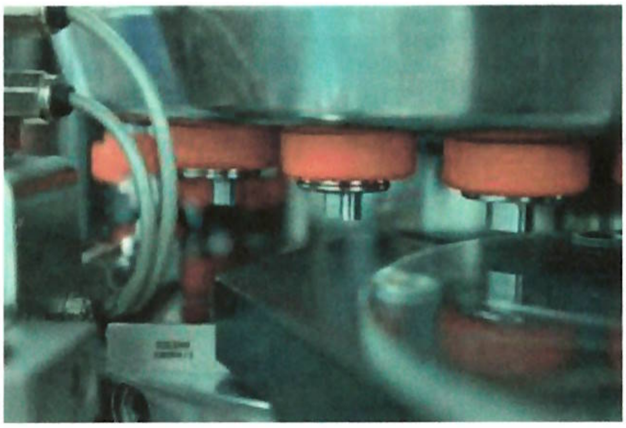
Annex B-21

Combino Pharm



ENERGY AUDIT REPORT 2020

Ref: EA_CP_09/2020

SCICLUNA &ASSOCIATES

ENGINEERING CONSULTANTS

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Executive Summary

As per LN196/2014 a second energy audit for Combino Pharm, a pharmaceutical company operating the plant at HalFar industrial estate, was conducted as per requirements. The energy and resources used mainly include electrical energy, water, LPG and Nitrogen consumptions. The data gathering and analysis strategy are in compliance with ISO 50002 guidelines. The segregation of the building designated areas in terms of energy consumed is being illustrated below:

- **Production**: Area dedicated for the production of goods mainly housing the equipment and machinery used throughout the process including areas equipped with auxiliary equipment such as boiler, chillers, air handling units, air compressors, reverse osmosis etc… Such areas are kept at ambient / controlled conditions depending on the requirements;

- **Warehouse**: Warehouses used to store both incoming raw material and finished goods both at ambient or controlled conditions;

- **Administration**: The main offices area and laboratory.

In general, the main energy requirement is electrical energy used for the day to day running of such a plant mainly distributed between HVAC equipment supplying the production areas and other auxiliary equipment supporting the plant.

Other energy sources include gas consumption used to run the boiler to supply continuous hot water/steam used in the production process.

Another resource is water used in the running of the plant after passing through a reverse osmosis. The yearly consumptions of each of the mentioned sources are:

- **Electrical energy**: supplied from the main electricity provider with 1,973,397 kWh of electrical energy consumed in 2018.

- **Gas consumption**; used to run the boiler that supports the production facility with hot water supply. An average of 8,304 m^3 of LPG consumed in 2018.

- **Water consumption**; used in the production process, a relatively high consumption due to the nature of the process in the pharmaceutical industry an average of 5,696 m^3 in 2018.

The coming discussion illustrate areas of importance to this audit that have been monitored and analysed to provide additional improvement. Further energy efficient measures, i.e. a continuation of measures recommended in the first audit, and ways of improvement are listed and discussed in order to continuously improve the overall energy performance of the plant.

Scicluna & Associates has been engaged as a consulting firm to carry out the energy audit of the premises. An extension for audit submittal to the 6th of March 2020 was approved by the Energy & Water Agency.

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Statement by the Directors

As directors of Combino Pharm, we declare our independence from the auditors and have no relationship whatsoever.

Signature:

Combino Pharm

Combino Pharm (Malta) Limited
HF 60 - Hal Far Industrial Estate
Hal Far BBG 3000 - Malta

Date: 04/03/2020

Identification of Experts

The experts who compiled the audit include:

- Lead senior auditor: Ing. Simon Scicluna B.Eng (hons), MSc.(Building Services)
- Field auditor: Ing. Karl Agius B.Eng (hons), MSc.(Sustainable Energy)

Signature: Ing. Simon Scicluna
Engineer Mechanical
Warrant No.515

Date: 11/02/2020

Background

An energy audit is a tool to assist an energy based activity in understanding the importance of energy efficiency. The monitoring of such energy highlights opportunities for improvement. Several bodies continuously publish ways and means to improve any activity that consumes energy during its' day to day running. These are based on continuously evolving technologies based on the best available techniques. The audited premises as described in the introduction, is a pharmaceutical company that operates on a weekday basis with a shift pattern covering the day from morning to evening. Such an industry imposes restricted operating conditions in terms of air quality which is a challenging aspect in terms of energy consumption.

The production plant being audited is mainly composed of a production area, warehouse and offices/laboratory areas. The area of production includes several clean rooms, rooms with specific ambient conditions, producing the end product which is then stored in a warehouse area used to keep both the raw material and finished goods at the optimal conditions before use /shipment.

Ambient conditions need to be kept up to specific requirements and are to be continuously maintained in the production area. Special personal protective equipment such as overall vests are used in areas where mixing and processing of substances used to obtain pharmaceutical products are made. These include medicinal products in different forms mainly powder tablets, solutions, capsules and other variants.

The building envelope is mainly built from brick/stone walls with concrete roof. Natural light is minimally used and is mainly coming from the North facing walls where the main offices are situated. The rest of the building facades, i.e. South, West and East have several penetrations with louvered windows to aid natural circulation in the plant. The building envelope including the production area, warehouse, laboratory and offices has a total footprint of 2500 m^2 with a total area of 6240 m^2 when considering the ring road surrounding the plant including a car park and soft areas.

The figure below shows an aerial view of the area being audited situated at Hal Far industrial estate.

Figure 1. Aerial View of Site

Address of premises: HF 60 Hal Far Industrial Estate, Hal Far. Malta

The production plant located in an open spaced industrial area is in the vicinity of the cliffs on the West coast of Malta. This makes the plant exposed to harsh weather conditions including a corrosive atmosphere.

Energy Audit Plan

The audit plan outlines the audit strategy and procedure followed throughout. In order to assure consistency and completeness of the audit, the plan goes through the requirements as listed in the ISO 50002 to make sure that no aspects are neglected or overlooked.

Steps involved:

- Plant operations review;
- An updated Energy Balance, highlighting the difference between the audited periods of Q1 in 2016 and Q3/Q4 in 2019;
- Status of the previous recommendations made;
- New observations;
- The introduction of performance indicators in order to provide a benchmark for comparison of energy consumed;

The period of energy audit includes a spread of 8 weeks, covering end of August, September and mid-October, of data gathering and logging of real time consumption followed by data analysis and reporting. The data gathered is used to determine the optimal energy saving measures that optimize the operations of the plant. No transport activities are carried out by the entity; therefore, no review of such considerations will be made. The aim of this second energy audit is to consolidate the measurements obtained which are then confronted with the previously gathered data and an analysis will follow.

Statement of Confidentiality

The parties hereto acknowledge that any information given as requested by the auditor is kept confidential and shall be used exclusively for the fulfilling of the exercise under this agreement and for no other purpose other than by the consent of the disclosing party.

Update of Parameters

No significant changes in layout and operations were noted. An increase in electrical energy consumption was noted which is being attributed to the warmer ambient conditions in which the second audit took place. The following analysis provides a detailed explanation of such consumption.

Data Measurement Plan

The points of main consumption are identified in order to have a clear scenario of the activity. These incorporate specific equipment used in the production process including:

- Fluid Bed Dryer;
- Dust Collecting Unit;
- Granulator;
- Coater;
- Compression system;
- Blister packaging line;

Other supporting equipment for the production process, offices, laboratory and warehouses include:

- Air Handling Units;
- Air Compressors;
- Chillers;
- Circulation Loop Pumps;
- Reverse Osmosis;
- Boiler.

The energy audit measurements provided hourly consumptions of the above-mentioned equipment which contributed to the much-needed analysis.

All the instruments used in the monitoring of power consumed were calibrated accordingly in order to ensure accuracy and repeatability of results.

Building Envelope

The building envelope is mainly composed of "franka" stone walls with concrete and steel ceilings. Being fully detached from the surroundings, the building offers a substantial amount of natural lighting.

Figure 2. North facing facade

The North façade has about 40 m^2 of double-glazed windows which aid the use of natural light. The other facades are characterized by louvered steel apertures that aids natural circulation in areas used for plant equipment. The following illustrations show the rest of the remaining facades.

Figure 3. West facing façade

The West façade has a low aperture to wall ratio as the main opening is the warehouse door used for loading/unloading of goods. The canopy built to provide shading contributes to reduced heat transfer gained during the hot Summer days.

Figure 4. South facing façade

In general, the South facing façade consists of 30 m^2 of louvered apertures that aid the natural ventilation into the respective areas, whereby the boiler, air compressors, R.O. and other equipment is contained.

Figure 5. East facing façade

The East façade is mainly housing the equipment used in the plant including the Air Handling Units (AHU's) and circulation cooling/heating pumps. The louvered aperture type provides the ideal ambient conditions as it aids natural circulation of fresh air.

Roof area: The illustration below shows the roof which is mainly covered with a dark colored waterproof membrane. It is being suggested that this is painted in a light color to reduce the heat gained during the hot Summer period.

Figure 6. Roof layout

Energy Consumptions

As previously discussed, the energy resources used in the running of the plant include electrical energy, gas and water. The following illustrates an analysis of these consumptions.

Electrical Consumption-Energy Balance

As shown in the first audit the HVAC system is the main consumer of electrical energy in the plant. This includes the chillers that provide the cooled media, mainly chilled water and the Air Handling Units (AHU's) that provide the fresh air as per requirements.

Other main consumptions include:

- Compressed air system;
- Production equipment;
- Lighting.

The first energy audit covering quarter 1 of the year shows a consumption of 65% of the overall electrical energy is consumed by the HVAC system with low ambient temperatures averaging between 13 to 14 degrees Celsius, representing the first 3 months of the year, January, February and March.

The second audit covering quarters 3 & 4 of the year shows an HVAC electrical consumption of 76% of the overall consumption with an average ambient temperature of 26 to 21 degrees Celsius thus representing August, September and October. This period shows an increase in electrical consumption of 20% with respect to the previous audit in terms of kWh consumed. The coming illustrations show the electrical consumption apportioned as per their respective use and the difference in percentages between quarter 1 (Q1) of 2016 and quarter 3/4 (Q3/4) of 2019.

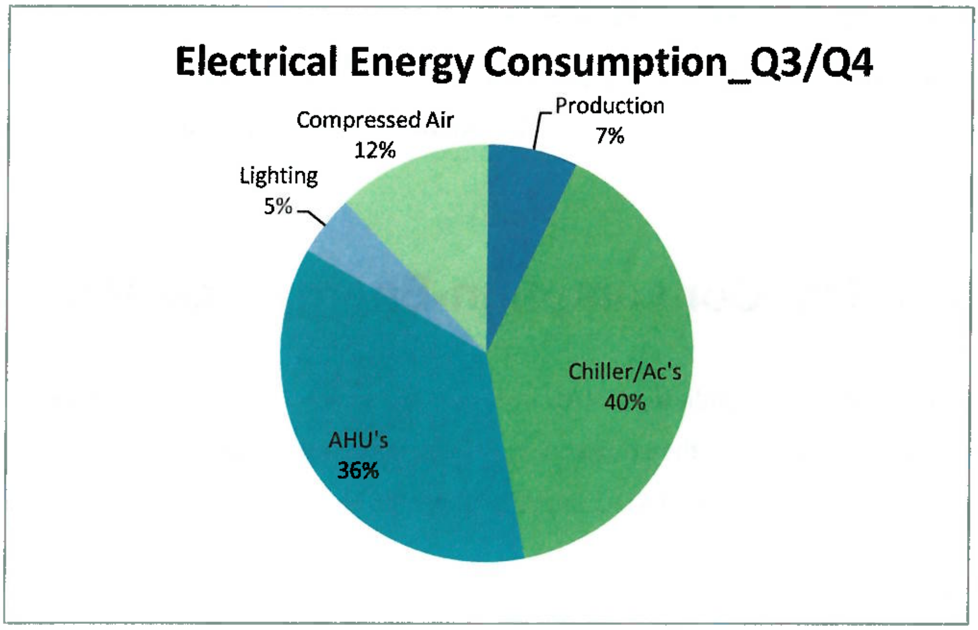


Figure 7. Electrical Consumption_Q3/Q4 2019 (during second audit)

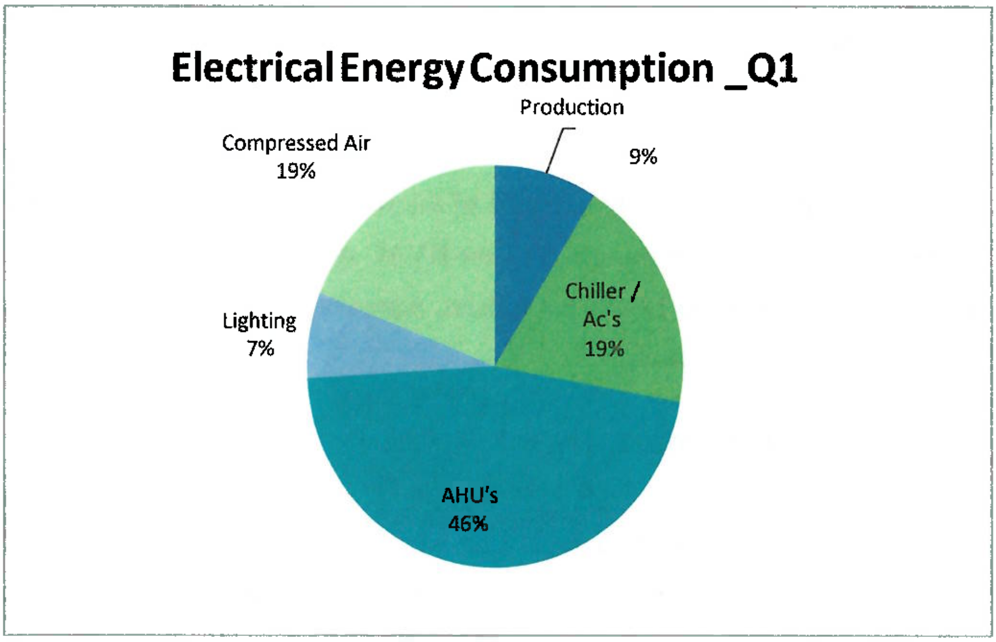


Figure 8. Electrical Consumption_ Q1/2016 (during first audit)

The table below shows the electrical consumption difference between audits in terms of kWh:

Table 1. Consumption of main equipment- Q1/ 2016 vs Q3/Q4 /2019

	Q1_2016 (kWh/day)	Q3/Q4_2019 (kWh/day)
Production equipment *	300	350
Chillers	644	1991
AHU's	1572	1809
Lighting	235 (Calculated)	235 (Calculated)
Compressed air	648	604

*The term production equipment includes all machinery used in the production department. As previously stated, the equipment and machinery used in the production is supported by the chillers, AHU's, compressed air system and lighting.

Second to the HVAC consumption are the air compressors and the machinery used in the production area. A slight difference can be observed between the first quarter of the year Q1, with relative colder months, and the third/fourth quarter of the year Q3/Q4, relatively warmer and humid months. The following points illustrate the difference between the quarters:

- **Production department**: The difference in consumption in the production department is estimated to reach 15% increase which is being attributed to the different production requirements;

- **Air compressors:** The difference in consumption attributed to the air compressors is estimated to reach 8%. Such a difference is being attributed to higher production requirements and higher humidity conditions. It is known that air compressor systems exhibit higher electrical consumption at higher air temperatures to compensate for the increase in air demands used during the drying cycle of the air. (refer to recommendations for system monitoring and improvements)

The other consumptions are attributed to lighting around the plant, including production, warehouse, laboratory and offices. Although such consumption is being calculated, not measured due to the difficulty of connecting meters, it is being assumed that such consumption is not affected by seasonality. This is due to the fact that the production and warehouse areas are enclosed and minimally exposed to natural light, therefore no changes are expected. (refer to recommendations for system improvements)

The below illustration shows the monthly average temperature spread on a year.

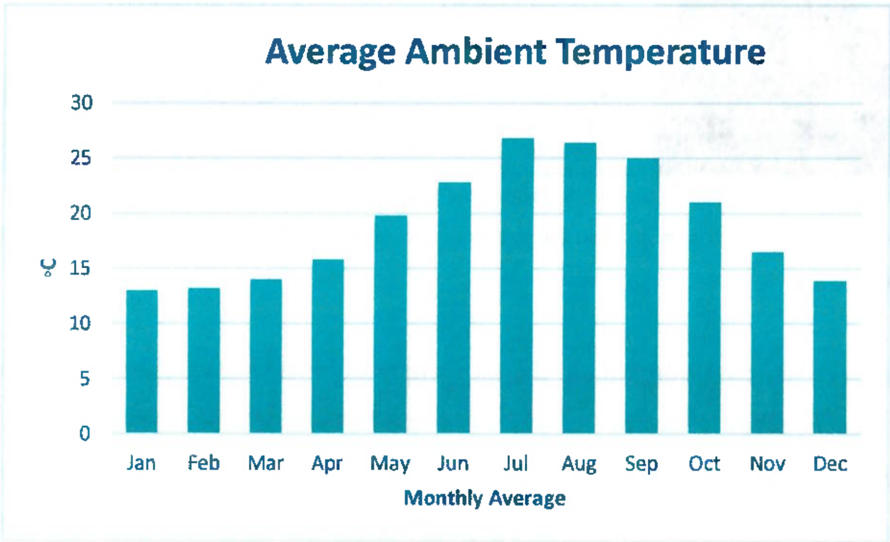


Figure 9. Yearly average temperature

Electrical Consumption -Year to year consumption

The figure below shows the yearly electrical consumption in kWh for the years 2015 and 2018. It is evident that the year 2018 exhibited an increase in consumption. This is being attributed to an increase in production output which inevitably reflects on extra energy required to support the production department.

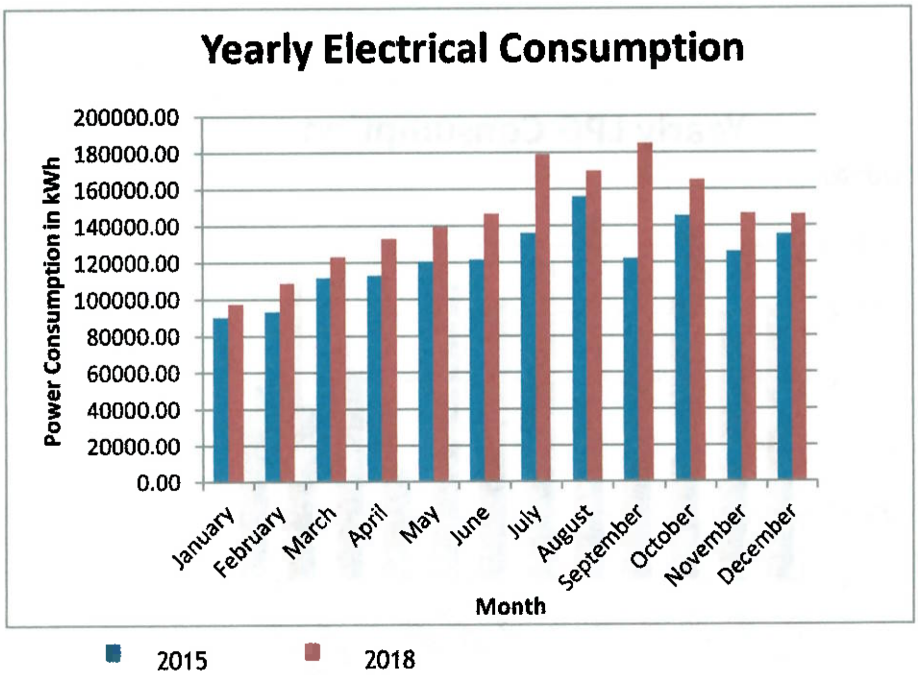


Figure 10. Yearly electrical consumption

A system of Key Performance Indicators (KPI's) is being suggested in the following recommendations in order to relate production numbers with energy consumed. This will provide a better control of the energy consumptions during the year.

Gas Consumption -Year to year consumption

The main consumption of gas is LPG which is used to fire the boiler to produce hot water for production purposes. The figures below show the yearly gas consumption in cubic metres for the years 2015 and 2018. It is evident that the year 2018 exhibited nearly the same consumption between the years. It is being recommended that the hot water loop is better equipped with temperature and flow devices in order to better analyse the system which then enables further system improvements.

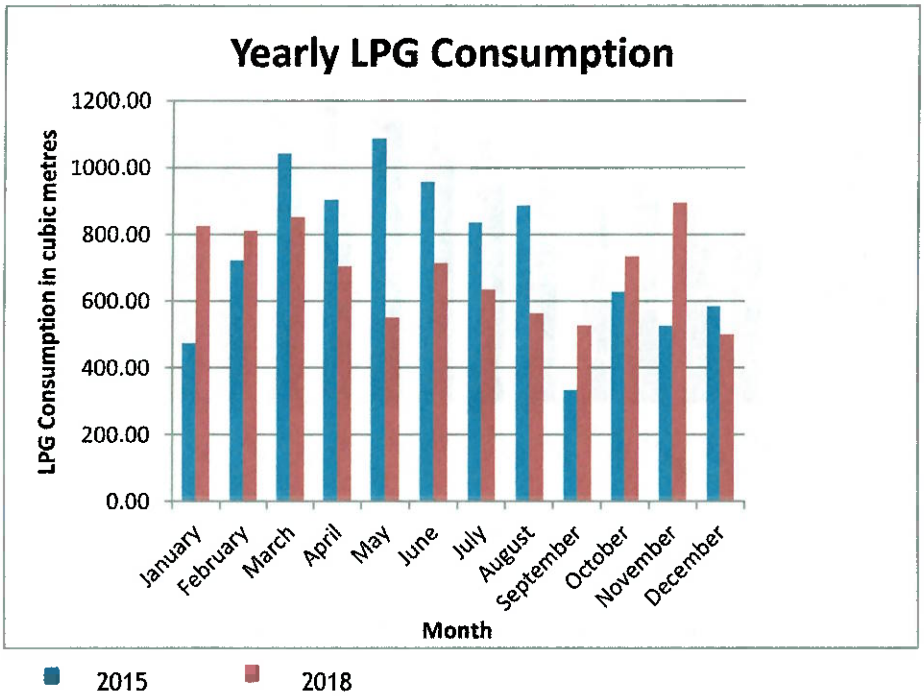


Figure 11. Yearly gas consumption

Some other minor consumptions of gas include Nitrogen gas used in the laboratory which is not being considered for this audit as only few bottles of Nitrogen are consumed on a yearly basis.

Water Consumption -Year to year consumption

The main consumption of water is directly supplied form the mains water provided by the water services corporation. Water is widely used as a direct ingredient as well as during rinsing, sanitizing and cleaning, after passing through a Reverse Osmosis (RO) The cleaning of the equipment requires large amounts of water. Other consumption goes for the daily requirements of staff at the administration and warehouse respectively.

The figures below show the yearly water consumption in cubic metres for the years 2015 and 2018. It is evident that the year 2018 exhibited a decrease in consumption.

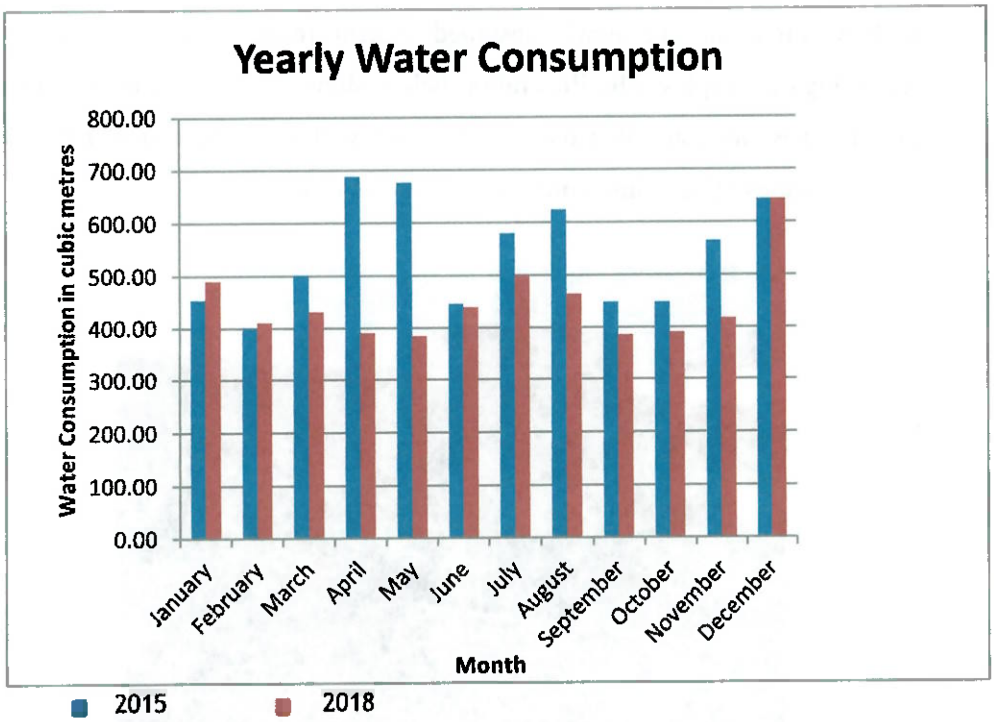


Figure 12. Yearly water consumption

Energy Efficient Measures- Implemented

As part of the recommendations proposed in the first audit a number of undertakings aimed to improve energy efficiency were carried out during the year, these include:

- Replacement of an old roof top HVAC system. Such equipment is used to provide cool fresh air in the plant area which has been replaced by new highly efficient scroll type compressors which provide an estimated improved efficiency of 20-30%* over the previous system installed years ago. The new system is an autonomous cooling only air-to-air rooftop unit which circulates cools down and filtrate the air. With hermetic rotary scroll compressors and R410A refrigerant the newly installed system respects the best available technology principles. The illustration below shows the unit being assembled on site. It is suggested that the coming audit will take into consideration the energy savings of such implementation. *as per manufacturer's claim

Figure 13. East facing facade

- Other improvements with respect to improved energy efficiency were noted in the lighting system whereby some of the T8 Fl light fittings were replaced by LED type technology, with an estimated improved consumption of up to 50%.

- A power factor corrector was installed to improve the reactive power consumption thus improving the electrical grid efficiency.

Figure 14. Power factor corrector

Recommendations for Further Improvement

The main electrical consumers are the ac motors and drives that are used to provide the controlled ambient conditions, water loops circulation, equipment used in production such as mixers, pumps, centrifuges and dryers. Moreover, most of the equipment is considered to be in a relatively advanced stage of its' life cycle therefore a system approach to identify, monitor, and if required replace is being proposed to systematically improve the overall plant efficiency. This includes:

- Identification of all motors and their applications, i.e. compressors, pumps, fans etc....;
- Measure and record the current absorbed by the motors when onload;
- Formulate a record sheet with a pre-defined schedule of measuring currents, (approximately every 6 months);
- Compare the readings obtained and check for any changes that can be attributed to wearing of motor;
- Perform a market research to identify possible replacements including implementation costs and potential annual savings;

Considering the fact that a scheduled preventive maintenance program is already in place it is being suggested that such a procedure is carried over during such maintenance. Any abnormal results in current absorbed may lead to investigation of any load imbalances, motor ventilation, and alignment or lubrication issues. Moreover, further data acquisition such as bearing temperatures using Infrared guns or thermographic cameras can help to determine any hotspots due to bearing wear. The replacement of old type equipment by new, as done in the roof top system, potentially contributes to higher operational efficiency with an average payback period of less than six years [1].

Justifying replacement may be more difficult when an old motor still performs adequately but even in these cases replacement can save money especially for motors that run for long hours at high loads. One study [2] showed a payback period of less than 15 months for old, more than 20 years old, 50 horsepower (hp) motors.

Improvements in compressed air system: The consumption of compressed air used for the day to day running of the plant vary between 12% to 19% of the total electrical consumption, depending on the equipment used in the production plant and ambient conditions including temperature and humidity.

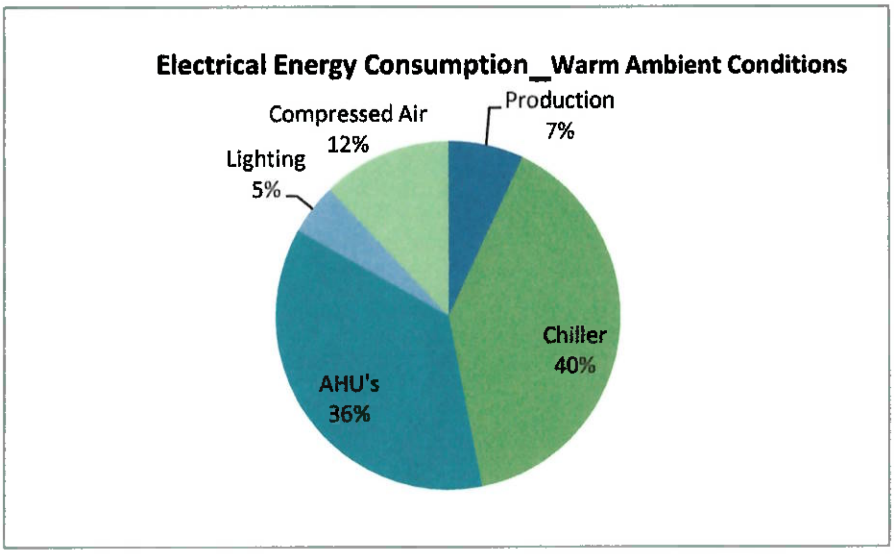


Figure 15. Electrical Consumption_Q4/ 2019 (second audit)

Compressed air is required for many applications of equipment operation. Generally speaking the process of compressed air is largely inefficient due to the heat involved, drying of the air and any leakages that might increase with time. Some important aspects in air compressors maintenance that are of importance are as follows:

- Keep motors properly lubricated and cleaned;
- Inspection of belts and fans and efficacy of desiccant used in the drying process;
- Inspection of any automatic water drain traps to ensure proper operation;

- Minimize leaks, by introducing monthly preventive maintenance schedules to inspect for any air leakages by using air leak detector sprays;

- Install pressure, temperature and flow gauges to closely monitor the performance of each compressor;

- To install permanent power meters to closely monitor electrical consumptions.

Key Performance Indicators (KPI's)

Key Performance Indicators (KPI's) are considered to be an effective way of monitoring energy consumption thus providing essential information based on real time data. Based on qualitative analysis the outcome provides real figures that shows the energy consumed versus production, this faciliates the introduction of targets directly related to improved energy efficiency. Due to this matter it is being suggested to introduce a KPI system to monitor and evaluate the energy cosnumed in the plant.

The below discussion suggest 3 variables, elecrical, water and gas consuption. Due to the fact that electrical consumption has a direct relationship with ambient temperature it is being suggested that quarterly KPI's are evaluated with respect to outdoor temperatures and products produced.

The below shows the electrical, water and gas consumption KPI for the year 2018. A factor k is being introduced to represent the production numbers for these particular months. A factor of 1 is being assumed for the months of 2018 (i.e. same production levels throughout the year)

Table 2. KPI's

	Quarterly Electrical Consumption (kWh)	Quarterly Water Consumption (m^3)	Quarterly Gas Consumption (m^3)	Quarterly Average temperature	Production (K factor)	KPI / degree Celcius	Quarterly KPI
Energy based factor	2	1	1				
Q1	375040	1570	2486	13.41	1	.754	10.112
Q2	474000	1326	1966	19.47	1	.951	18.521
Q3	604683	1349	1724	26.06	1	1.212	31.596
Q4	519672	1451	2128	17.13	1	1.042	17.865

**The energy based factor is meant to attribute different weighting to the energy sources used. This reflects a high energy based factor on electrical consumption, i.e. multiplied by 2, due to the considerable ammount of electrical energy used with respect to gas and water consumptions. The overall KPI is calcualted by adding up the quarterly electrical, water and gas consumptions multiplied by the quarterly average temperature.*

The equation below is an example of the philosophy behind the calculation of the overall KPI.

E.g.

*Overall KPI for Q1 = ((Q1_Electrical Consumption *2) + Q1_Water Consumption*

*+ Q1_Gas Consumption) * Q1_Average Temperature*

The benefits of setting up a KPI system are considered to be effective in the medium to long term rather than in the short term. This is due to the fact that the set targets with improved KPI's require an ivestment plan in order to reach the target KPI's. It is being suggested that the respective recommended measures in the first energy audit (refer to appendices) are considered in tandem with the target KPI's and financial investment.

Conclusions

Some of the objectives reached include:

- Comparison between energy consumption registered in previous years, between audits and between different months of the year. Detailed data is now available for Q1 & Q3/4 of the year;

- The introduction of Key Performance Indicators list with the objective of defining standard energy consumptions with the possibility of improved targets for the coming years;

Some of the 2016 recommendations have been partially implemented. Others are in the pipeline, these include:

- The installation of PV panels;
- Continuation of new HVAC equipment installation;
- Further changes from T5 to LED lighting.

A minor change to the water storage proposal referred to in the 2016 audit is being suggested. Due to rainwater contamination issues it is being proposed that the reverse osmosis reject is saved and used as a second-class water.

As previously stated, the period between the first and second audit is considered to be too short to implement all the respective recommendations, therefore the recommendations of the first audit are being suggested once more for implementation in the coming years. (refer to appendix D)

References

[1] Irish Energy Center. Good Practice Case Study 12, Energy Use in Cleanrooms. Dublin, 2002.

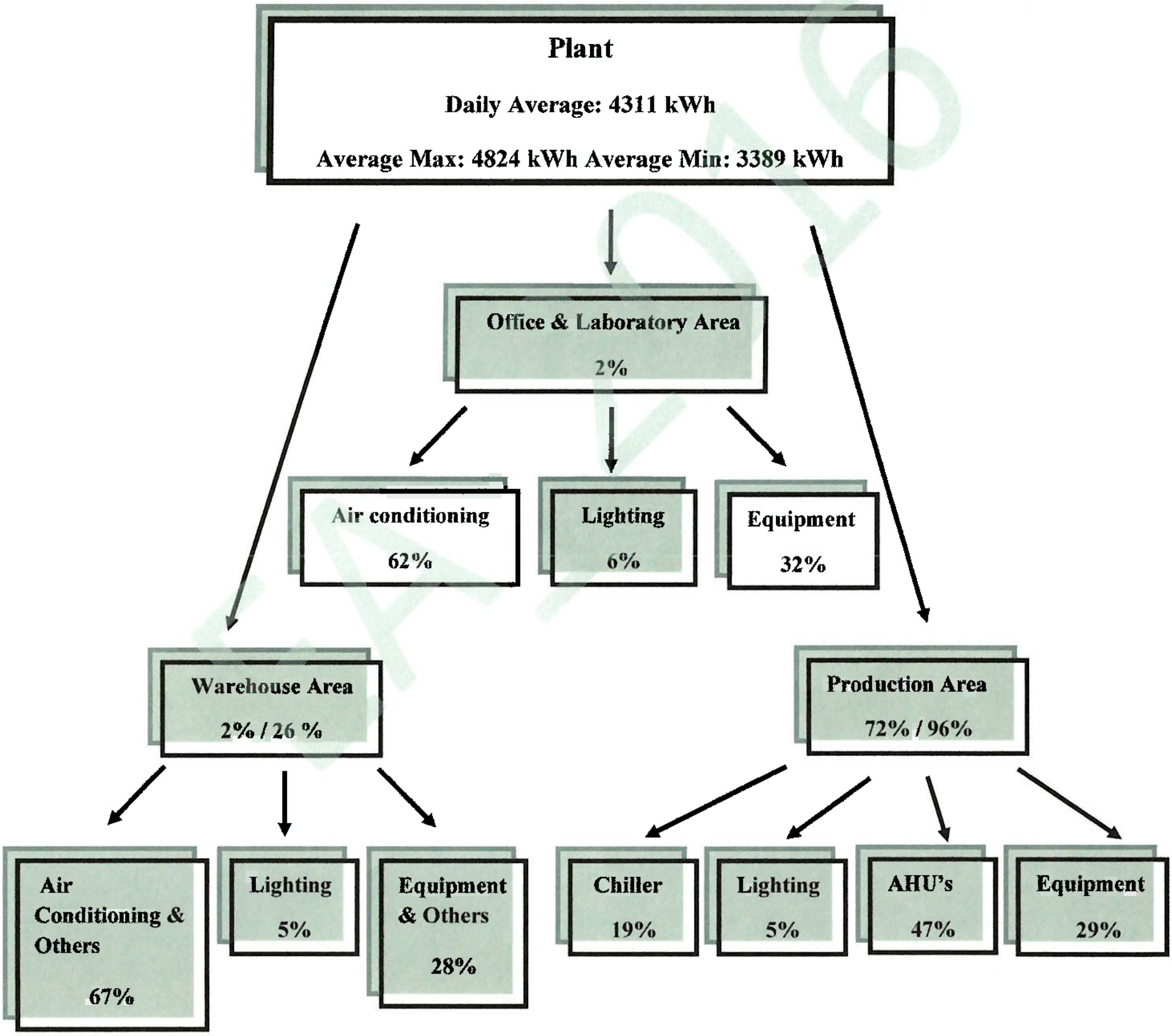
[2] Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). Air Purification in Gene Laboratories. Newsletter No. 2, 1999

Appendices_EA 2016

Appendix A-Plant Energy Consumption Layout

As shown in the figure below, the production facilities are the main electrical energy consumers.

Figure 16. Electrical Consumption Layout_Q1/2016



Offices: The office areas include personal desks with their respective computers that are used for the daily office work;

Laboratory: The laboratory area includes several workstations that are used for daily tests that are carried out as required;

Warehouse: The warehouse area includes the area used to store both the incoming materials and the outgoing products;

Production / Technical Area: The production area includes power consumed by the equipment designated in such area that keeps the atmospheric conditions required. Also including the compressed air system and the production machinery such as the granulator, dryer, coater, blister etc....

The HVAC system mentioned in the warehouse and production area includes several air handling units, chiller system and other split and multi split air conditioners.

The Production Process

The production process is made up of several stages to end up in a finished product. It is imperative that both the ambient temperature and air quality are always maintained at pre- defined levels. Contamination of air between clean rooms with different products is not tolerable at all. The principle of positive pressure between areas inhibit the cross contamination between production areas, service corridors and dressing rooms.

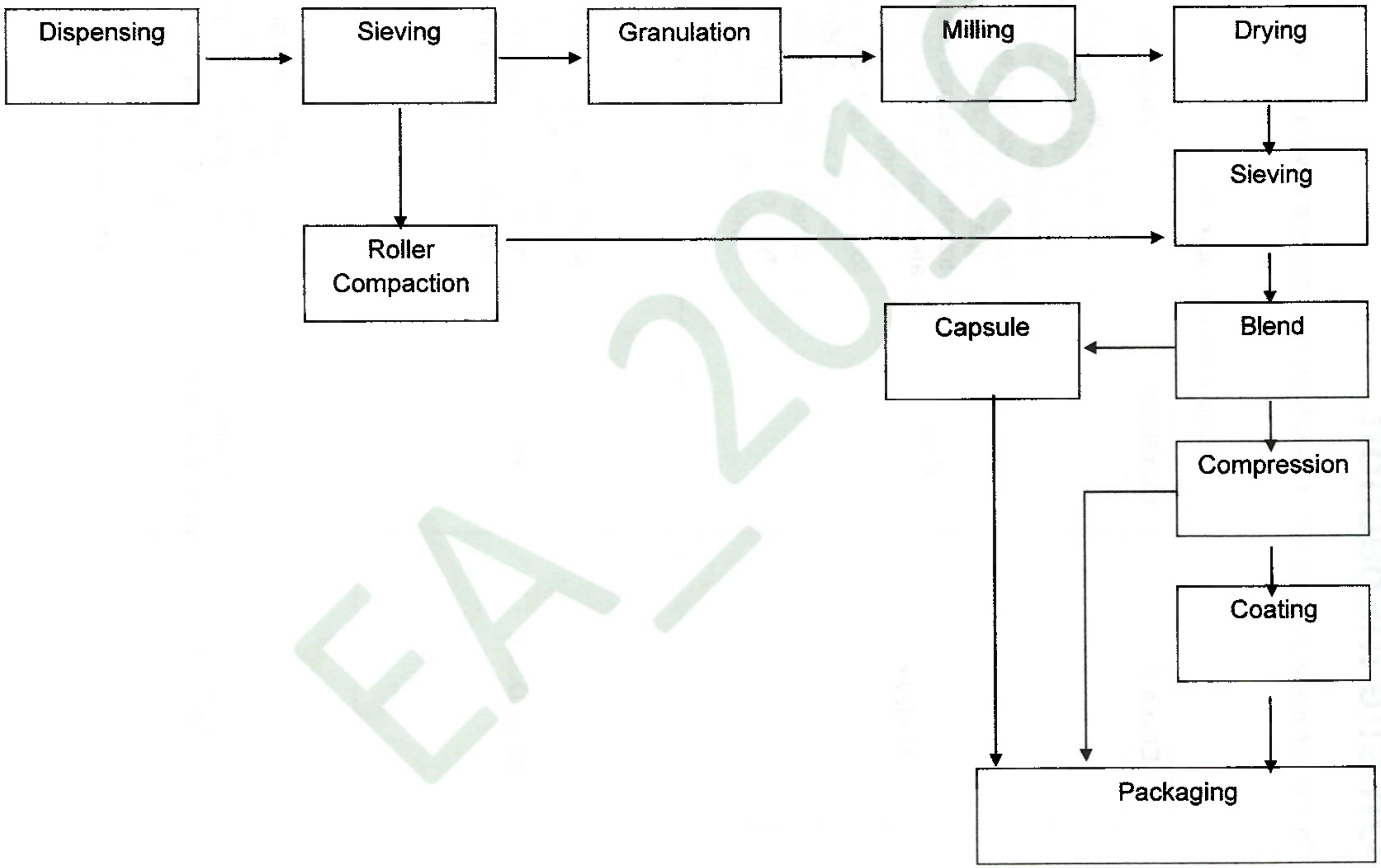
The production process initiates by cleaning of the equipment and machinery used for that specific batch of products.

In general, the plant is operated on 16 hours a day, 5 days a week. This includes the continuous running of the boiler and compressed air system. Other equipment such as the blister and coater are put in service according to the product necessities. On the other hand, the air handling system is always kept in service on a 24/7 basis to keep the production area pressurized. This prevents any contamination and keeps the production process on standby. Such circumstances present the fact that the air handling and air conditioning devices are kept in service during the weekend when no production takes place. Otherwise the production is not ready for use on the next working day.

Process Description

The raw materials are dispensed in terms of weight and according to the process, then are generally sieved and/or compacted. Material is then granulated and milled in order to achieve a particular size. The mixture is then dried in order to reduce the humidity level and sieved according to requirements. The end material is then blended, compressed and coated or otherwise capsuled in particular shapes. The final stage is the packaging of the end product. Such a procedure may vary according to the different requirements of different products. The table below illustrates the flow of the process.

Table 3 Process Description



On-site Inspection

The on-site inspection provides a good basis for a building envelope analysis.

Table 4. On-site inspection

Element	Condition	Remarks
Windows	Good	In general windows are of the double-glazed type with the exception of some on the West facing facade that are of the single glazed type. No excessive heat transfer is deemed to be lost from apertures as the conditioned areas are facing North. East façade louvers add up to 36m^2 and North façade windows 35m^2. West façade is characterized by steel type doors with an area of 12m^2, South façade with a 20 m^2 of louvered apertures.
Exterior Doors	Good	As implies for the windows, glass doors are facing North. On the other facades, louvered doors are installed to aid ventilation in the plant area.
Ceiling/Roof	Needs improvement	In the production area the majority of the ceiling has a double roof system where some of the auxiliaries of the plant are situated. Except for the warehouse and offices. Thus, some recommendations for improvement will be discussed.

Exterior Walls	Good	The majority of the exterior walls are of the double type 7 or 9 inch stone with 10mm air gap. The exterior plastering is painted with a light waterproof media.
Roofs	Needs improvement	The roof is mainly covered with membrane to protect water ingress. Recommendations for improved heat resistance from direct sunlight is discussed
Storage Areas/Warehouse	Good	The warehouse is used to store both the raw materials and the finished goods products
Loading and Unloading Areas	Needs improvement	It is being suggested to introduce plastic curtains at the opening of the loading/unloading areas. This can potentially reduce the heat transferred from the warehouse to outdoor conditions
Lighting	Needs improvement	In general lighting is of the T8 type and varies from fittings including 4 by 36W or 4 by 18 Watts. It is being suggested to introduce T8 LED lighting with PIR sensors in order to reduce the lighting consumption in passageways and other areas that are used in an intermittent way.

Heat Distribution	Good	The heat used in the process is supplied through a boiler fired by gas, which in itself is a highly efficient with low emissions production. It is being suggested to explore new emerging technologies including condensing boilers that reach 90% thermal efficiency.
Cooling Plant	Good	The cooling equipment used for air conditioning is mainly produced from a chiller system which supplies both the plant and office areas. Other split unit devices are used to condition the warehouse.
Power Meters	Needs improvement	It is being suggested to introduce kWh power meters that measure the consumption in the laboratory area and offices area. This would enable to trend consumption over a period of time.
Water Consumption	Needs improvement	The process uses a relatively high-water consumption that is used both during the process and for cleaning and sanitization purposes. A water reservoir is used as a buffer for mains water before treated in the RO system. Proposal for a rainwater reservoir is being recommended.
Compressed Air	Good	Compressed air is supplied by two compact screw compressors, which is then passed through the air hum driers to provide optimal compressed air supply

The following drawing shows a general plant layout with different atmospheric pressures in the designated areas to prevent air contamination.

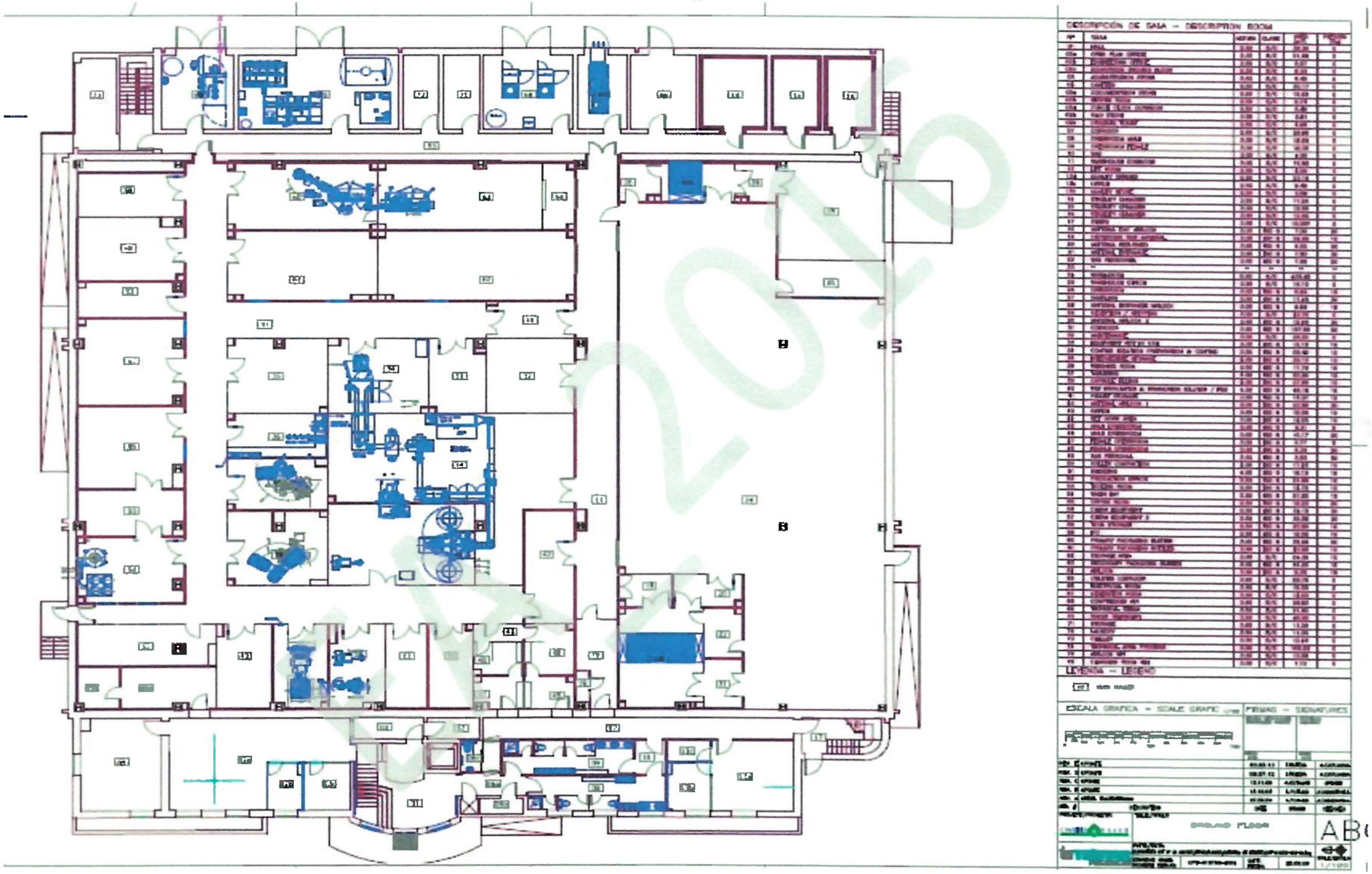


Figure 17. Plant Layout

The illustration below shows the area of concern to the audit. The plant room, the main area of consumption, is partially indicated below. This includes 12 in number air handling units, 2 chillers, 2 air compressors, boiler, reverse osmosis plant, and others.

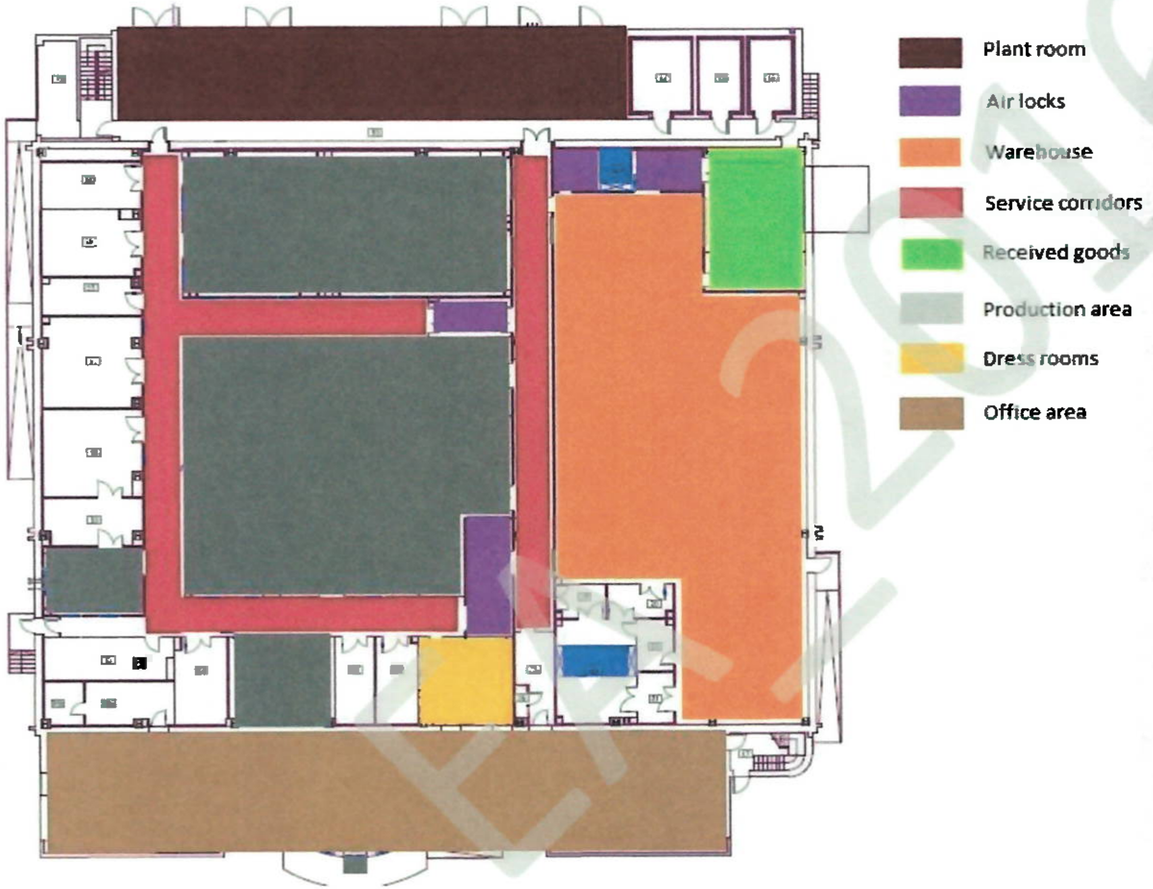


Figure 18. Production Layout

With a total building area of 2500 m2, the main areas of energy consumption are:

- Plant room: 160m2
- Production area: 575m2
- Office areas: 350m2
- Warehouse: 400m2
- Other areas including, corridors, clean rooms / air locks, dress rooms etc....

Appendix B- Systems Layout

In general, the main plant equipment and machinery are grouped in dedicated areas. This consists of the reverse osmosis system, air compressors, boiler, air handling units, chillers, air conditioners and specific machinery. On the other hand, the equipment used for the production itself is positioned in the production area with specific air quality requirements.

The below illustrations show the layout of the main equipment used to support the production process.

Figure 19. Air Compressors

The illustration above shows a set of 2 air compressors that keep the air compressed system at a set pressure. Compressed/service air is used in different stages of the production process. In principle the air compressors work with one in service and the other on standby. Another set of air hum drier, work in parallel with the compressors to reduce the moisture in air to ensure a smooth-running operation.

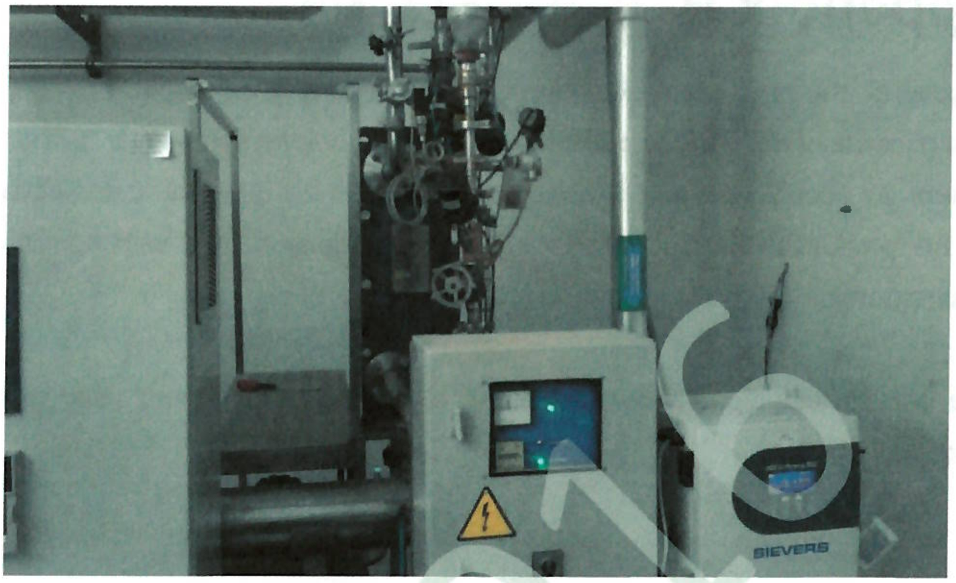


Figure 20. Reverse Osmosis System (RO)

The illustration above shows the water treatment plant which reduces the conductivity of mains water to the required levels as dictated by such a process. In parallel with the RO is the water loop system shown in the next illustration. Such a system is continuously kept in service in order to supply the treated water system around the plant.

Figure 21. Water Loop System

The illustration below shows a gas fired boiler. Such a boiler is kept in service during production hours in order to charge the hot water system used in different stages of production.

Figure 22. Gas Fired Boiler

Figure 23. Dust Collecting Unit

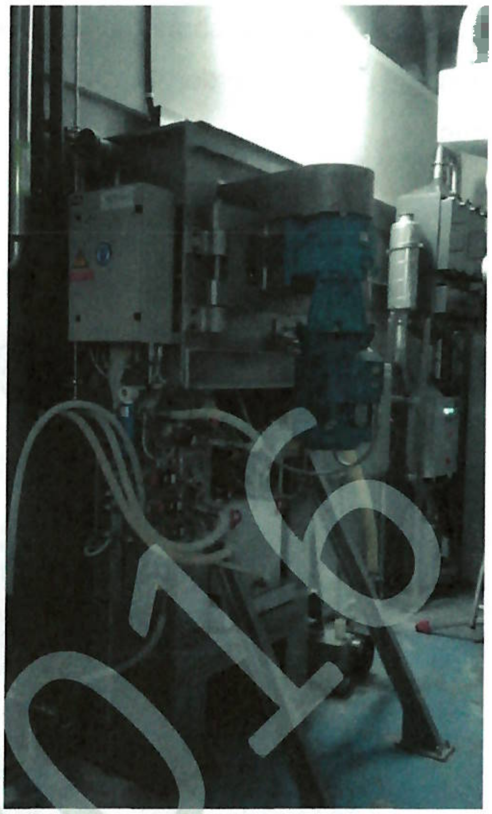


Figure 24. Granulator

The illustrations above show particular equipment that is specifically used during the production process.

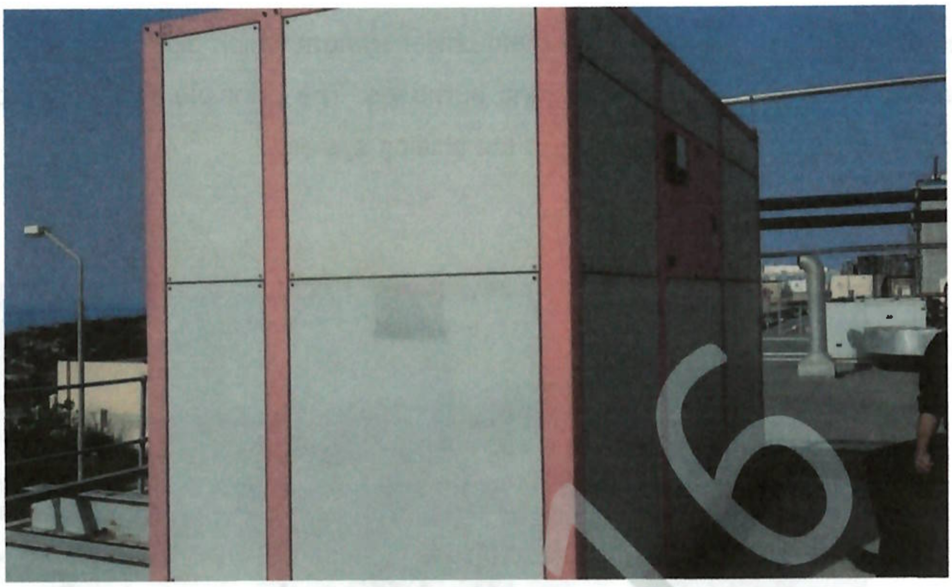


Figure 25. Chiller System

The illustration above shows a chiller system used during a particular process.

Figure 26. Main Chiller

The illustration above shows the main chiller system which distributes cold water around the plant for cooling and air conditioning purposes. The principle of one compressor in service and the other on standby applies to the chilling system.

Figure 27. AC Outdoor units used in the Warehouse Area

The illustration above shows some of the outdoor units that provide air conditioning in the warehouse area.

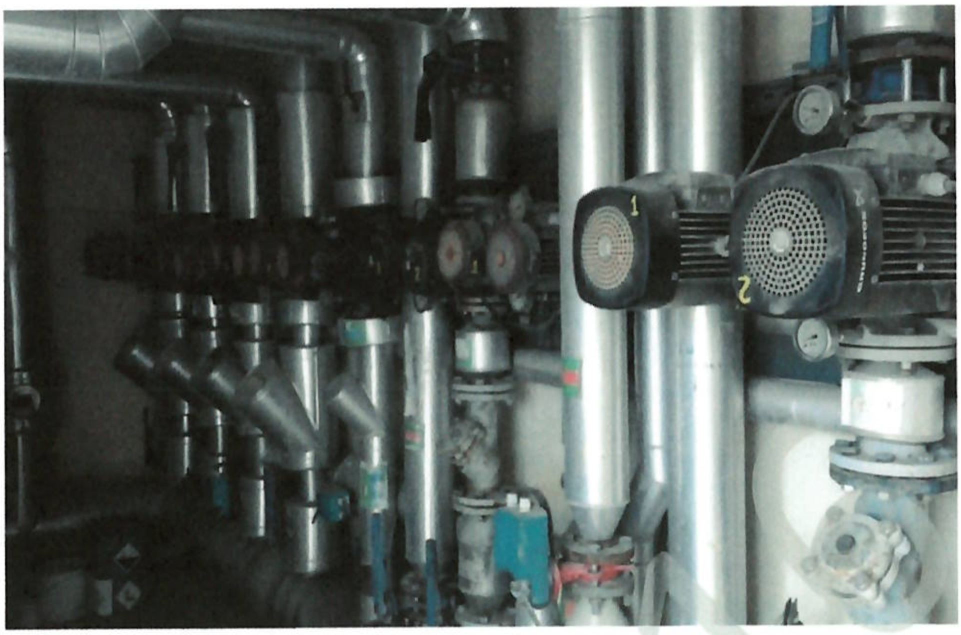


Figure 28. Circulation Pumps

The above illustration shows a system of circulation pumps that circulate the chilled and hot water throughout the plant.

Figure 29. Air Handling Units

The illustration above shows a typical air handling unit system that provides fresh/circulated air throughout the plant and keeps the area at the required pressure and temperature.

Appendix C. Data Gathering and Analyses

As previously explained the data gathering process is initiated by logging power consumed by specific equipment and machinery. This process goes into a particular detail when dealing with high consumption equipment and machinery.

A challenging aspect of the data recording process was the limited number of installed sub meters. Therefore, the data gathering process consisted of real data measurements of power consumed by specific equipment. In parallel with the above, an exercise to identify the number of light fittings, air conditioning split units and other ancillary equipment, including office equipment was done. This was useful to calculate the energy consumed by low power equipment.

The main bulk of the power consumed is absorbed by the air handling units and chiller system that conditions the indoor environment. The compressed air system is also considered as a main consumer of energy. The illustrations below depict the measured & calculated power consumption over the 8-week period, compared with the actual power consumed and measured by the main electrical meter.

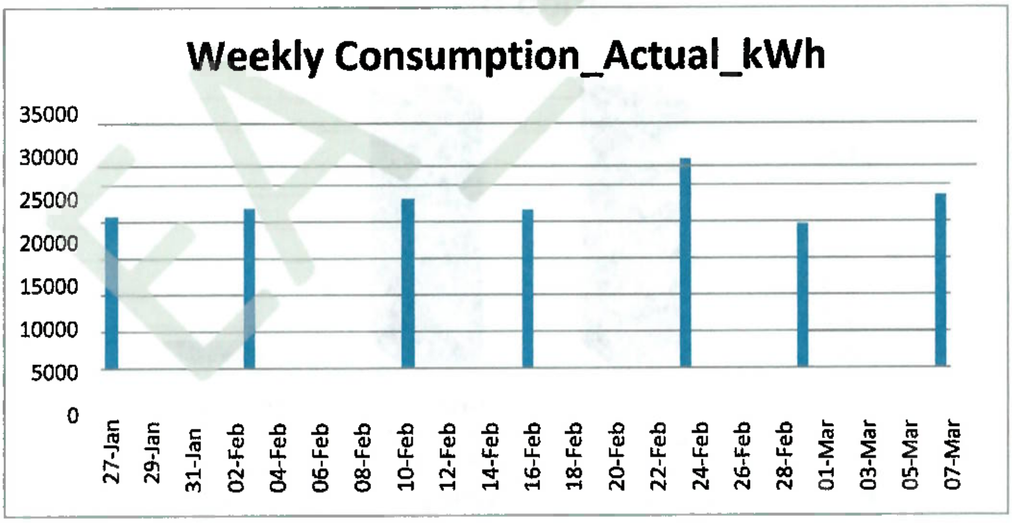


Figure 30. Electrical Energy Consumption on an 8 Week Period

Such a difference is highlighted in the following illustration. It shows that the mismatch between the measured consumption and the actual consumption is less than 2%.

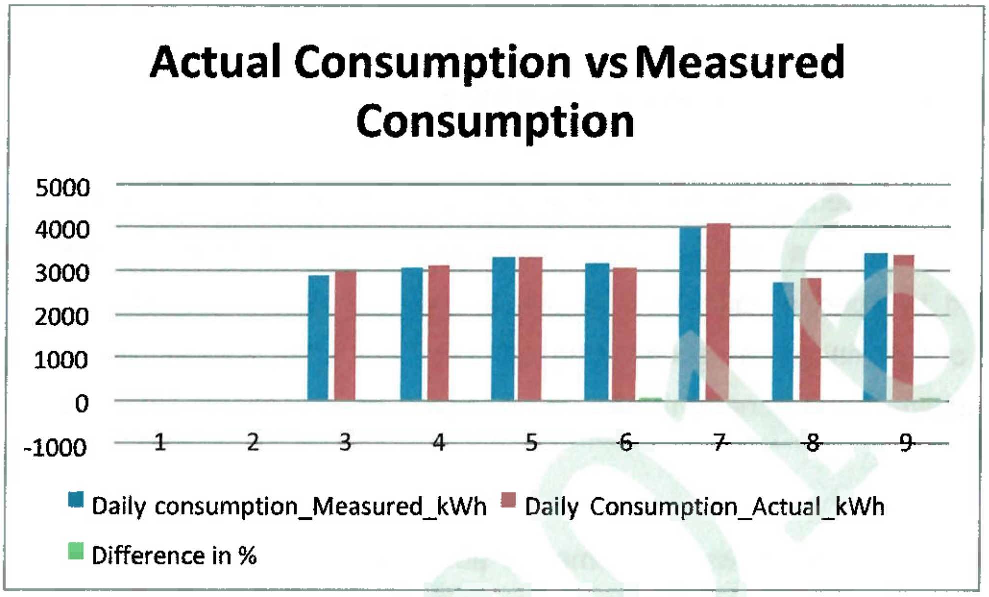


Figure 31. Actual vs. Calculated Consumption in kWh

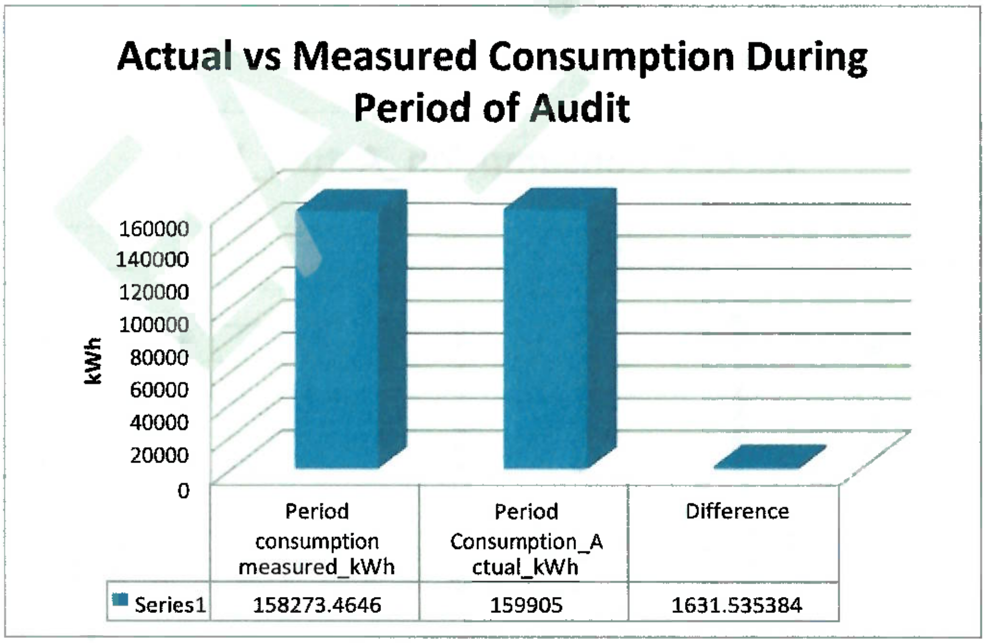


Figure 32. Actual vs. Calculated Consumption in kWh_ During Period

Overview of Electrical Energy Consumption

As previously described the process involves the conditioning of the environment both in terms of pressure and temperature. Thus, the consumption of the air handling units and chillers/ air conditions to keep the indoor ambient conditions, tends to consume the absolute majority of the energy consumed in the plant. The illustrations below show the monthly consumption during the year and the portioned percentages of the total electrical energy consumed on a typical production day during the audit.

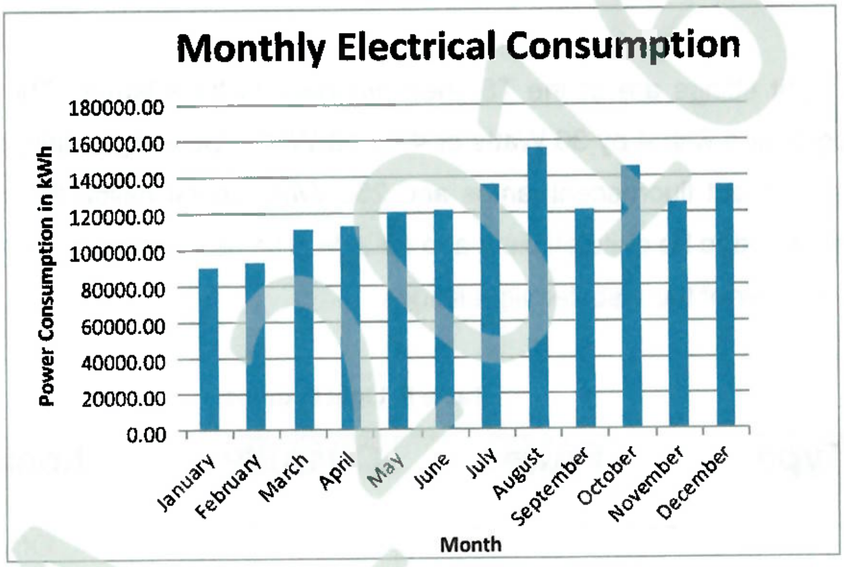


Figure 33. Monthly Electrical Consumption

It has to be appreciated that the above illustrations are representing a period with average outdoor conditions. As earlier explained the difference in outdoor temperature has a direct impact on the energy profile consumed by the plant. Due to the fact that the chillers and ac equipment absorb a large amount of energy, their consumption masters the general trend of electrical load. In general, such consumption reflects the difference in seasonal load profiles.

Lighting

In general, light fittings are of the T8 linear fluorescent tube lamps. These vary from fittings incorporated with 4 by 36 Watts or 4 by 18 Watts. Other light fittings include TC-D 18 Watts compact fluorescent lamps and 250 Watts metal halide lamps. Such light fittings are deemed to be quite efficient and reliable. The table below shows the location, quantity and power of the installed light fittings.

Table 5. Light Fixtures

Type	Power	Quantity	Location
T8 FL	36	174	Offices/ Warehouse/ Laboratory
T8 FL	18	41	Offices/ Production Area
TC-D Compact FL	18	32	Corridors
HID- Metal Halide	250	15	Warehouse
HID	150	15	Outdoor

Therefore, a maximum installed capacity of 13.5 kWh, however not all light fittings are kept in service at the same time in particular at the production and offices area.

The energy absorb by light fittings is in the region of 7% of the total energy consumed by the plant. The below illustration shows the lighting consumption as per different departments. Calculations show that the main consumption of lighting is used at the production area. This is mainly due to the amount of light fittings that need to be in service nearly at all times during production as no type of apertures / skylights are found in the production area. Therefore, it is totally dependent on artificial lighting.

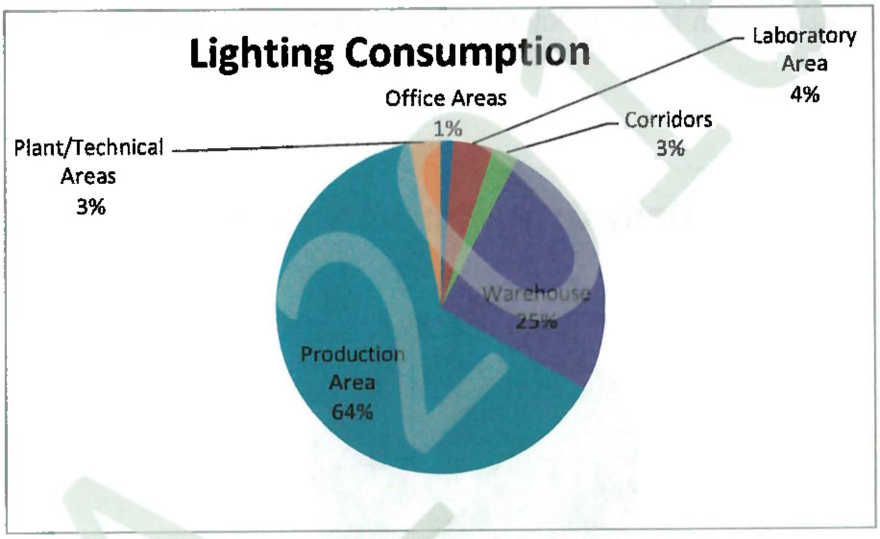


Figure 34. Overall lighting consumption

In the recommendations section, suggestions to replace the fluorescent type of fittings with LED technology are discussed in order to aid the possibility of altering the lighting consumption during the day. This includes:

- Occupancy sensing;
- Providing better energy management for ongoing fine tuning;
- Enhanced reliability and durability.

HVAC System

In general the plant is designed with a chiller system servicing the main area. The coolant running through the chiller is used to cool the air supplied/circulated by the air handling units and other areas including the offices. Others, including the laboratory and warehouse are equipped with split unit systems in order to condition the atmosphere accordingly. The illustration below shows the electrical consumption used by the air handling units and chiller/ac systems on a typical day with average outdoor conditions. As stated, before a day with average outdoor conditions is considered as having an average temperature ranging between 10 to 20 degrees Celsius, thus representing November to April. From May to October is considered to present warm / hot outdoor conditions.

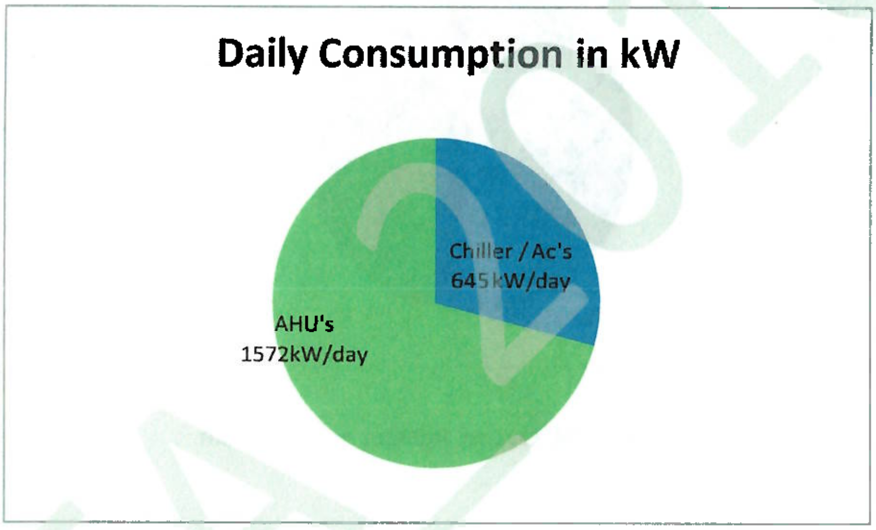


Figure 35. Air Conditioning and Air Handling Units Consumption

The next illustration shows the consumption during average outdoor ambient temperature. This indicates that the power consumed is almost absorbed by the production plant.

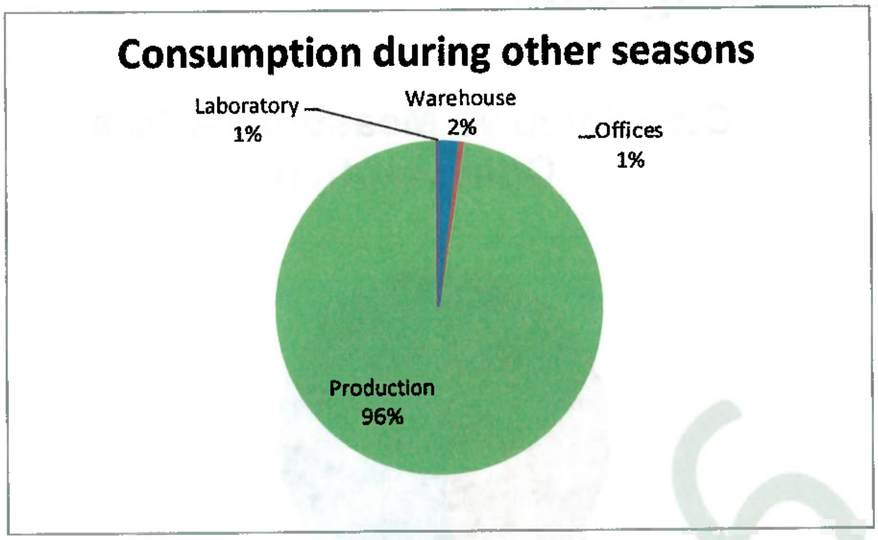


Figure 36. Overview of General Consumption_Average Outdoor Temperature

On the other hand, it is being calculated that during the warm periods the electrical energy consumed is apportioned between the warehouse and the production area.

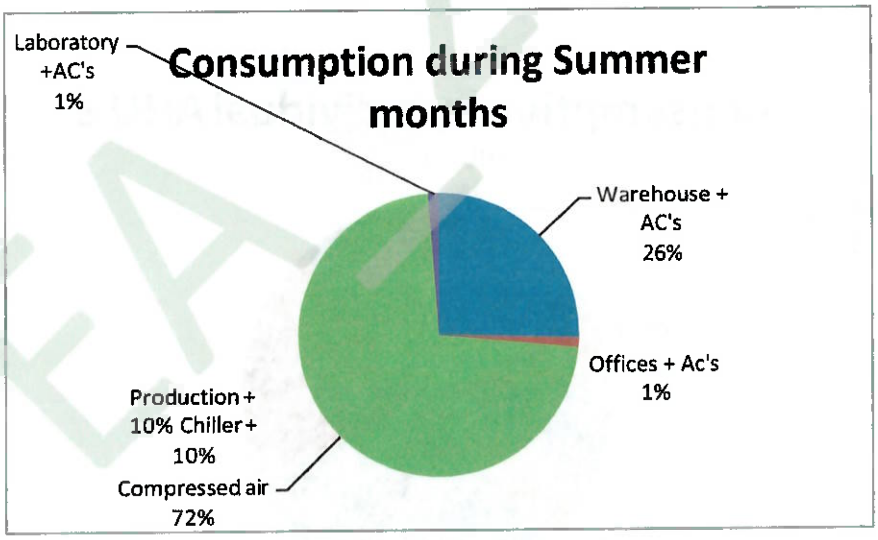


Figure 37. Overview of General Consumption_Warm Outdoor Temperature

Air Handling Units

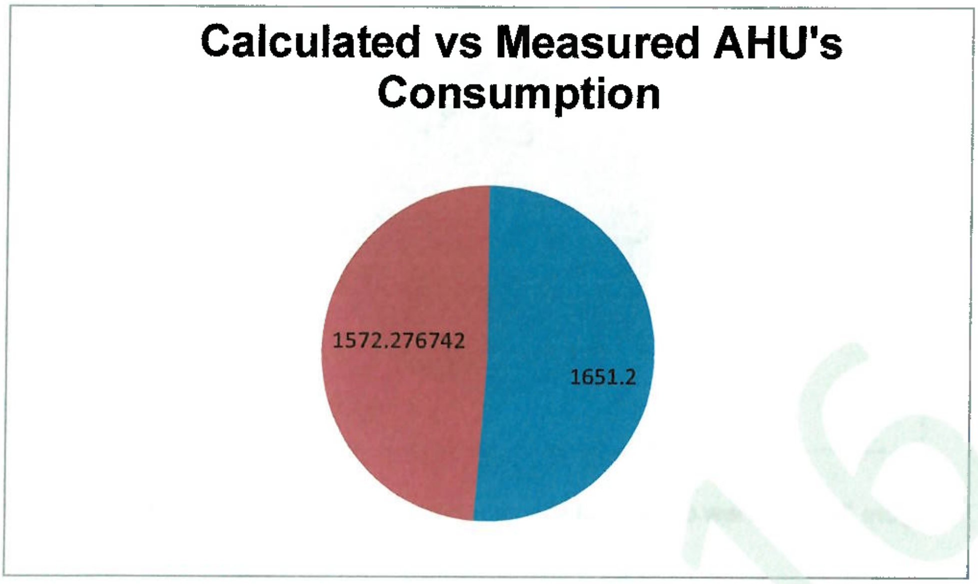


Figure 38. Daily Consumption of Air Handling Units in kWh

The above illustration shows that the difference between the actual power consumption and the calculated consumption, i.e. manufacturer specifications, is relatively low.

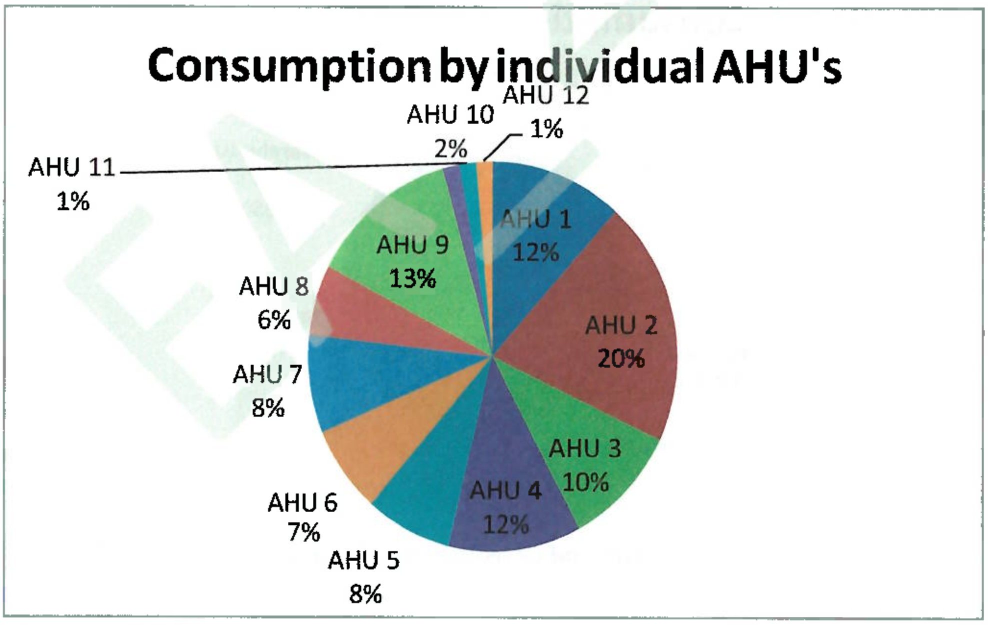


Figure 39. Electrical Consumption of AHU's

Appendix D- Renewable Technologies

The existent roof area available for PV's installation is 1700 m^2. This can be used to contribute towards a reduced consumption in fossil fuel energy. Installation of such a system enhances the energy mix used by the plant and buffer any sudden changes in utility rates. Considering that every 1kWp requires 15m^2 of shade free area a total of 110 kWp system can potentially be installed with a yearly contribution of 170000 kWh of electrical energy. Moreover, this will contribute to a reduced heat transfer to and from the plant due to the shading and cooling effect that the panels create during the hot summer months. This reduces the overall energy used to condition the air supplied. The below illustration shows the potential overall shading pattern of a PV system It is being estimated that 75% of the roof area will benefit from the shading effect with a potential heat reduction transferred from the roof into the plant.

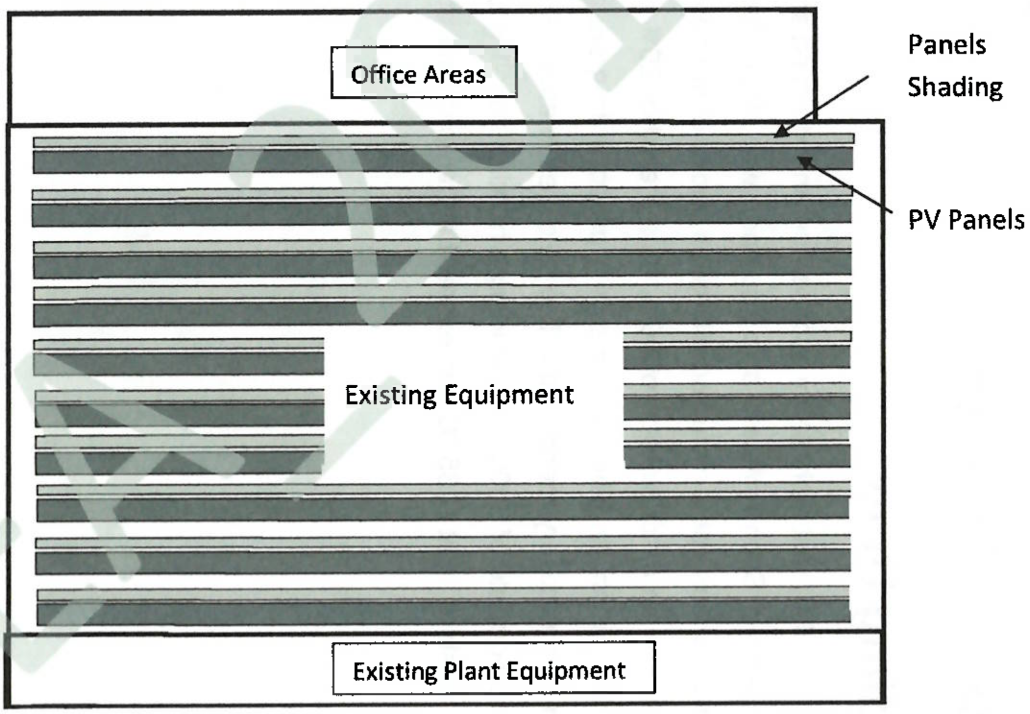


Figure 40. Shading of Photovoltaic Panels

Recommendations

Air Handling Units

The current air handling unit technology is based on an extraction and supply system with integrated heating and cooling coils for air cooling/heating. Such units are also equipped with High Efficiency Particulate Arrestance filters (HEPA). These filters are able to catch contaminants including allergens, mold, dust and others. In principle the AHU's are used to circulate the air inside the plant with an air circulation of 80%, thus the other 20% are deemed to be fresh air. One of the installed AHU's is operated on 100% fresh air. The table shows a proposal to gradually change the AHU's technology to variable type motor with integrated heat recovery mechanism. The below estimations illustrate the replacement of an AHU with a supply of 19500 m^3 and an extraction rate of 3000 m^3, including a heating / cooling coil for air conditioning, and a heat recovery unit with 69% efficiency, at a fresh air inlet of 35 °C and exhaust air temperature of 22°C at a 50% relative humidity.

Table 6 LCCA AHU's

Life Cycle Cost Analysis												
	Year 0	1	2	3	4	5	6	7	8	9	10	11
Initial Cost of Heat Recovery System (€)	€ 18,000											
4% reduction in running cost of Chiller	16997 kWh/year											
Savings per year (€)	0	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192	2192
NPV (€)	€ 17,340.63											
Assuming that a variable drive AHU installed with HRU (both supply / extraction) at a cost of € 18000 Based on cost per unit of 12.9 c/kWh												

The above calculations show that the HRU unit will contribute to annual savings of 968 Euros per year and another 1225

Euros due to the variable drive concept based on 4 hours per day at 25% of nominal load. This new concept can potentially works in parallel with a building management system that triggers the presence of any activity and alters the amount of circulated air accordingly. Such control can potentially be adopted during the whole night from 22:00 Hrs. to 06:00 Hrs when no production is taking place. This doubles the estimated savings, thus reducing the payback period to 6 years. Such a long payback period is mainly due to the fact that the majority of the AHU's are operated in circulation mode, thus reducing the effectiveness of a heat recovery unit. However, the installation of variable drive fan units, can potentially reduce the payback period by half if the load on AHU's is reduced to a minimum during the night hours when no personnel is in the production areas.

Photovoltaic Panels

The installation of PV panels is being considered to contribute in different ways. Apart from the generation of electrical energy, it is contributing to a reduction in heat absorbed by the roof under the panels. The calculated area available of 1700m^2 is deemed as free from any shading that might be experienced during the year. Such an investment contributes to the generation of 170000 kWh of electrical energy per year which equates to about 11% of the total electrical energy consumed by the plant. Such a mix in energy supply can potentially buffer any sudden changes in utility rates and ultimately reduce the net energy consumption used to run the plant.

Table 7 LCCA PV's

Life Cycle Cost Analysis										
	Year 0	1	2	3	4	5	6	7	8	9
Initial Cost of PV's (€)	€ 150,000									
Mean generated units per year (kWh)	170000 kWh									
Income per year (€)		21930	21930	21930	21930	21930	21930	21930	21930	21930
NPV (€)	155,874.53									
Assuming 110 kWp System										
Based on cost per unit 12.9 c/kWh										

Water Reservoir

The yearly consumption of water amounts to 6911 m^3. The aim of this measure is to reduce such consumption by introducing a supply from rainwater. The construction of a reservoir to store rainwater is estimated to save about 1400 m^3 from mains consumption. This reduction will contribute to 22% of the total current water consumption. Moreover such a measure opens new operating strategies by introducing the delivery of water by road tankers, which is estimated to lower the current cost of water from €2.37 per cubic metre to €1.85 per cubic metre, which reduces the overall cost by another 22%. The below LCCA refers to the benefits from rainwater consumption only.

Table 8 LCCA Water Reservoir

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19
Initial Cost of Construction and booster pump set (€)	€ 56,000																			
Water saving per year (m3)	1400																			
Income per year (€)		3318	3318	3318	3318	3318	3318	3318	3318	3318	6636	6636	6636	6636	6636	6636	6636	6636	6636	6636
NPV (€)	€ 56,614.44																			
Assuming reservoir capacity of 1400 cubic metres																				
Based on cost per unit of € 2.37/m3 and € 4.74/m3 in ten years' time																				

Light Management

It is being proposed to change the current light technology to LED type. This is proposed to be installed in the corridors of technical area and corridors of office / laboratories. In parallel with LED technology, the installation of presence detection sensors that permit the frequent ON and OFF switching of lights in order to reduce light consumption is crucial.

Table 9 Estimations_Light Technology

Replacement of Light fittings in Corridors (Qty)	Replacement of Light fittings in Technical Area (Qty)	Total fittings to replace (Qty)	LED Cost per fitting of 45 Euros	Total cost (€)	Cost to install 10 PIR devices on each circuit (€)	Total Cost (€)	Estimated Savings in Corridors due to LED Power per fitting 18W to 5W (€)	Estimated Savings in Techincal area due to LED Power per fitting 18W to 5W (€)	Estimated Savings in Corridors and Technical Area due to PIR assumed at 50% of current usage (€)	Estimated Total Savings per day (kWh)	Estimated Yearly savings (kWh)	Estimated tyearly savings in Euros at 12.9 c/kWh
32	16	48	45	2160	500	1700	13	13	0.96	10.944	2845.44	367.06176

Below is the LCCA that illustrates the savings and the payback period.

Table 10 LCCA Light Management

Life Cycle Cost Analysis									
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Initial Cost of fittings replacement (€)	€ 2,160								
Electrical Energy savings per year (kWh)	2845								
Income per year (€)		367	367	367	367	367	367	367	367
NPV (€)	€ 2,372.00								
Based on cost per unit of 12.9 c/kWh									
Estimated savings of 2845 kWh									

The implementation of the above measure can potentially be extended to the production area; however, it is appropriate to first install in the indicated areas, and then installed all over the plant.