Annex C-5

medichem

2020

Energy Audit Report

Reference Number: EA_MC_12/2020

SCICLUNA &ASSOCIATES

ENGINEERING CONSULTANTS

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Executive Summary

As per LN 196/2014 transposing the Energy Efficiency Directive 2012/27/EU an enterprise is bound to carry out a second energy audit by not later than 5th December 2019*. The following audit illustrates the energy consumption at Medichem Manufacturing Ltd a pharmaceutical company that operates from its' plant at HalFar industrial estate. The building has an overall area of 3600 m^2 spread on different levels. The analyses show areas of energy consumption mainly electrical energy, water and LPG. The data gathering and analyses strategy are in compliance with LN196/2014 and based on the ISO 50002 guidelines. The premises audited are being divided into 3 main areas;

- **Production Area;**
- **Administration area;**
- **Warehouses.**

Yearly consumption of the energy resources includes:

Electrical energy; Supplied from the main electricity provider, accounting for 0.502 kg of CO^2 for each kWh produced, (estimated on power plants run on LNG) with 2,709,140 kWh of electrical energy consumed in 2018;

Gas consumption; used to run the boiler that supports the production facility with hot water supply. A consumption of 33,570 m^3 of LPG was registered in 2018;

Water consumption; mostly used in the production process with a consumption of 7561 m^3 in 2018.

Nitrogen consumption; with a consumption of 483,560 Kg in 2018.

Scicluna & Associates are engaged as a consulting firm to carry out a full energy audit of the activity.

*An extension to the 6th of March 2020 was approved by the Energy & Water Agency

Statement by the Directors

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

Signature:

medichem
Medichem Manufacturing (Malta) Ltd.

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

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Background

In general the products produced by the plant at Hal Far are pharmaceutical products that are subsequently used as raw material for other industries. The plant consists of an outdoor and an indoor warehouse, an area dedicated to offices, a laboratory area and the actual production area including the ancillary equipment that backups the process.

Due to the fact that the production process requires strict air quality conditions, i.e. free from any contaminants, a number of air handling units including heat exchangers to cool/heat the air supplied, are continuously kept in service. Moreover, the atmospheric conditions of different plant areas are kept under positive pressure in order to eliminate the risk of cross contamination between processes. Special equipment including personal protective equipment is used to prevent contamination of air.

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

Figure 1. Aerial View of Site

Address of premises: HF 61 Hal Far Industrial Estate, Hal Far. Malta

Energy Audit Plan

Following the first energy audit in 2016 a detailed description of the energy consumption was made available. The trends and consumptions of the electrical, water and LPG are known. The variations in daily, weekly and monthly consumptions were also highlighted. The second audit takes into consideration the following aspects:

- An on-site inspection, which provides an updated building envelope status;
- An updated analysis of energy consumption including any changes in operational aspects;
- The introduction of a scheme indicating some of the Key Performance Indicators (KPI's) dedicated to energy consumption;
- Evaluation of previous recommendations, their implementation and plans for the future;
- Observations and further recommendations.

This energy audit scheduled on a monitoring period of 8 weeks, includes data acquired and analysis of the energy and resources consumed. The months of data gathering includes the end of quarter 3 and quarter 4 of the year. This enabled the analysis of different energy consumptions in the transition months from Summer to Autumn, considered to be an interesting period with regards to energy consumption vis a vis ambient conditions.

Considering the fact that the first energy audit focused on energy consumptions in quarter 1, combining the results of both energy audits provides a good base for data analysis throughout the whole year. This is crucial to highlight the differences in consumption due to different ambient conditions.

With regards to the energy audit requirements it is being declared that there are no transport activities related to the activity.

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.

Data Measurement Plan

The points of main electrical consumption identified are as follows:

Specific equipment used during operation:

- Production machines;
- Cooling/Heating circulation pumps;
- Vacuum pumps;

Other supporting equipment:

- Air Compressors;
- Chiller (large);
- Chiller (Small);
- Air Handling Units;
- Reverse Osmosis;
- Boiler;
- Offices/Laboratory;
- Warehouse;

The measurement duration includes a weekly log of the above energy consumers during the 8-week period of audit. The measuring instrument used is calibrated accordingly in order to ensure accuracy and repeatability of results. Water and Gas consumption data is based on main integrators that are logged on a weekly basis.

Building Envelope

The structure of the building is made of different building materials with a squarish layout. These include “franka” stone walls, bricks, concrete walls/ceilings and steel structures. The façade is characterized by “franka” stone walls which in general are of the double type. The roof is mainly made of concrete and steel structures.

Given that the building is fully detached from surroundings aids the use of natural lighting. Such an advantage is not being exploited to the full as the offices are situated on the North facing facade which provides much less light than the rest of the other sides. The South facing façade is characterized by louvered steel apertures that aids natural circulation in areas used for plant equipment. These include the boiler room, reverse osmosis, circulation pumps, switchgear rooms etc...

The illustrations below show the 4 main facades of the building.

Figure 2. North facing facade

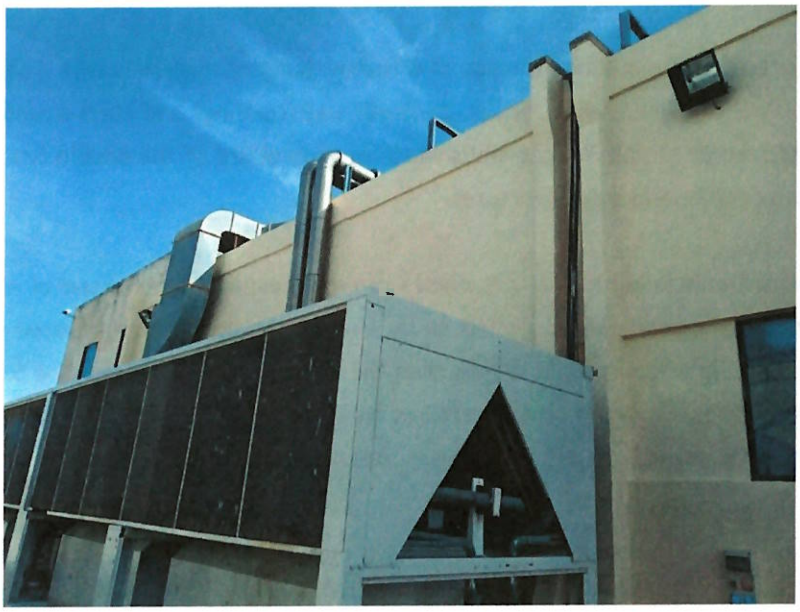


Figure 3. West facing facade

Figure 4. South facing façade building envelope

Figure 5. South facing façade plant equipment

In general, the South facing façade consists of 20 m^2 of louvered apertures that aid the natural ventilation into the respective areas. Some other 15 m^2 are closed with fixed steel doors and some 4 m^2 of glass windows. Both the fixed steel doors and windows have room for improvement by introducing shading mechanism to reduce the heat transfer from the summer heat coming through the building.

The West façade which absorbs heat during sunset has 10 m^2 of single glazed windows and 8 m^2 of steel doors. The installation of louvers to aid shading during the hot summer months will have a positive impact on the heat transfer.

The North façade has about 50 m^2 of double-glazed windows, while the East façade has a low aperture to wall ratio which further benefits from the shading provided by the warehouse structure.

The building envelope including the production area, warehouses and offices area has a total footprint of 2700 m^2 with a total area of 8300 m^2 (including the area dedicated to the auxiliary equipment, laboratory, water treatment plant and others)

The glazing used in most of the apertures is made of double-glazed glass which provides improved U-values, thus a reduction in heat transfer to and from the building. The illustration below shows a low glass to frame ratio on the apertures facing South façade.

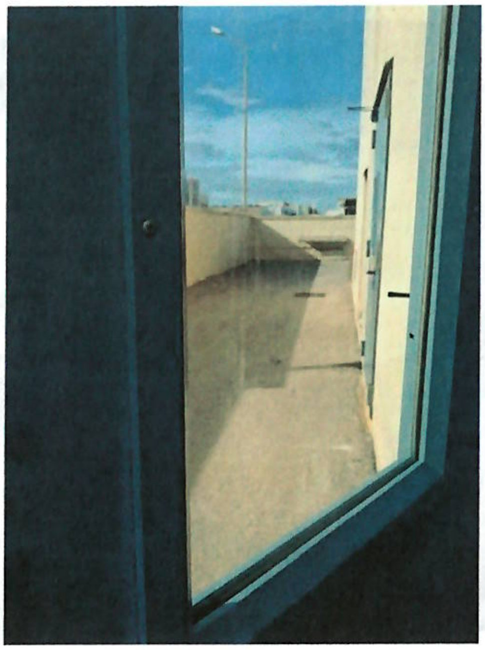


Figure 6. South facing facade

The figure below shows the apertures for the indoor warehouse with a temperature-controlled environment. Such apertures are of the single glazed type which is being suggested to change to double glazed low U-value type of glass. This will greatly improve the building heating and cooling efficiency.

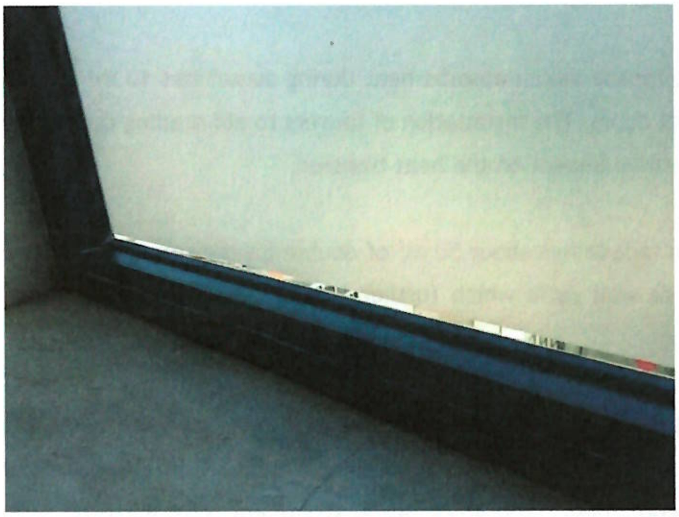


Figure 7. East facing facade

Occupancy

The table below shows the different areas dedicated to their respective activities:

Table 1. Areas occupied by different activities

Activity	% of total area	2016 (m^2)	2019 (m^2)	Changes
Production	43	1730	1730	No changes
Indoor Warehouse	21	816	816	No changes
Outdoor Warehouse	10	400	400	No changes
Plant rooms (auxiliary equipment)	6	200	200	No changes
Circulation, toilets and other common areas	13	500	500	No changes
Offices	4	145	175	Slight changes
Laboratory	3	125	95	Slight changes
Overall	100	3900	3900	No changes

Data Logging and Analysis

The technical personnel responsible for the day to day running of the plant logs weekly readings from the energy meters. This was helpful in the determination of power consumption profiles and their changes with respect to the different times of the year. Moreover, an intensive power consumption logging process spread on a period of 8 weeks covering end of August, September and mid-October was crucial to anlayse the behavior of major power consumers mainly HVAC and utilities equipment. The HVAC system needs to keep not only the temperatures and humidity but also the right ambient conditions in terms of atmospheric air pressure and air particulates. Power consumption of other non-metered equipment was calculated from data sheets as per quantities installed.

As previously described the production itself requires attention to prevent cross contamination. The principle of positive atmospheric pressures in designated areas is imperative to keep up to standard.

The production plant is operated on weekday basis, with the main plant equipment kept in service during these hours. During the weekend some of the equipment is kept in service including the main chiller, air handling units and other auxiliary equipment, in order to keep the production areas clean.

The following illustration shows the actual electrical power consumed compared to the measured data from power logging meters during the period. The same applies for other utilities, mainly water and LPG.

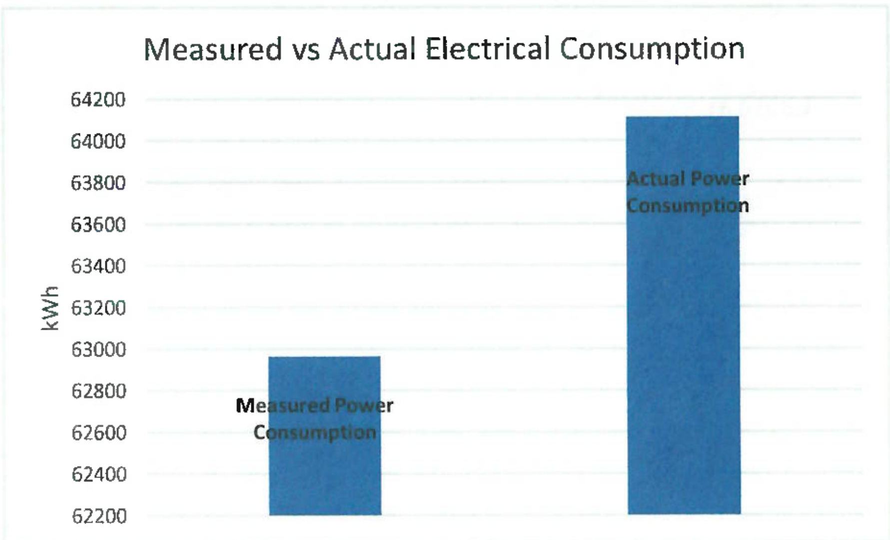


Figure 8. Accuracy of Data_Weekly_Average

The above shows the high accuracy of the data gathered, in terms of the power consumed by the equipment that was calculated according to hours in service. The data gathering process concentrated on real data logging of high consumption equipment and calculated consumption on low power consumption units. This resulted in 98% accuracy of results. Such data provided a solid base for analysis which potentially contributes for practical energy savings.

The data gathered during the energy audit covers August, September and October. During such a period the electrical energy consumption is seen to be reduced due to milder ambient conditions. At the same time the LPG consumption is observed to increase due to the lower temperatures. With regards to water consumptions no patterns between Summer and Winter periods can be observed.

Electrical Consumption

As highlighted in the previous energy audit the high consuming electrical equipment includes the chiller system, based on 2 main chillers one referred large and the other referred as small. The other most consuming are the air handling units and the air compressors system. The total consumption of such equipment equates to 56% of the total electrical consumption (based on average consumption of Q3/Q4 of 2019). Such chillers consumption is substantially higher than Q1 of the year 2016. The following illustrations show the weekly electrical consumption between August and October.

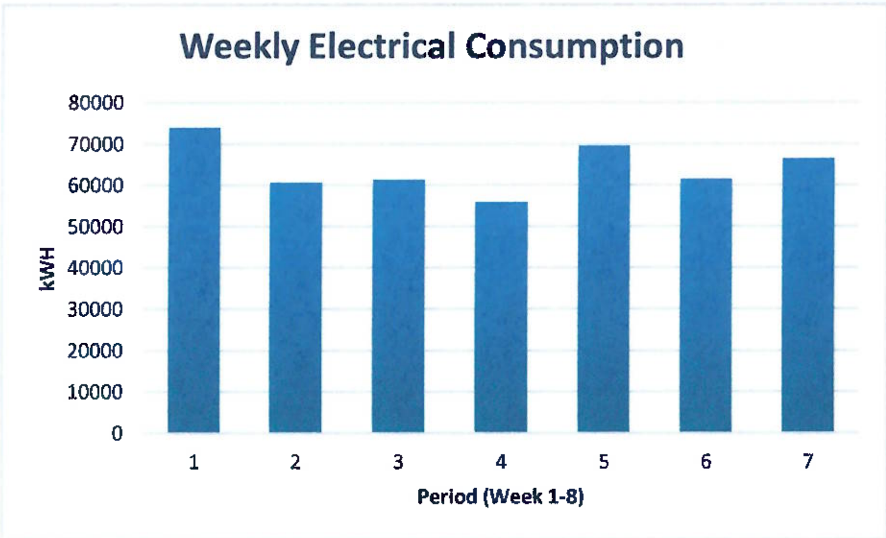


Figure 9. Weekly electrical Consumption during period of Audit

It has been noted that due to the heat generated by the process, including hot water used in the production, a minimum demand for cooling is always active irrespective of the outdoor conditions. The data shows a trend of reduction in electrical energy due to lower ambient temperature. The figure below "Electrical Consumption Trending" shows that the consumption trends established in 2016 are still experienced today with a direct relation to ambient temperatures.

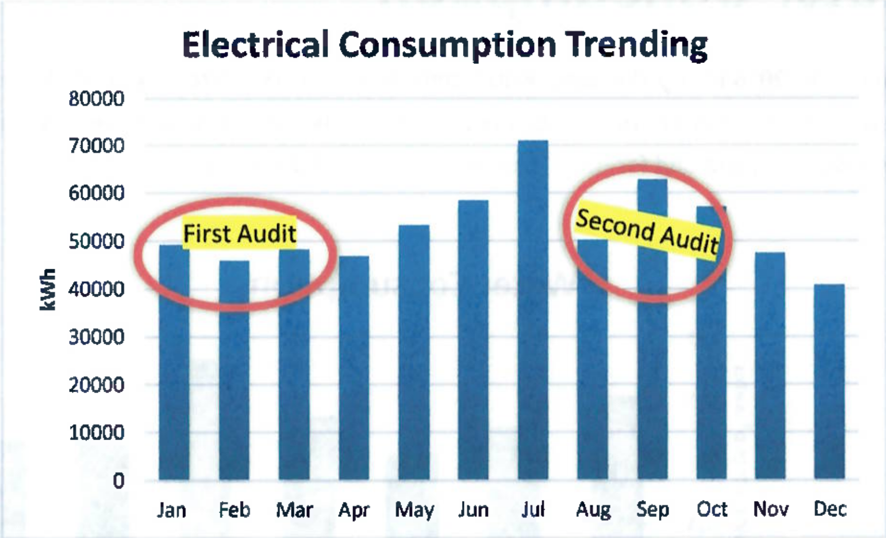


Figure 10. Electrical consumption during the year

The figure below shows the average temperature gradient in Malta throughout the whole year.

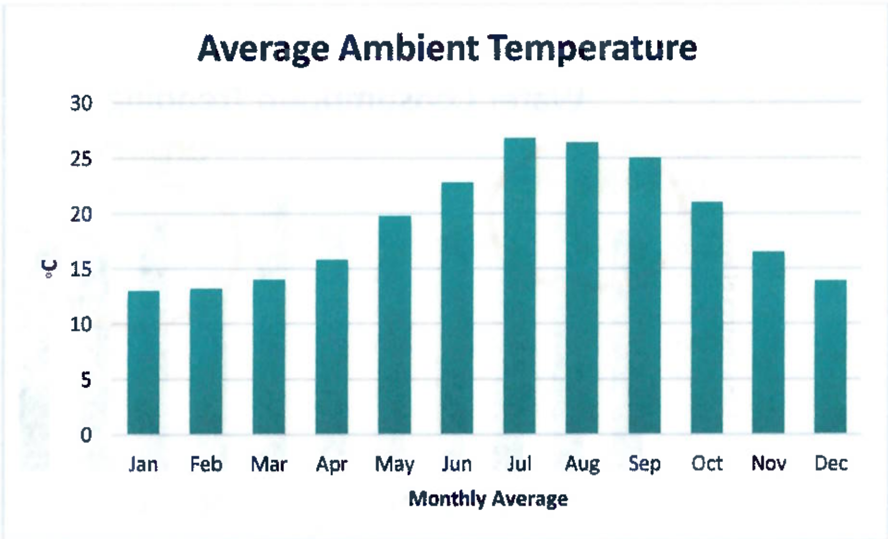


Figure 11. Average yearly ambient temperatures

Water Consumption

Compared to 2016 nearly the same water consumption levels were observed. Water is an important resource used daily in the running of the plant which is used for pure water production through the reverse osmosis plant and for other uses as required in the process.

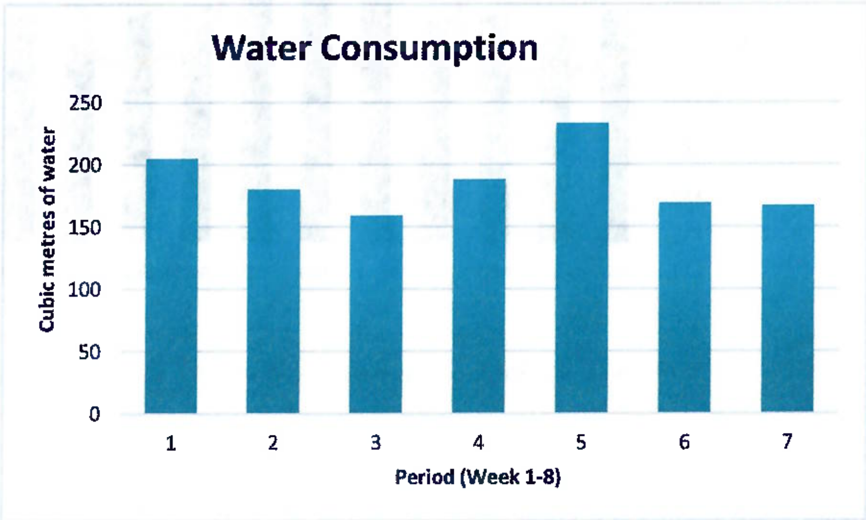


Figure 12. Weekly water consumption during period of Audit

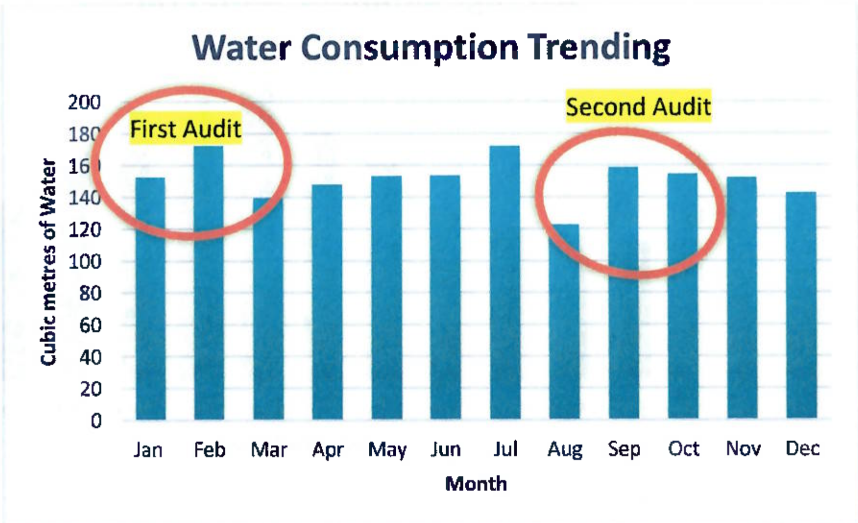


Figure 13. Yearly water consumption

As shown in the above illustration no trends or seasonality factors can be noted in the water consumption.

Gas Consumption

LPG consumption is used to run the boiler to produce hot water used in the production process. Such consumption is considered to follow a seasonal pattern, with a high consumption during the winter cold months due to higher hot water demand.

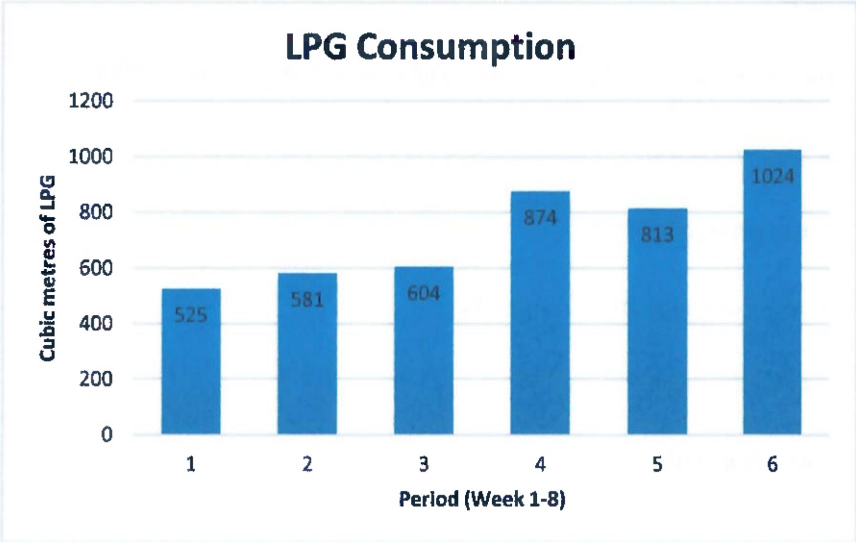


Figure 14. LPG consumption during period of Audit

The below illustration shows the gas consumption trends with a gradual increase in demand in September constantly reaching a high at the peak of the Winter season.

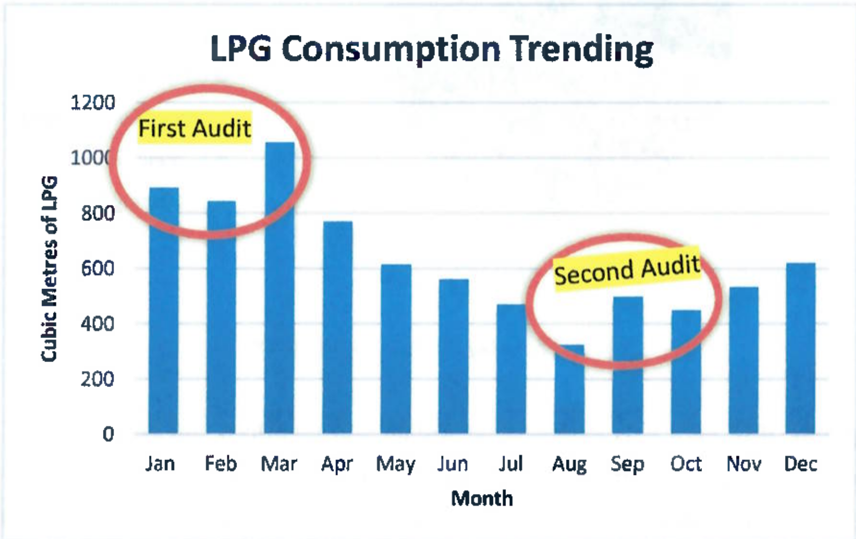


Figure 15. Yearly LPG consumption

Consumption-Analyses

The following illustrates the main high consuming electrical equipment identified and respective power consumption.

These include:

- Chillers, one depicted as L for the main chiller and S for the smaller one;
- Air handling units;
- Air compressors;
- Office's consumption, AC's, lighting etc...
- General Lighting consumption;
- Other equipment.

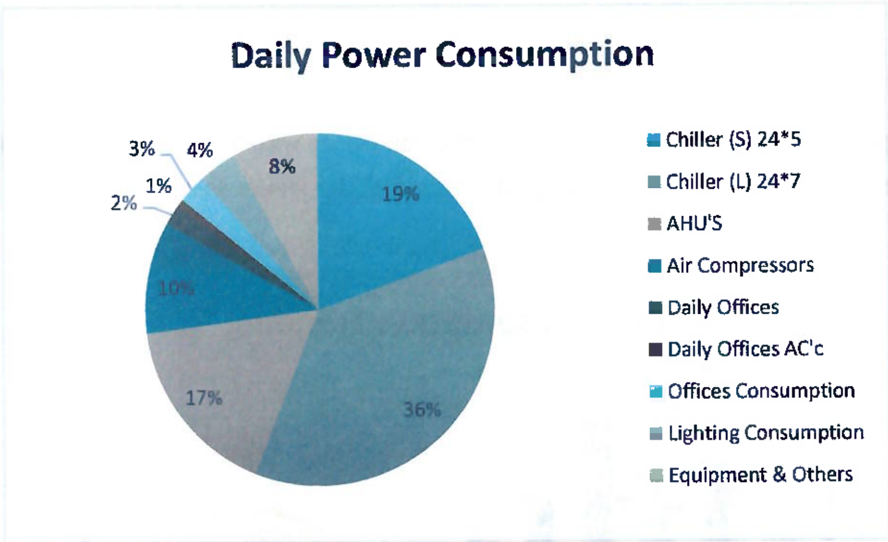


Figure 16. Daily power consumption

On Comparing 2016 data it is evident that similar consumptions can be observed. The main difference identified is the chillers consumption. This difference is attributed to the different ambient conditions mainly warmer ambient conditions which demand higher cooling requirements.

HVAC Consumption

A detailed analysis of the HVAC equipment shows that the air conditioning requirements are mainly apportioned between the air handling units and chiller system. It is noted that the main chiller consumption contributes to the main portion of energy consumed. Such a chiller system feeds the heat exchangers of the AHU's and supports cooling of equipment used during the process.

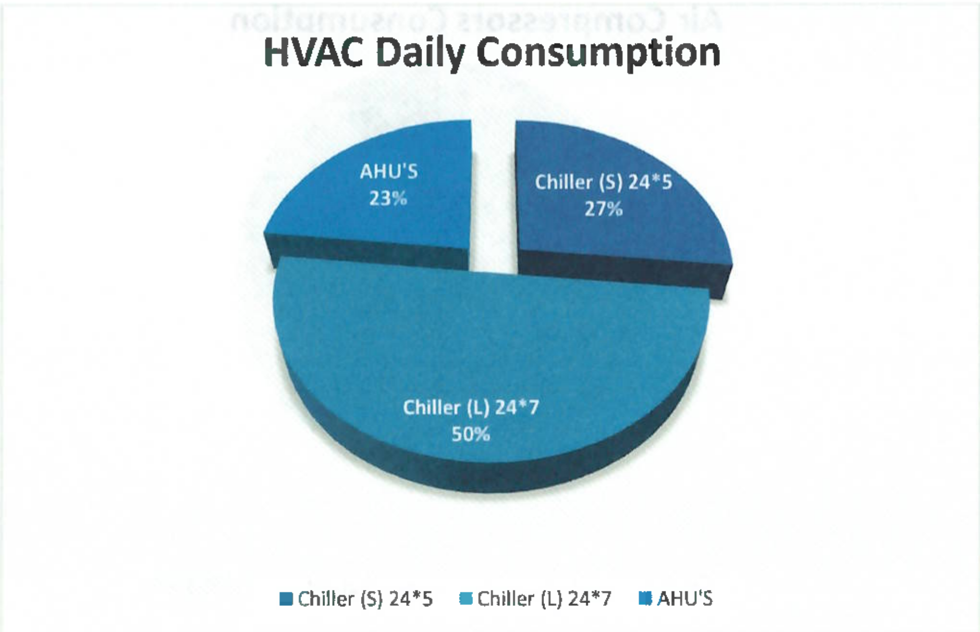


Figure 17. HVAC Daily Consumption

The air handling units, 6 in total, are considered as a single pass unit. These air handling units are equipped with heating and cooling coils that condition the supplied fresh air according to the set requirements. Given that the main chiller scored as the main electrical consumer in both audits the slightest efficiency improvement on the system will drastically improve the plant total efficiency, refer to recommendations for further details.

The following illustrations show the consumption of other high consuming machinery with respect to the total electrical power consumption.

Plant Equipment

As previously described the air compressors system is one of the main electrical energy consumers. Comparing 2016 data vis a vis 2019 data, refer to appendices, a slight increase was noted. This is being attributed to production requirements and to higher humidity during the audited period. It is understood that higher humidity requires higher air consumptions in order to complete the drying cycle.

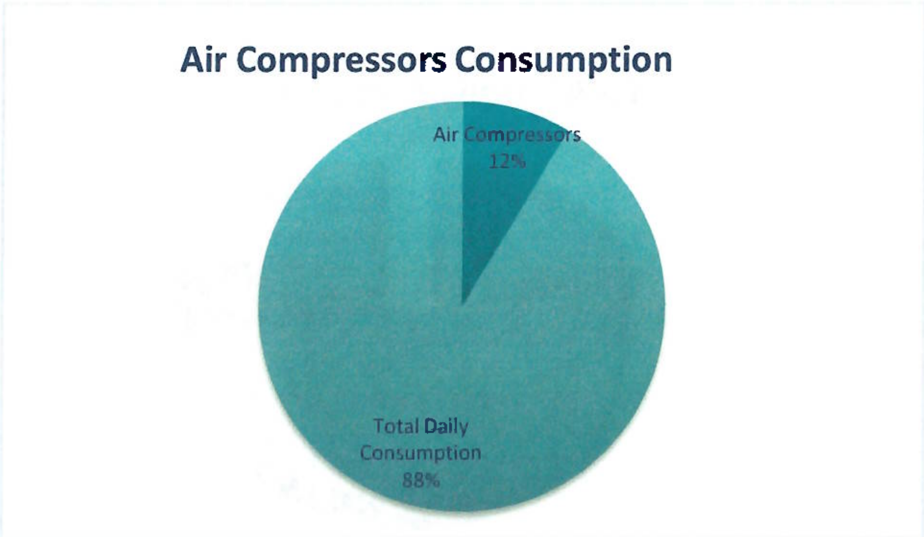


Figure 18. Consumption of Air Compressors System

Lighting

The lighting philosophy described in the previous audit is still in place; refer to appendix F for further analysis. Improvement was noted as some light fittings were replaced by LED lighting, thus further improving the energy efficiency. It is being suggested that the coming audit analyse the savings of such a measure.

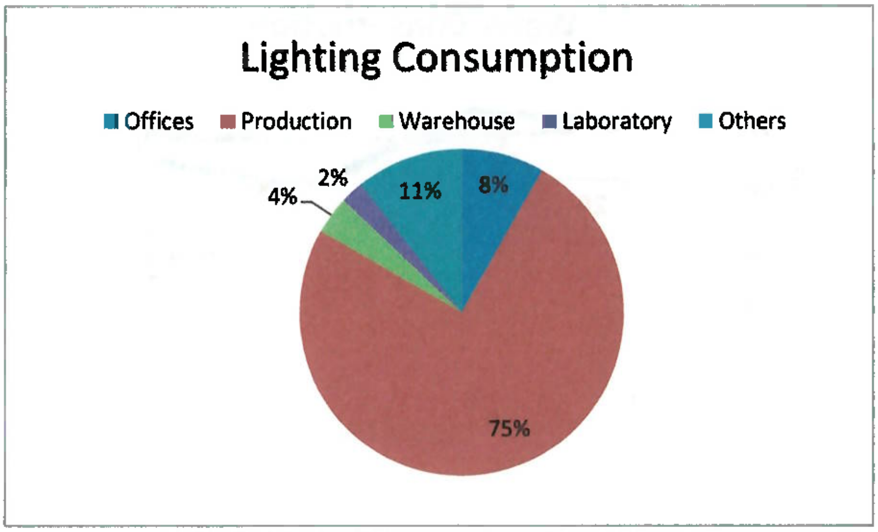


Figure 19. Lighting Consumption

The previous lighting capacity of 13.5 kWh in 2016 is estimated to experience a 10% reduction due to the introduction of LED technology. Further light fittings replacement and the introduction of PIR systems, as per 2016 recommendations, will contribute to a significant decrease in the overall electrical consumption of the plant. It is being proposed that such an investment continues thus addressing most of the consumption.

Consumption Trends- 2015 vs. 2018

Water consumption: Mainly used for the daily plant requirements including topping of evaporated water from cooling/heating system, cleaning of equipment, plant requirements and others. It is also used for cleaning purposes of the premises, warehouse etc....

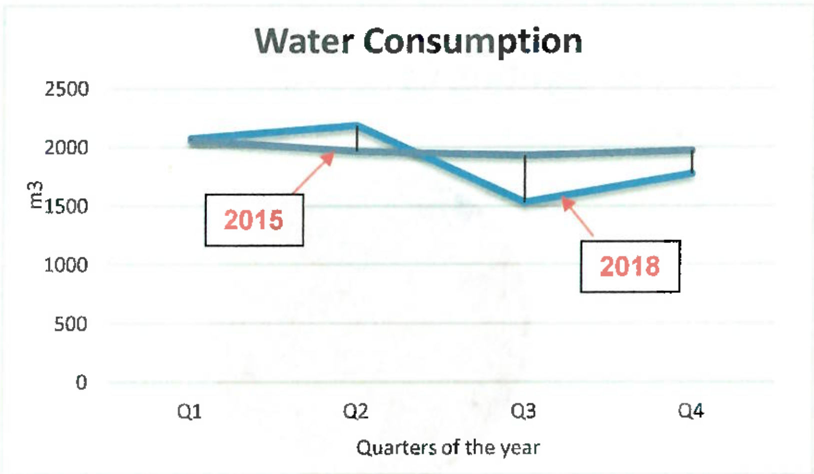


Figure 20. Quarterly Average Water Consumption

The above shows quarterly consumption for the years 2015 and 2018. Such consumption is constant throughout the year with no seasonality factors. All the water consumed is coming from the mains water supply.

Electrical consumption: The year to year electrical consumption shows nearly the same levels and trends with a minimum consumption during the Winter months and a higher consumption during the Summer months. The figure below illustrates such a trend.

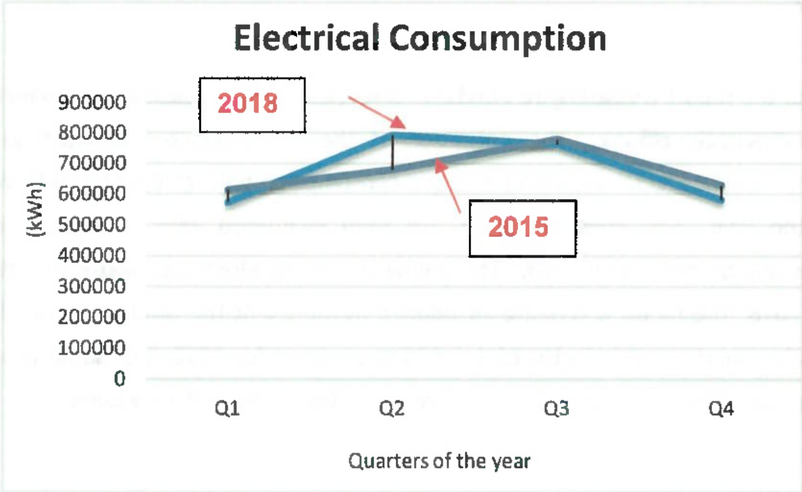


Figure 21. Quarterly Average Electrical Consumption

Gas consumption: The gas consumption is considered as a seasonal dependent type of consumption. It is clearly shown that consumption peaks during the winter months and reach a lower level during the summer months. The gas fired boiler is deemed to be the most thermal efficient process to produce hot water/steam.

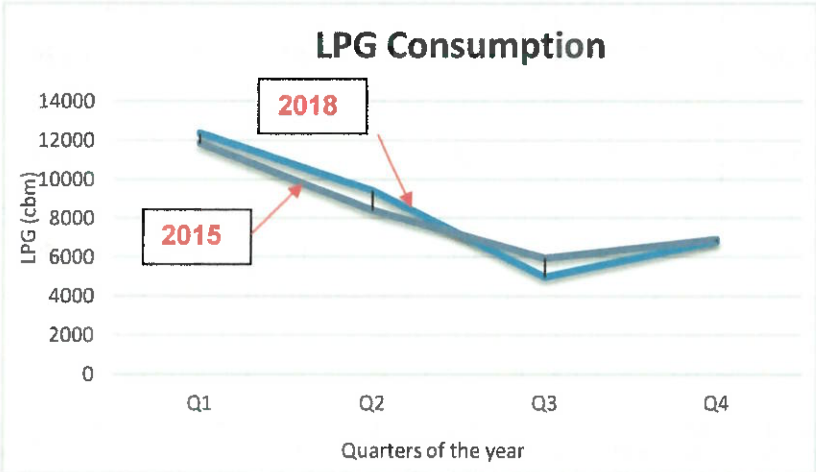


Figure 22. Quarterly Average Water Consumption

KPI's

This section of the report is suggesting the introduction of key performance indicators that set energy targets to improve energy consumption efficiency. The definition of the performance indicators suggested consist of 3 variables. Electrical, water and gas consumption will reflect the KPI's for each quarter of the year. The quarterly KPI's are then evaluated with respect to outdoor temperatures and products produced. The below shows the electrical, water and gas KPI's for the year 2018. The factor k is being introduced to represent the production numbers for these particular quarters. A k factor of 1 is being assumed for 2018 (i.e. same production levels throughout 2018), this has to be adjusted according to the actual values.

Table 2. KPI's

	Electrical Consumption (kWh)	Water Consumption (m^3)	Gas Consumption (m^3)	Average temperature	K factor	KPI / degree Celcius	Overall KPI
Energy based factor	2	1	1				
Q 1	571910	2074	12368	13.41	1	1.158	15.532
Q 2	792305	2183	9411	19.47	1	1.596	31.078
Q 3	764400	1530	4968	26.06	1	1.535	40.009
Q 4	580525	1774	6823	17.13	1	1.169	20.036

**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 philosphy 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 table above shows how KPI's are introduced for the quarters of the year. Such an initiative needs to be kept updated depending on the products produced within that quarter in terms of weight, volume or value of the end product. This wil help to improve the value added and improve the overal production eficicency.

Energy Efficient Measures- Implemented

As part of the recommendations proposed in the first audit several undertakings aimed to improve energy efficiency were considered and the implementation of the below was noted.

- Some of the T8 FL light fittings were replaced by LED type technology with an estimated improved consumption of up to 50%.

- Power factor capacitor banks were improved thus further improving the power factor.

Observations

Observations made during the audited period include the commitment for implementation of the best available technologies in the field. Some of the proposed recommendations in the 2016 audit have stil not materialised mainly due to to the short period between the recommendations date and the second audit. In spite of this the plant owners commit themselves to continously improve energy efficiency.

Continous Improvement

The need for continous improvement is coming even more relevant in today's competitive environment. Thus it is crucial to improve energy efficiency and aim for net zero emmissions. Altghough such a production plant is considered to be a high energy consumer, there are numerous measures that can be adopted to reduce energy consumption.

As part of this process a set of energy friendly guidelines are being introduced to be made familiar with employees delivering their principal work in an office setup:

- Set and maintain air-conditioned room temperature between 24°C and 26°C in summer;
- Switch off office equipment that is not in use;
- When leaving office, arrange for the last-man-out to check and switch off the power source to all air conditioning, lighting and office equipment that are not in use;
- Switch off lighting and heat-producing appliances that are not in use to reduce air-conditioning load;
- Dress light to minimize the use of AC;
- Set the indoor fan unit to "low" fan speed as the normal setting;
- Use a high fan speed rather than lowering the temperature setting to cater for increased cooling demand;
- Switch off lights that are not in use. Affix "Save Energy" stickers near the switches as a reminder;
- With few people working in the office, switch off the non-essential lighting and use task

lighting to directly illuminate work areas;

- Switch off photocopiers and printers after office hours. Set the "Low Power" and "Off" mode default. Use the "Print Preview" function to check the layout and style of document before printing. Adjust the margins and font size of documents in order to optimize use of paper.

Recommendations

Further to the recommendations of the first audit, is the below suggestion for the implementation of new technology to improve chiller/ac unit's performance. It is being recommended to implement some basic modifications to the condensing units by introducing the Eco MESH technology.

In principle this technology consists of a mesh and a spray water installation on the condensing unit. The mesh is kept wet by the spray water which provides an adiabatic cooling effect on the incoming air stream. The manufacturer claims reduction in energy consumption of up to 44%. For air inlet cooling systems Eco MESH is placed within the airstream.

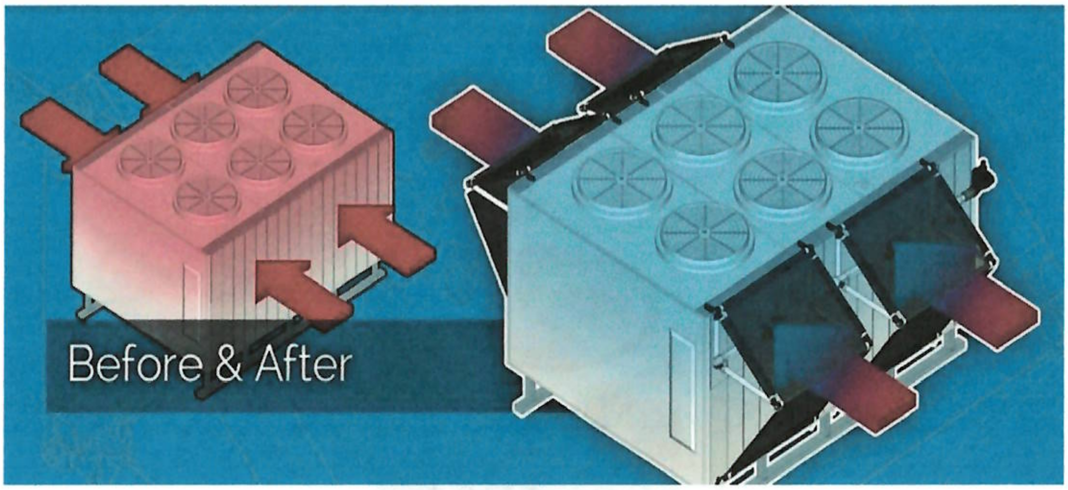


Figure 23. Water spray effect on condenser

Operating philosophy.

The below shows some important aspects of system control:

- Automatic water spray durations and frequencies in order to optimise on water consumption;
- High ambient temperature conditions requires more frequent water spraying;
- Automatic system shut down once outdoor ambient conditions are favourable.

The main advantages of the system includes:

- Maintenance free;
- Easily retro-fitted;
- Provides protection against harsh weather conditions;
- Automatic water dosing system to prevent bacteria formation;

As shown in the figure below this technology can also be applied to the outdoor units of the air conditioning devices. The EcoMesh manufacturer claims that the investemnt cost for system setup approximates to € 1500 for every metre of mesh installed, which is the estimated length required for a a typical ac outdoor unit.

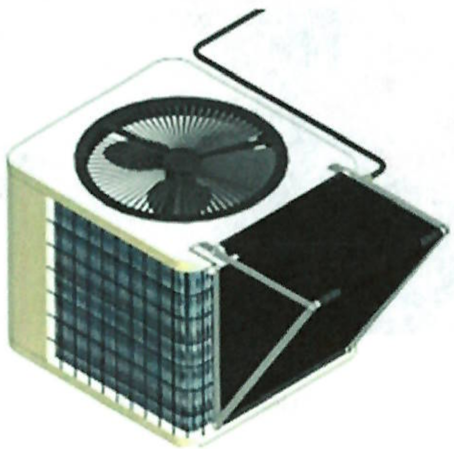


Figure 24. Ecomesh installation on an air condition out door unit

The table below shows the LCCA for system setup and operation installed on the chiller unit. Estimates show that the investment is recovered in less than 2 years. It is being suggetsed that the management of the plant seriously consider the mentioned recommendations which presents such attractive returns on investment.

Table 3. Eco Mesh Installation on large Chiller Unit

Life Cycle Cost Analysis			
	Year 0	Year 1	Year 2
Initial Cost of retrofit (€)	6,000		
Savings per year (kWh)*1	54,750		
Income per year (€)		4258	4258
NPV (€)	7,917.37		
Running cost of system *2	450		
Based on cost per unit 12.9 c/kWh			

*1 Assuming a 5% energy reduction on chiller electrical consumption equates to 100kWh/day.

*2 Based on 500ltrs of water consumption per day and related pump consumption.

Some other recommendations on the HVAC system include:

- The introduction of a building management system to optimize the plant efficiency, especially the HVAC system;
- The construction of water reservoir and the use of reverse osmosis reject water;
- Light management system;
- Gradual change of Air handling Units.

As previously stated in this report, the period between the first and second audit is too short to implement the respective recommendations. Therefore, these are being suggested once more for implementation in the coming years.

Conclusions

Some of the objectives reached include:

- Comparison between energy consumptions registered in previous audit vis-a-vis this audit. Providing data of energy consumptions during the different months of the year. To date, a detailed consumption of Q1, Q3 & Q4 of the year is made available;

- 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.

The previously recommended measures, included in 2016 audit, proposed the installation of a PV system. Such possibility was evaluated and turned down due to:

- The installation of a PV system is not possible due to roof structure restrictions which are not capable to withstand the potential forces exerted by the PV's during high winds.

Another change in 2016 recommendations is the rainwater storage proposal:

- The introduction of a second-class water system based on rainwater storage is not possible due to limitations set by Environment and Resource Authority. Due to possible rainwater contamination from vents and exhaust systems leading to the roof area such a system has been discarded. However, a project that recovers the reverse osmosis reject is currently under consideration for future implementation.

Together with the recommendations listed in the first audit the newly energy efficiency improvements are considered as a blueprint for the organization's future.

Appendices *(Energy Audit_2016)*

Appendix A_Plant Layout

In the coming pages, plans showing the building being audited are shown. These areas are mainly composed of the production area, offices area and warehouses. The illustrated plant layouts show:

- The ground floor, housing the main production and office areas;
- The first floor, a continuation of the production and office areas;
- The second floor dedicated completely to the production area;
- The roof level which houses the plant equipment.

Plant Energy Consumption Layout

The illustration below shows the main energy consumers as per different areas. The percentage of electrical energy used by each department shows that the production area absorbs the bulk of the electrical energy consumed. The below figures are based on average daily consumption.

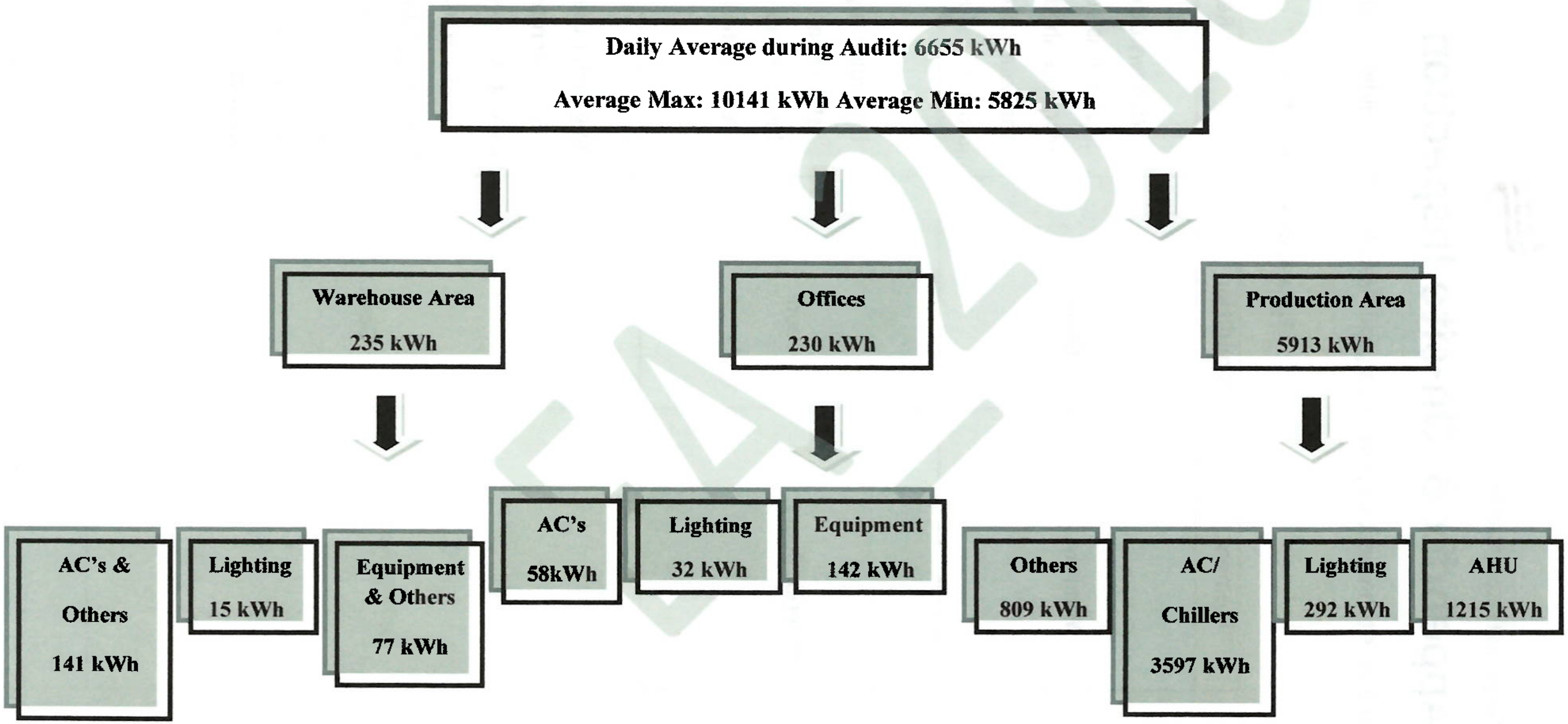


Figure 25. General Daily Consumption

Appendix B_On-site Inspection

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

Table 4. On-site inspection

Element	Condition	Remarks
Windows	Good	Windows condition is deemed good. It is being suggested to introduce shading mechanisms on the South and West facades in order to reduce the heat gains.
Exterior Doors	Good	It is being suggested that solid steel doors are replaced by louvered apertures in order to reduce the heat gain factor.
Ceiling/Roof	Good	In general the ceiling /roof is of the concrete type with some exceptions in the production and outdoor warehouse areas. It is being suggested to open louvered mechanical openings on the roof of the production area (reactors upper part) to introduce fresh cool air during the hot summer months.

Exterior Walls	Good	The majority of the exterior walls are made of double 9 inch stone with 10mm air gap.
Outdoor Warehouse	Good	The warehouse is used to store raw materials and has adequate natural ventilation.
Lighting	Needs Improvement	In general lighting is of the T8 type with fittings including variants of 36W power with 2 or 4 units per fitting. It is being suggested to introduce, T8 LED lighting with PIR sensors in order to reduce the lighting consumption in passage ways and other areas that are used intermittently.
Heat Distribution	Good	The heat used in the process is supplied from a gas fired boiler, which in itself is a high efficient device with low emissions. New emerging technologies including condensing type boilers are to be considered in the future.

Cooling Plant	Good	The cooling equipment is mainly composed of two main chillers
		used in the production area and some other VRF units with respective indoor units, mainly used at the offices area. Some other 14 split units are used in the electrical cabinets, control room and plant site cabinets.
Power Meters	Good	Power meters are well distributed around the plant.
Water Consumption	Good	The process has a relatively high water consumption that is used both during the process and for cleaning and sanitization purposes. A water reservoir to store rain water, is being suggested.

Compressed Air	Good	Compressed air is supplied by two compact screw compressors, which is then passed through the air driers to provide optimal compressed air supply.

Appendix C_Site drawings

The drawings below highlight areas of importance to the audit. The air handling units and other cooling and auxiliary equipment is installed at critical points that feed the plant accordingly.

In general the plant equipment includes two main chillers that support the day to day plant requirements, one gas fired boiler, six air handling units and an air compressor system. Other machinery and equipment contribute to the smooth running of such a plant. This includes independent extraction systems, specific equipment, localized air conditioning units and others.

With a total footprint of 2700 m2, the areas of importance to the audit add up to:

- Production area, including the clean rooms: 1730m2
- Office area: 672m2
- Indoor warehouse: 816m2
- Outdoor warehouse: 400 m2
- Roof Space: 1450 m2
- Other areas include corridors, air locks, dress rooms etc...

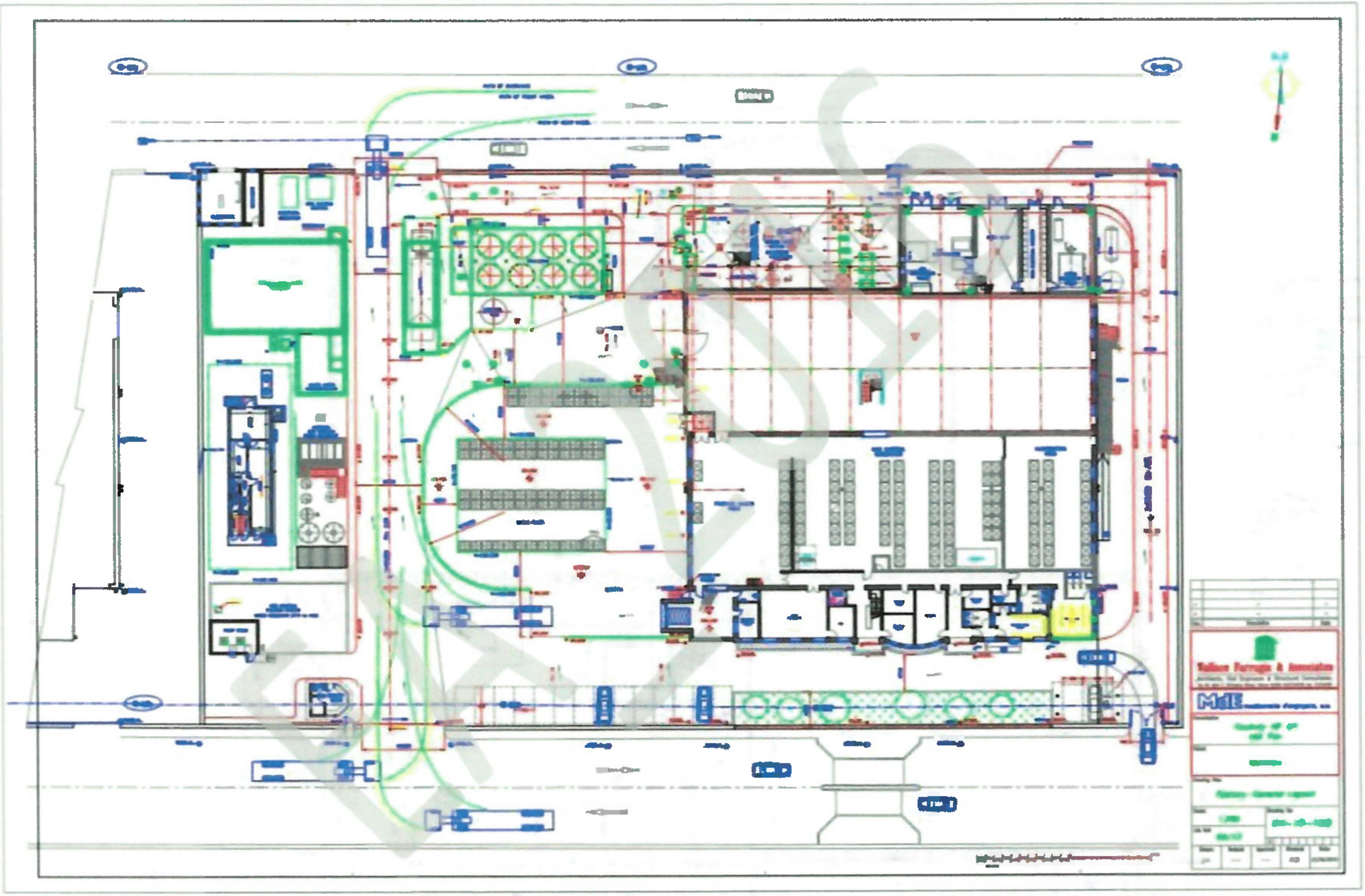


Figure 26. Ground Floor

Figure 27. First Floor

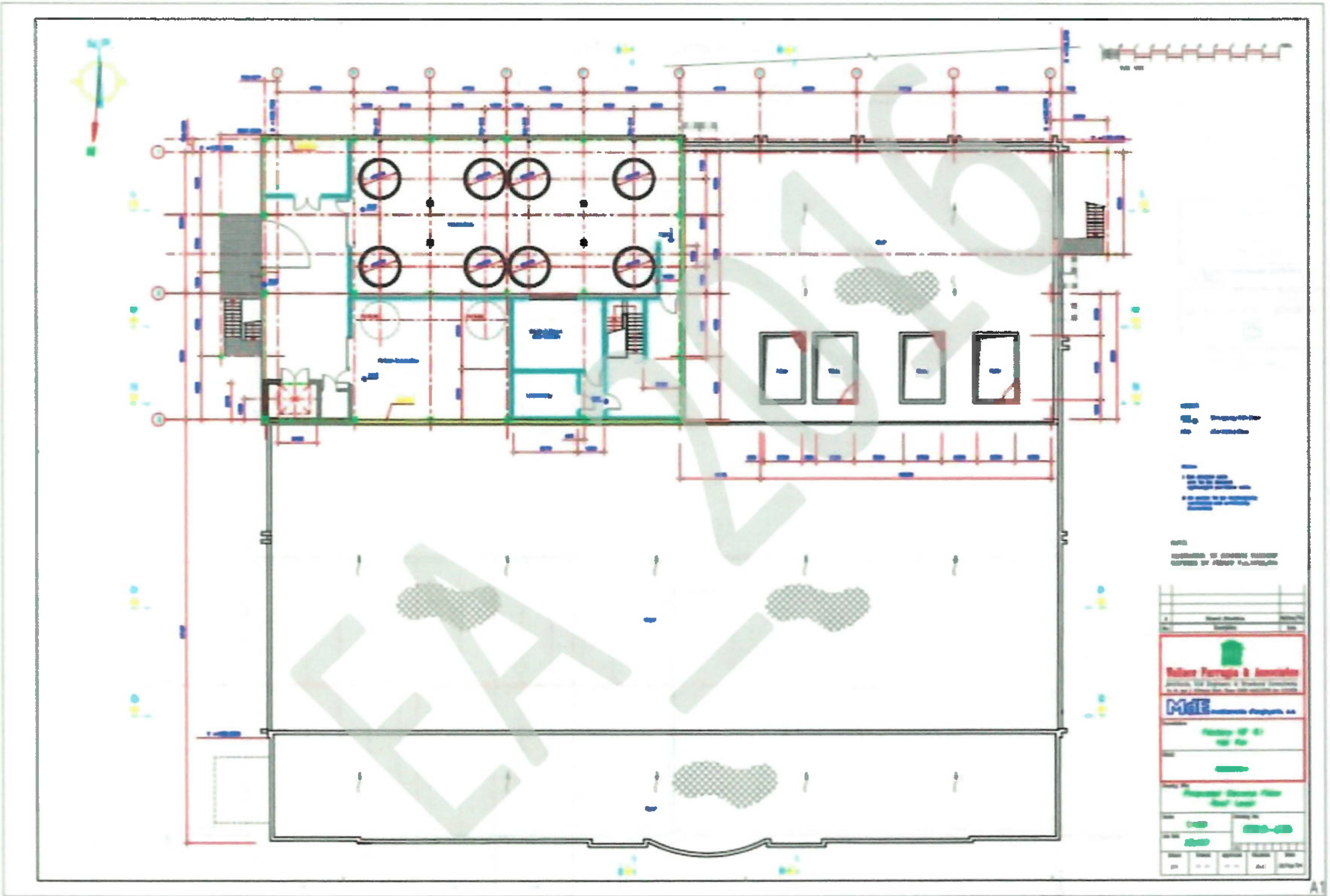


Figure 28. Second Floor

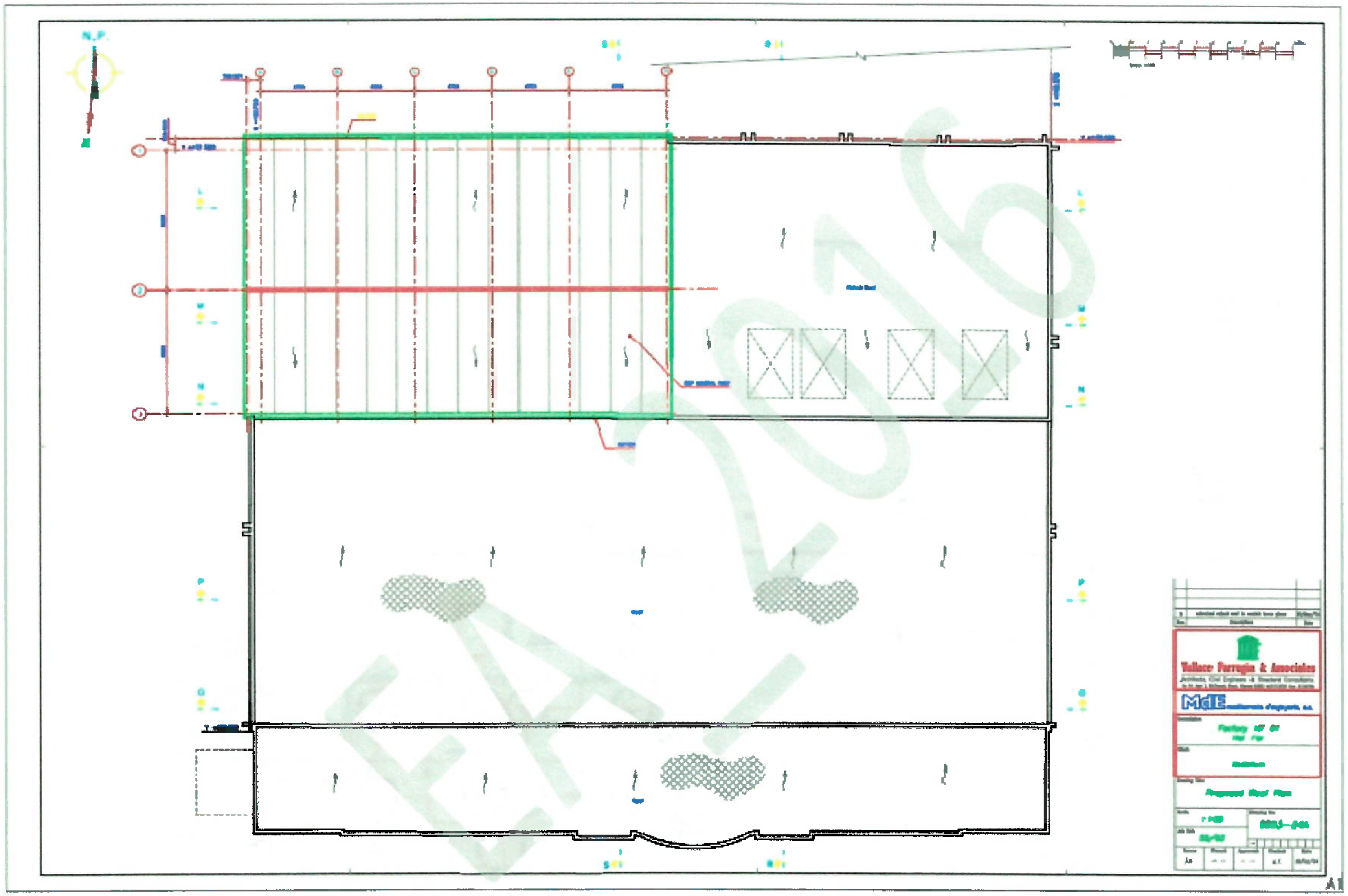


Figure 29. Roof area

Appendix D_Systems Layout

The illustrations below depict the general layout of the plant.

Figure 30. Air Compressors

Compressed air is used during the production process with one compressor is kept in service and the other on standby. The air compressors system includes a set of air driers that conditions the compressed air to the set requirements.

Figure 31. Chiller System_Small (Used as part of process)

Figure 32. Chiller System_Large (General cooling system)

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.

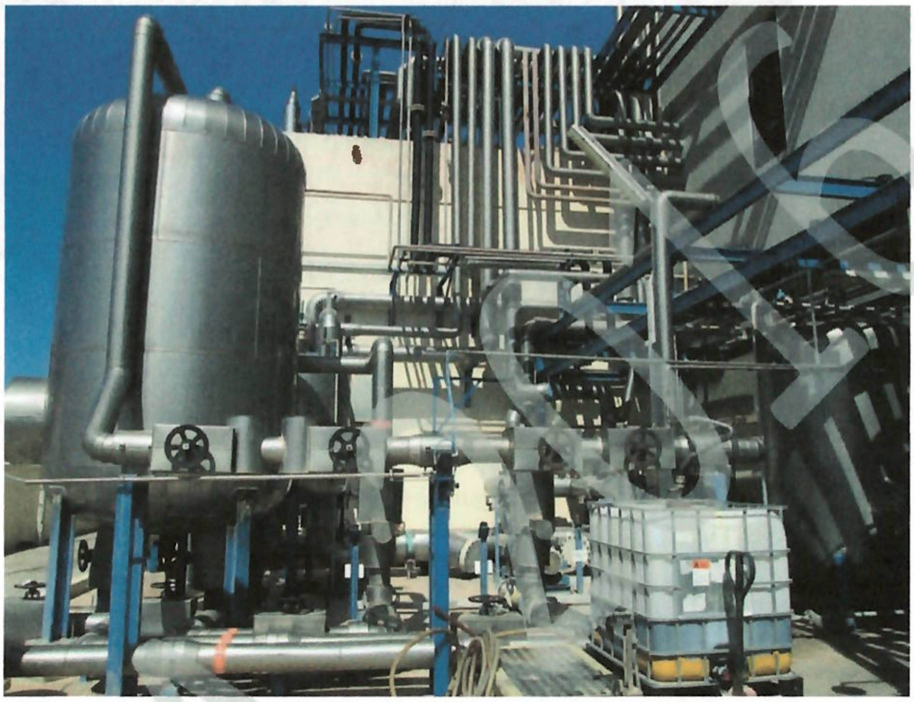


Figure 33. Auxiliary Equipment and Pumps

Figure 34. Warehouse_Indoor

Figure 35. Warehouse_Outdoor

The illustration above shows the outdoor warehouse, where raw material is stored, the laboratory section and the waste water treatment plant. The waste water treatment plant treats the water used in the process before discharged into the drainage system.

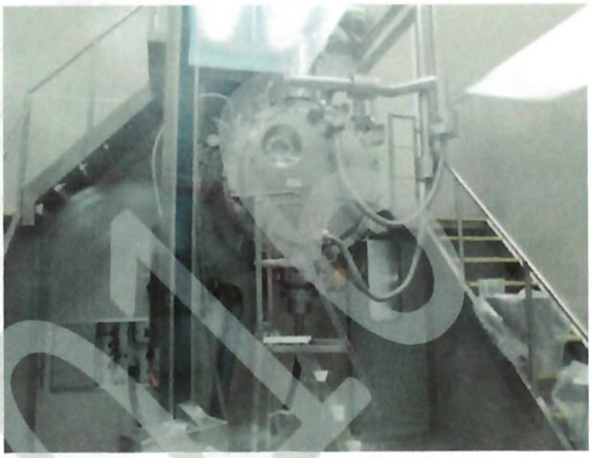


Figure 36. Production Area

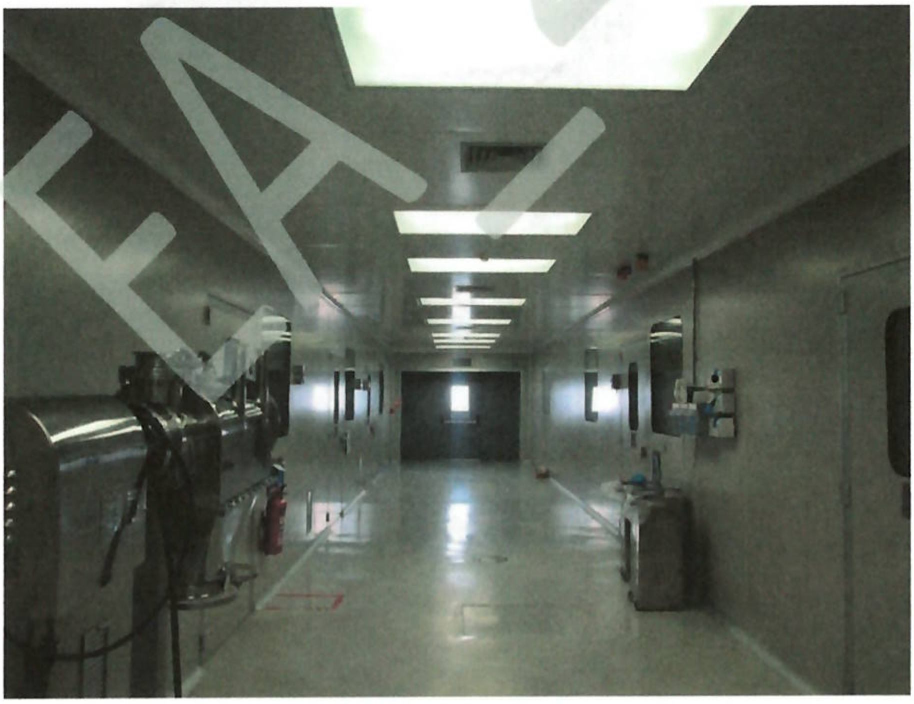


Figure 37. Corridor Wet Area_Pressurized

Figure 38. Corridor Dry Area_Pressurized

Figure 39. Variable Drive Unit_AHU

The above illustration shows the variable drive unit that drives some of the air handling units according to the power required.

Figure 40. Reverse Osmosis Plant

Figure 41. Reverse Osmosis Plant

Figure 42. Other Plant Equipment

Figure 43. Plant Equipment

Figure 44. Independent Air Extractors

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

Figure 45. Gas Fired Boiler

The illustration below shows some of the outdoor equipment including heat exchangers and hot water supplies.

Figure 46. Equipment_Other

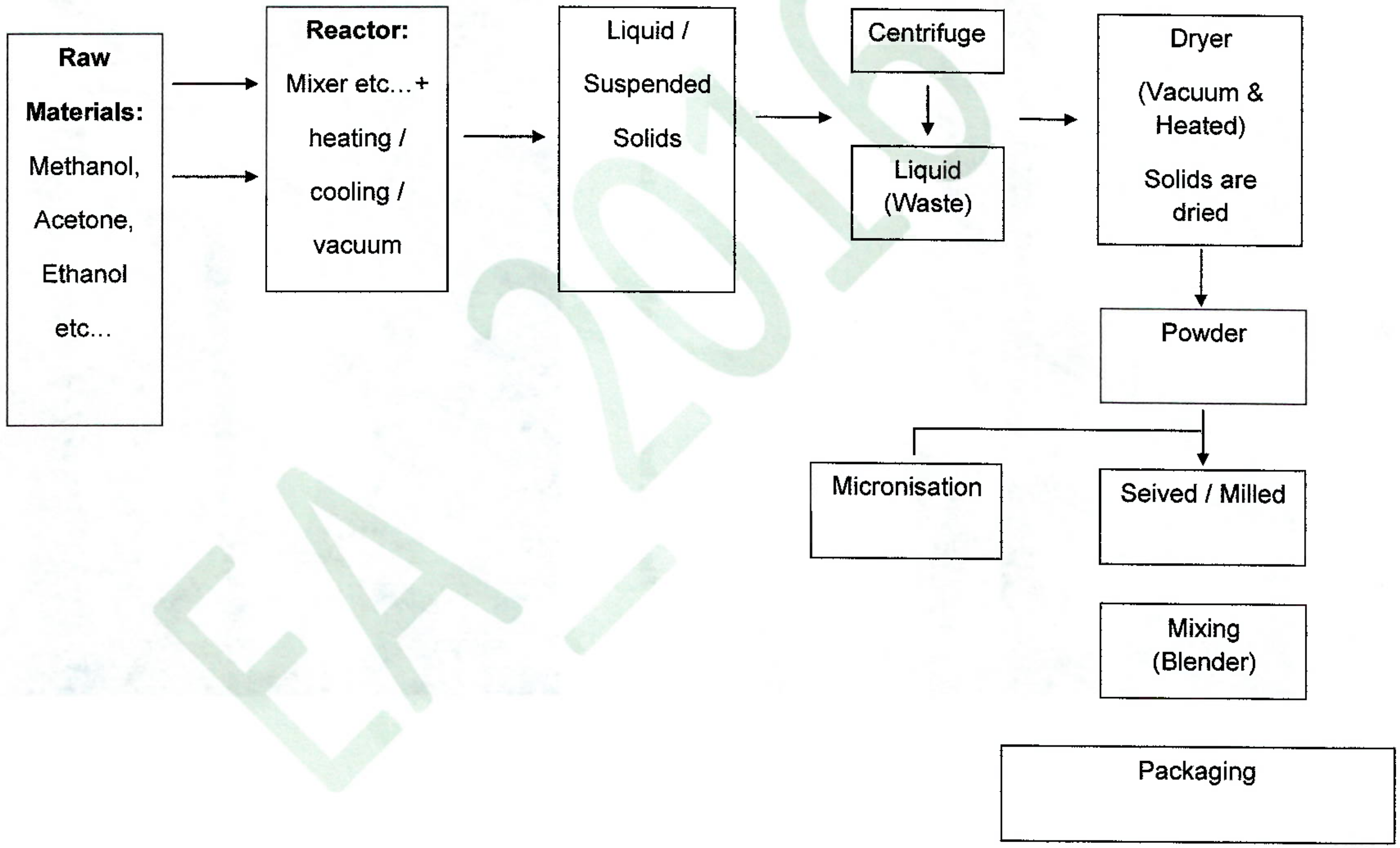
Figure 47. Air Handling Units

Figure 48. Roof Area_Above Production 1st Floor

Figure 49. Roof Area_Above Production 2nd Floor

Appendix E_Process Description

The flow diagram below shows how the raw material is processed and ultimately transformed into the end product.



Appendix F_Overview of Electrical Energy Consumption

The following illustrations show the analysis of electrical consumption of different equipment in the plant. The data analysis is carried out on a real set of data gathered during a fixed period. Reference to past consumptions or calculated consumptions are frequently made in order to compare any noted variations.

Lighting Consumption

In general, light fittings are of the T8 linear fluorescent tube lamps. These vary from fittings equipped with 4 by 36 Watts or 4 by 18 Watts. Such light fittings are considered to provide good power to light efficiency and low maintenance. It is being suggested that these light fittings are replaced with LED type in order to have better light control. Such lighting can be replaced without changing the fitting itself. LED technology provides flexibility in terms of light management which enables frequent switching according to presence detection. The table below shows how the lighting power is consumed in the different areas of the plant.

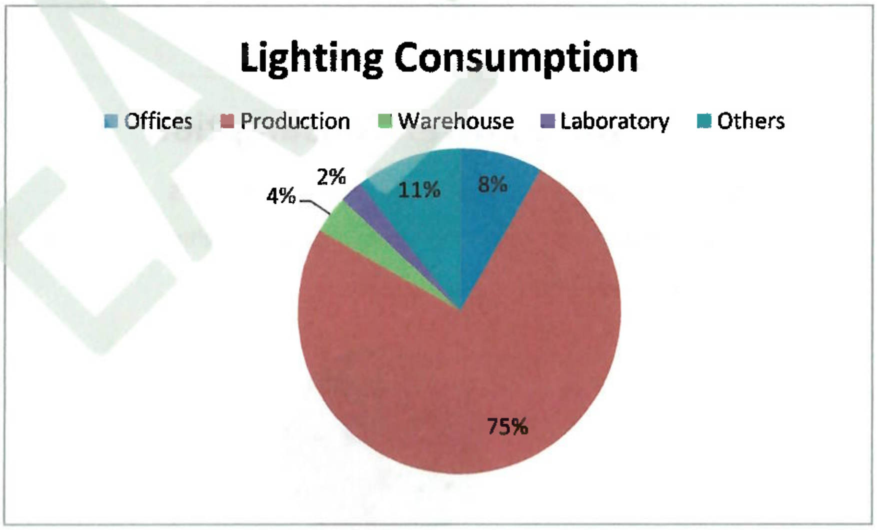


Figure 50. Lighting Consumption

With a maximum installed capacity of 13.5 kWh, light fittings are in service according to the particular activity, at the production and offices area. The table below indicates the daily and weekly consumptions in different areas.

Table 5. Lighting Consumption in different areas

Period	Offices kWh	Technical Areas/Production/Utilities kWh	Warehouse kWh	Laboratory kWh	Outdoor kWh
Daily	32.5	292.6	14.6	9.1	29.8
Weekly	162	463.2	73.4	45.7	209.1

Main Power Consumption

The coming illustrations detail how the electrical energy consumption is apportioned. The depictions chiller (S) refers to the chiller that feeds a particular process, the chiller (L) feeds all the other plant cooling requirements.

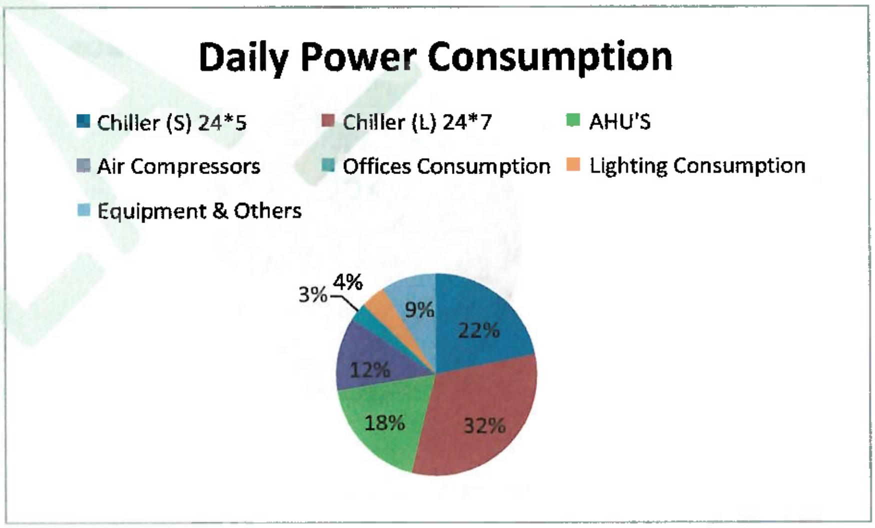


Figure 51. Daily Power Consumption

HVAC Consumption

The electrical consumption of the HVAC equipment is mainly attributed to the chillers and air handling units that keep the ambient conditions as required. It can be noted that the daily chiller consumption (L) contributes to a great portion of energy consumed. Such a chiller system feeds the heat exchanger of the AHU's and supports cooling equipment used during the process.

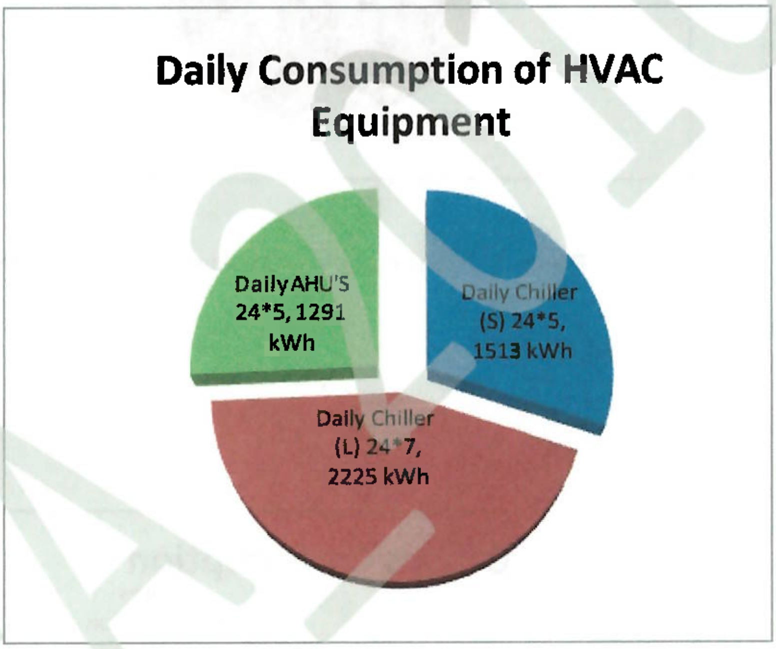


Figure 52. HVAC Daily Consumption

The air handling units, 6 in total, are considered as a single pass unit. These air handling units are equipped with heating and cooling coils that condition the supplied fresh air according to the set requirements. The following illustrations show the consumption of the high consuming machinery with respect to the total electrical power consumption.

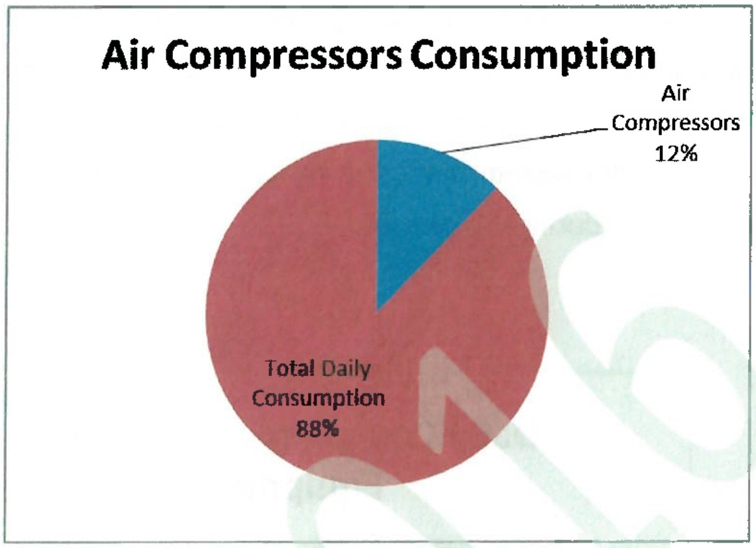


Figure 53. Consumption of Air Compressors System

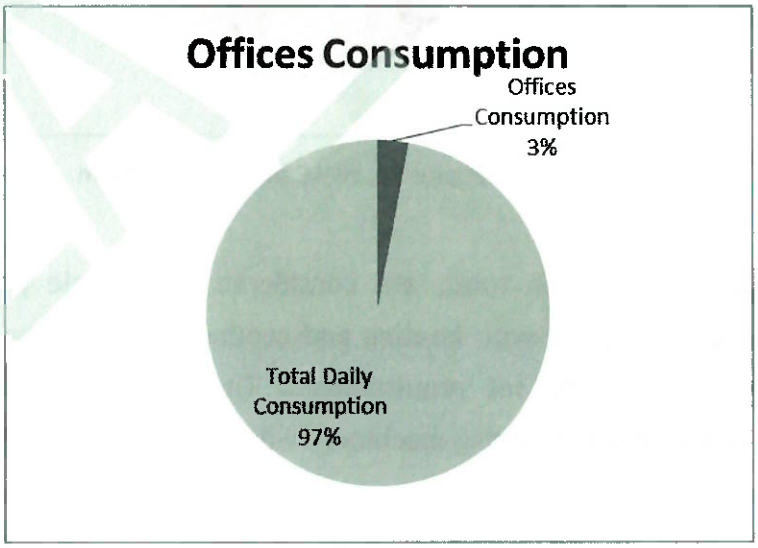


Figure 54. Consumption of Offices Area

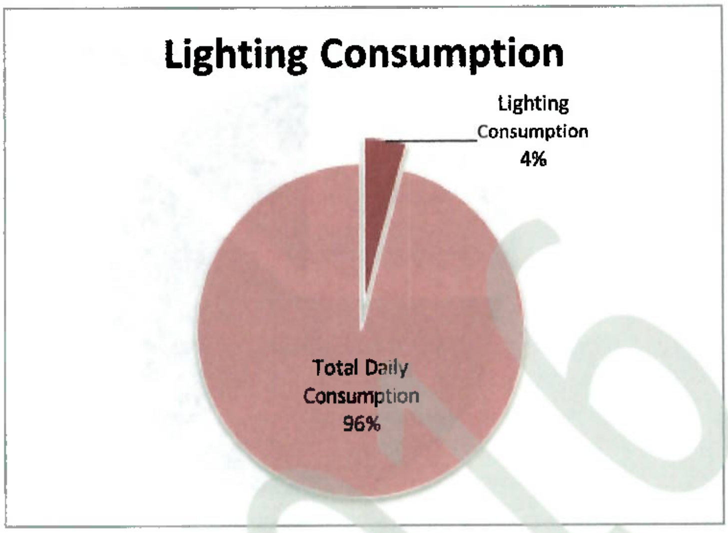


Figure 55. General Consumption of Lighting

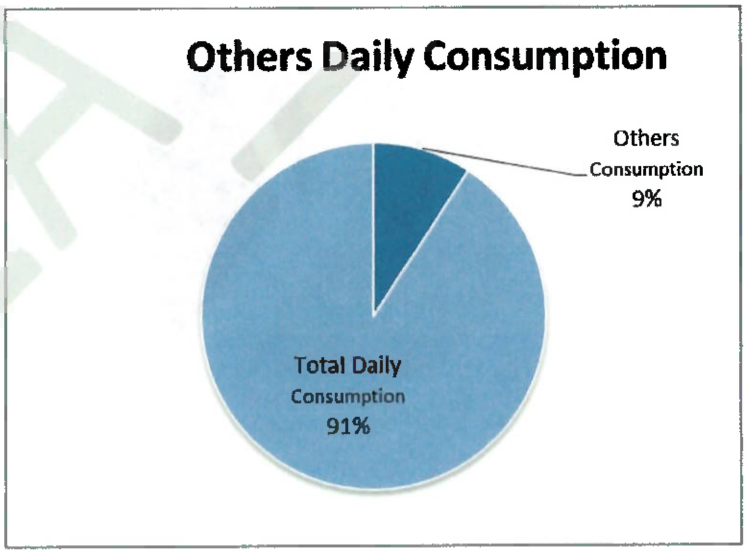


Figure 56. Consumption of Auxiliary Plant Equipment

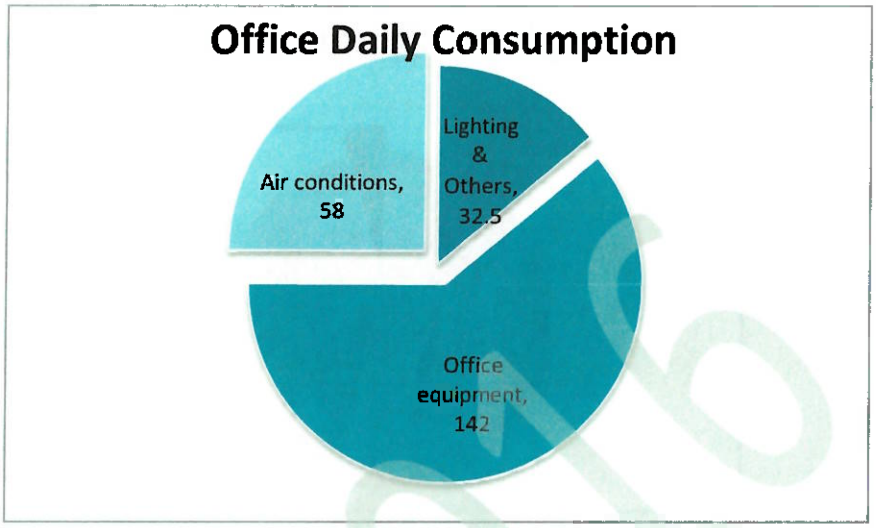


Figure 57. Apportioned Offices Consumption in kWh

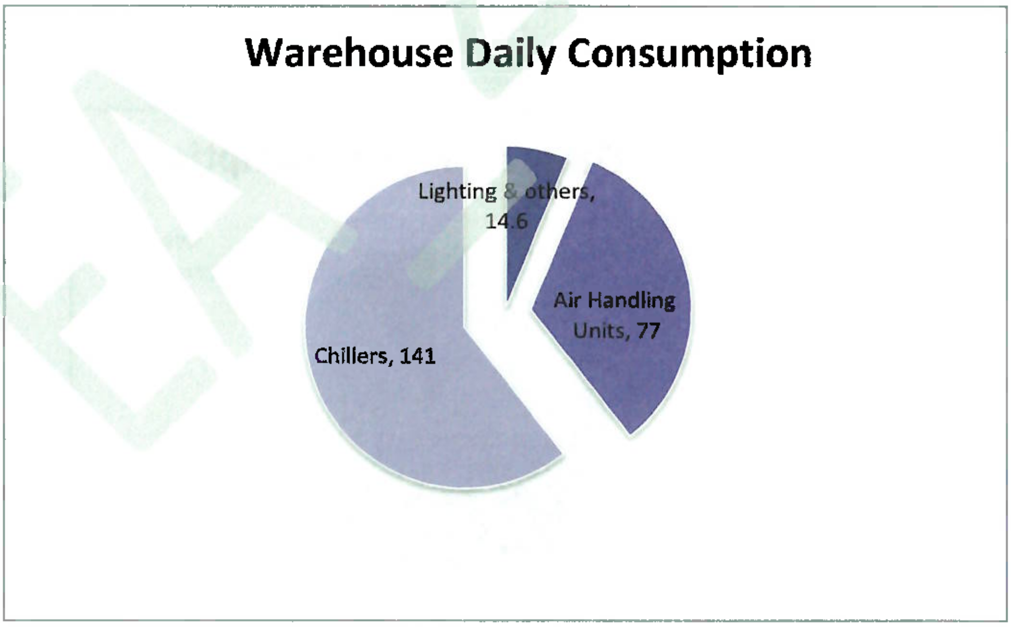


Figure 58. Apportioned Consumption_Warehouse Area in kWh

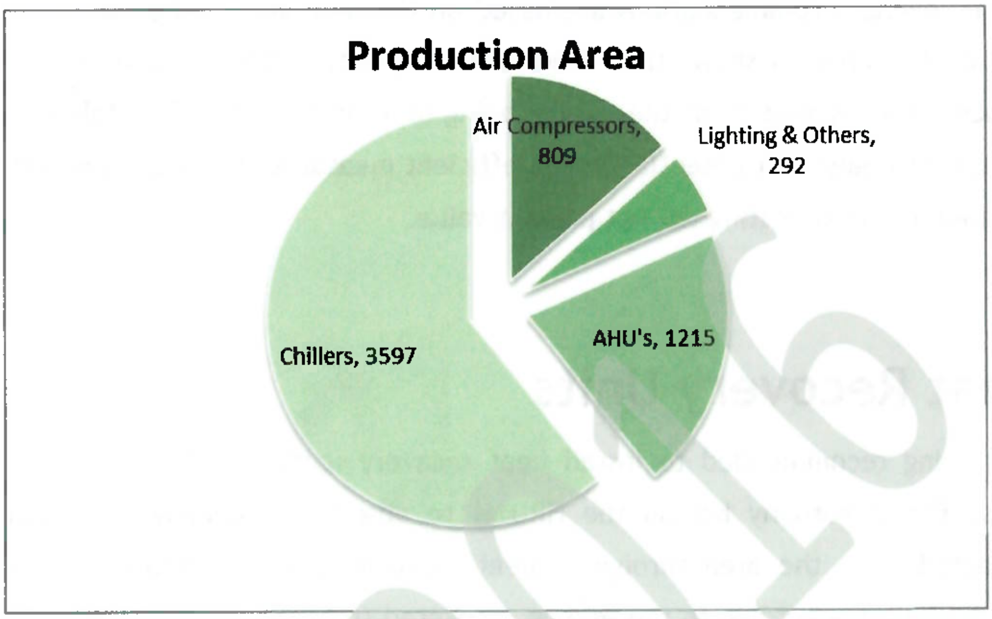


Figure 59. Apportioned Consumption Production Area in kWh

Appendix G_Recommendations

The following recommendations are based on the data gathered throughout the audit period. The analysis shows that a number of energy efficient measures can possibly reduce the consumption of the energy being used in the plant. The following are Life Cycle Cost Analysis of potential energy efficient measures. A 5 % discount rate is being considered on calculating the net present value.

Heat Recovery Units

It is being recommended to install heat recovery units (HRU's) on the air handling units. The philosophy behind the HRU is to absorb the cold/hot air that is being extracted from the area through a heat exchanger. This reduces the load on the chiller/ boiler according to the energy recovered from the heat exchanger. It is being proposed to install a new variable drive AHU with a heat recovery unit to replace the existent AHU in the production area. Due to the fact that no HEPA filters are installed on either side of the AHU a heat exchanger with 0% cross contamination must be considered. The table below shows the total investment costs and savings. The maintenance costs of such a system are incorporated in the units saved each year.

Table 6. LCCA_HRU's

Life Cycle Cost Analysis					
	Year 0	Year 1	Year 2	Year 3	Year 4
Initial Cost of Heat Recovery System (€)	€ 19,000				
12.79% reduction in running cost of Chiller	45370 kWh/year				
Savings per year (€)	0	5852.73	5852.73	5852.73	5852.73
NPV (€)	€ 19,765.23				
Assuming that a variable drive AHU including HRU installed to replace existent AHU at a cost of € 19000 each Based on cost per unit of 12.9 c/kWh					

The above calculations are based on real market data. The yearly savings are also calculated based on the claimed efficiency of the HRU and the savings by the chiller / boiler load reduction.

Building Management System

It is being proposed to install a building management system (BMS) that aid the control of the AHU's. Subsequently this will also connect other main equipment for optimised control. The philosophy behind the installation of a BMS is to increase or decrease the load of the fan depending on the process requirements.

The fact that some of the AHU's are already controlled by a variable drive system can enhance the system operating efficiency. The installation of sensing devices, such as presence detectors, remote controlled dampers, humidity sensors, temperature sensors, pressure sensors and other gauges will ease the overall air quality management. Such an installation will provide the facility to lower down the air flow induced by the AHU's to a set minimum during, break times, change of shifts and when in no need to circulate the full amount of fresh air. This is done without sacrificing the positive pressure principle in these particular areas. This will contribute to reduced consumption during off peak hours including night hours.

It is estimated that the cost of a BMS system including all transmitters and sensing equipment for each AHU is to reach 15000 Euros including a workstation in the current control room. The table below shows the cost of installing such a system on the variable drive AHU's.

Table 7. LCCA_BMS

Life Cycle Cost Analysis							
	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Initial Cost of BMS (€)	€ 30,000						
Savings per year (kWh)	52109 kWh/year						
Savings per year (€)	0	6722	6722	6722	6722	6722	6722
NPV (€)	€ 32,494.39						
Assuming that BMS system installed on each Variable type AHU at a cost of € 15000 Based on cost per unit of 12.9 c/kWh							

The savings are calculated based on a period of 4 hours per day on reduced flow, taking in consideration both the energy saved from cooling and the energy saved from lowering the AHU fan to a set minimum of 25 % of operating power.

Photovoltaic Panels

The existent roof area available for PV panels installation is 1050 m2. This area is deemed as free from any shading that might be experienced during the year. Installation of such a system enhances the energy mix used by the plant and buffers any sudden changes in utility rates. Moreover, such an installation will contribute to a reduced heat transfer to and from the plant due to the shading and cooling effect of the panels themselves. This will ultimately reduce the net energy consumption used to run the plant.

Table 8. LCCA_PV's

Life Cycle Cost Analysis										
	Year 0	1	2	3	4	5	6	7	8	9
Cost of PV's (€)	€ 95,000									
Generated units per year (kWh)	108000 kWh									
Income per year (€)		13932	13932	13932	13932	13932	13932	13932	13932	13932
NPV (€)	99,026.17									
Assuming 70 kWp System										
Based on cost per unit 12.9 c/kWh										

Water Reservoir

The water yearly consumption of 7864 m^3 classifies such an activity as a high-water consumer. The following recommendation shows an annual potential water savings of 1500 m^3. By constructing a 1500 m^3 reservoir the rainwater will be stored and used for production purposes. This results in a 20% reduction of 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 9. LCCA_Water Reservoir

Life Cycle Cost Analysis																				
	Year 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Cost of Construction & booster pump (€)	64,800																			
Savings per year (m3)	1500																			
Income per year (€)		3839	3839	3839	3839	3839	3839	3839	3839	3839	7678	7678	7678	7678	7678	7678	7678	7678	7678	7678
NPV (€)	65,504																			
Assuming reservoir capacity of 1500 cubic metres																				
Based on cost per unit of €2.37/m3 and 4.74/m3 in ten years' time																				

Light Management

The table below shows the projected cost to change the current light technology to LED technology. It is being proposed to change the fittings of those areas with maximum operating hours these include the Wet & Dry Area and the production area.

Table 10. Light Technology Replacement

Location	Qty	LED Cost per fitting of 85 Euros	Cost (Euros)	Cost toPIR devices on a circuit of 10 fittings & 35 Euros per PIR per circuit (Euros)	Estimated daily running consumption (Wh)	Estimated Savings due to LED Power per fitting (from 36 Watts to 18 Watts)	Estimated Savings due to PIR installation 50 % in service (Wh)	Estimated Consumption due to LED Power per fitting (from 36 Watts to 18 Watts) + PIR installation (Wh)	Estimated total savingsSavings due to PIR assumed at 50% of current usage and LED replacement (Wh)	Estimated Total Savings per day (kWh)	Estimated Yearly savings in (kWh)	Estimated yearly savings in Euros at 12.9 c/kWh
Wet & Dry Corridors area	204	17340		700	176256	88128	88128	44064	132192			
Production 1st & 2nd Floor	136	11560		490	117504	58752	58752	29376	88128			
Total			28900	1190	293760	146880	146880		220320	220.32	57283.2	7389.5328

The above shows that the annual potential savings from changing over the light technology used in the mentioned areas is of 146.8 kWh per each production day. Another 73.4 kWh per day are estimated to be saved if presence detection is installed. Such light management is permissible due to the fact that the LED technology permits intermittent ON/OFF of the light fittings without compromising the hours of service of LED lighting.

Table 11. LCCA of LED Technology

Life Cycle Cost Analysis					
	Year 0	Year 1	Year 2	Year 3	Year 4
Initial Cost of PIR Installation & LED's installation (€)	€ 30,090				
Savings per Year (kWh)	57283				
Savings per year (€)	7389	7389	7389	7389	7389
NPV (€)	€ 31,990.50				
Based on cost per unit 12.9 c/kWh					

The above LCCA shows that the annual savings from the LED technology and PIR's installation reach 7389 Euros per year which is estimated to be paid back in less than 4 years' time.