalpy(Water;T=t_mix;P=p_low)

h_out_bio=Enthalpy(Water;T=t_out_bio;P=p_low)

h_in_gv1=Enthalpy(Water;T=t_mix;P=p_high)

h_in_gv2=Enthalpy(Water;T=t_out_bio;P=p_high)

h_out_gv=Enthalpy(Steam;T=200;P=p_high)

Delta_h_pompa1=h_in_gv1-h_in_bio

Delta_h_pompa2=h_in_gv2-h_out_bio

risparmio_spec_pompa=Delta_h_pompa1-Delta_h_pompa2

RISPARMIO_POMPA=risparmio_spec_pompa*m_water/3600*prezzo_el

prezzo_el=0,12

"Steam generator"

H_comb_gas1=m_gas1*LHV_gas*eta_comb_GV

H_comb_gas2=m_gas2*LHV_gas*eta_comb_GV

H_comb_gas1=m_water*(h_out_gv-h_in_gv1)

H_comb_gas2=m_water*(h_out_gv-h_in_gv2)

RISPARMIO_kg_gas=m_gas1-m_gas2

RISPARMIO_€=RISPARMIO_kg_gas/1000*prezzo_gas-prezzo_bio*m_bio/1000

prezzo_gas=830,73

prezzo_bio=139,06

"ENERGY BALANCE"

"biomass BOILER"

H_comb_bio=m_bio*LHV_biomass*eta_comb_BIO

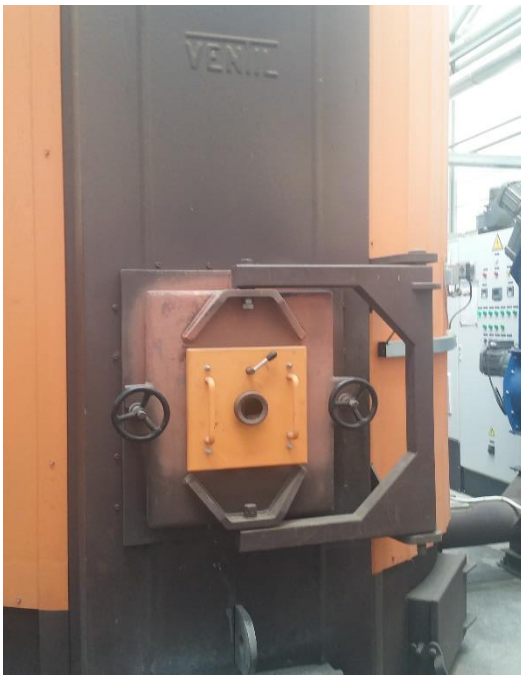
H_comb_bio=m_water*(h_out_bio-h_in_bio)

Ironing Area

Cutting Area

Steam Central Distributor

Electric Panel



Biomass Manual Inlet

Steam Generator

Normative requirements

As regards Portugal's national legislation [21], [24]:

- Decree-Law No. 58/82 of February 26, which regulates energy management on standard parameters.
- Order No. 359/82 of April 7, which was the first Energy and Consumption Management Regulation.
- Decree-Law No 428/83 of December 9, which replaced the Decree-Law No. 58/82 of February 26, for "energy intensive use installations" by the term "high intensity services companies and consumers" energy '.
- Decree-Law No 250/86 of August 25, which has created the incentive system for the rational use of energy and the development of renewable energies.
- Decree-Law No 188/88 of May 27, which created the Rational Energy Incentive Plan (SIURE).
- Ordinance n228 / 90 of 27 March, which approved the Regulation for the Consumption and the Tasks of Energy Management for the Transport Sector
- Resolution of the Council of Ministers No 154/2001 of October 19 approving the E4 program, its energy efficiency and its own energy sources.
- Resolution of the Council of Ministers 169/2005 of October 24, confirming the national energy strategy.
- Council Resolution 104/2006 of 26 August approving the National Program on Climate Change 2006 (PNAC 2006) and repealing Council of Ministers Resolution 119/2004 of 31 July.
- No 71/2008 of 15 April, which establishes the system for the management of energy consumption by undertakings and consumers of intensive installations and repealing Decree Law n 58/82 of 26 November decree law and 428/83 Of 9 December.
- Order n 519/2008 of 25 June approving the requirements for the accreditation of technical and responsible bodies, of which Decree-Law No 71/2008 of 15 April, which has created the Intensive Energy Consumption System (SGCIE).
- Ordinance N.17449 / 2008 of June 27, under the SGCIE, considers the elements for carrying out energy audits to prepare the rationalization of energy consumption plans (prENs) and implementation and progress reports (REPs).

- Ordinance No 1530/2008 of 29 December establishing fixed rates on petroleum and energy (ISP) products on industrial fuels.

- Decree Law No 319/2009 of 3 November 2006 transposing into national law Directive 2006/32 / EC of the European Parliament and of the Council of 5 April 2005 on the efficiency of final energy uses and public energy services and aims to improve the efficiency of Costs in end uses of energy.

- No 50/2010 of May 20, which establishes the energy efficiency of the Fund under the National Action Plan for Energy Efficiency.

- Decree-Law No 141/2010 of December 31, which, under the national 2020 energy strategy, sets the targets for renewable energies in final energy consumption and partly transposes Directive 2009/28 / EC of the European Parliament and the Council of 23 April.

- Law No 64-A / 2011 of December 30, approving the main planning options for 2012-2015 - introduces an electricity taxation system for industrial consumers, which transposes Directive 2003/96 / EC .

- Ordinance No 320-D / 2011 of December 30, update of tax rates on petroleum and energy products (ISPs), those containing oils and fuels as well as petroleum products normally having lubricant function, diesel fuel heating and other industrial fuels, In particular coal and coke, petroleum coke and petroleum gas used as fuel, and establishes the rate of ISP applicable to electricity.

- Law 7/2013 of January 22, approving access to and performance of energy audit activities, preparation of energy efficiency rationalization plans and monitoring implementation and progress reporting of implementation and development under the SGCIE.

- Resolution of the Council of Ministers 20/2013 of 10 April shows the National Action Plan for Energy Efficiency for the period 2013-2016 and the National Action Plan for Renewable Energy for the period 2013-2020.

- Law No 82-A / 2014 of December 31, approving the major energy plan operations for 2015.

Regarding European law, however, we recall:

- Council Regulation (EEC) No 3301/86 of 27 October 1986 establishing a Community program for the development of less-favored regions of the Community by enhancing the endogenous energy potential (VALOREN program).

- Council Directive 2003/96 / EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity.

- Council Directive 2004/74 / EC of 29 April 2004 amending Directive 2003/96 / EC as regards the possibility for certain Member States to apply to energy products and electricity exemptions or reduced rates of temporary taxation.

- Directive 2009/29 / EC of the European Parliament and of the Council of 23 April 2009 amending Directive 2003/87 / EC to improve and extend the Community system for the exchange of emission quotas for greenhouse gases (ETS) 2013-2020).

- Directive 2009/115 / EC of the European Parliament and of the Council of 21 October 2009 on the establishment of a framework for the ecodesign setting of energy-related products.

- Directive 2010/30 / EU of the European Parliament and of the Council of 19 May 2010 on the indication of the use of energy and other resources of energy-related products through labeling and standard product information.

- Directive 2010/75 / EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control and control)

- Directive 2012/27 / EU of the European Parliament and of the Council of 25 October 2012 on energy performance, amending Directives 2009/125 / EC and 2010/30 / EU and repealing Directives 2004/8 / EC and 2006/32 / CE.

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- [24] https://dre.pt/home
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- [28] http://www.direttiva27.it/
- [29]

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