Power Audit Report

DeveloPPP Project: WP2 Power Audits

Power Audit at Givanas Cosmetics Factory

Lagos, Nigeria

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1. EXECUTIVE SUMMARY

Givanas is one of the two SMEs selected as part of the DeveloPPP project for the implementation of a pilot power audit. During this visit, a OneShore engineer performed the power audit following the OneShore auditing process and installed the in-house developed measurement tool OneAnalyser for permanent power auditing.

During the site visit it was found that the main roof of the factory provides enough space for PV installation. The OneAnalyser measurement device captured the transition between the two production seasons in the factory and their equivalent electricity consumption. During the "jelly" season the site increases its operation to 24/7 times which results in an estimated 16% higher demand respect to the rest of the year. Non-production times especially during the weekends and 18:00 to 06:00 outside the jelly season, have a minimal power demand (~ 0 kW). Peak power demand can reach up to 180 kW. The site demand is covered entirely by two diesel generators on site which are deployed separately depending on the load required.

To assess the potential of energy cost reductions and fuel savings, the following 4 scenarios were assessed:

1. Replacement of current lamps for higher efficiency lighting
2. Resizing of the large diesel generator and synchronisation of the diesel generators
3. Installation of a diesel PV hybrid system
4. Installation of a diesel PV hybrid system with energy storage (including a hybrid controller)

Below is a summary of the energy savings opportunities investigated in this report and their financial key indicators:

Case	Total Savings (USD)	Total Investment (USD)	Simple payback
Lighting replacement	$ 1,010	$ 719	1.2 years
Replacement of large generator	$ 49,000 (fuel) $ 27,000 (replacement)	$ 48,000	n.a.
PV with diesel generators	$ 446,187	$ 127,000	6.3 years
PV with battery and diesel generators	$ 634,000	$ 256,000	7.5 years

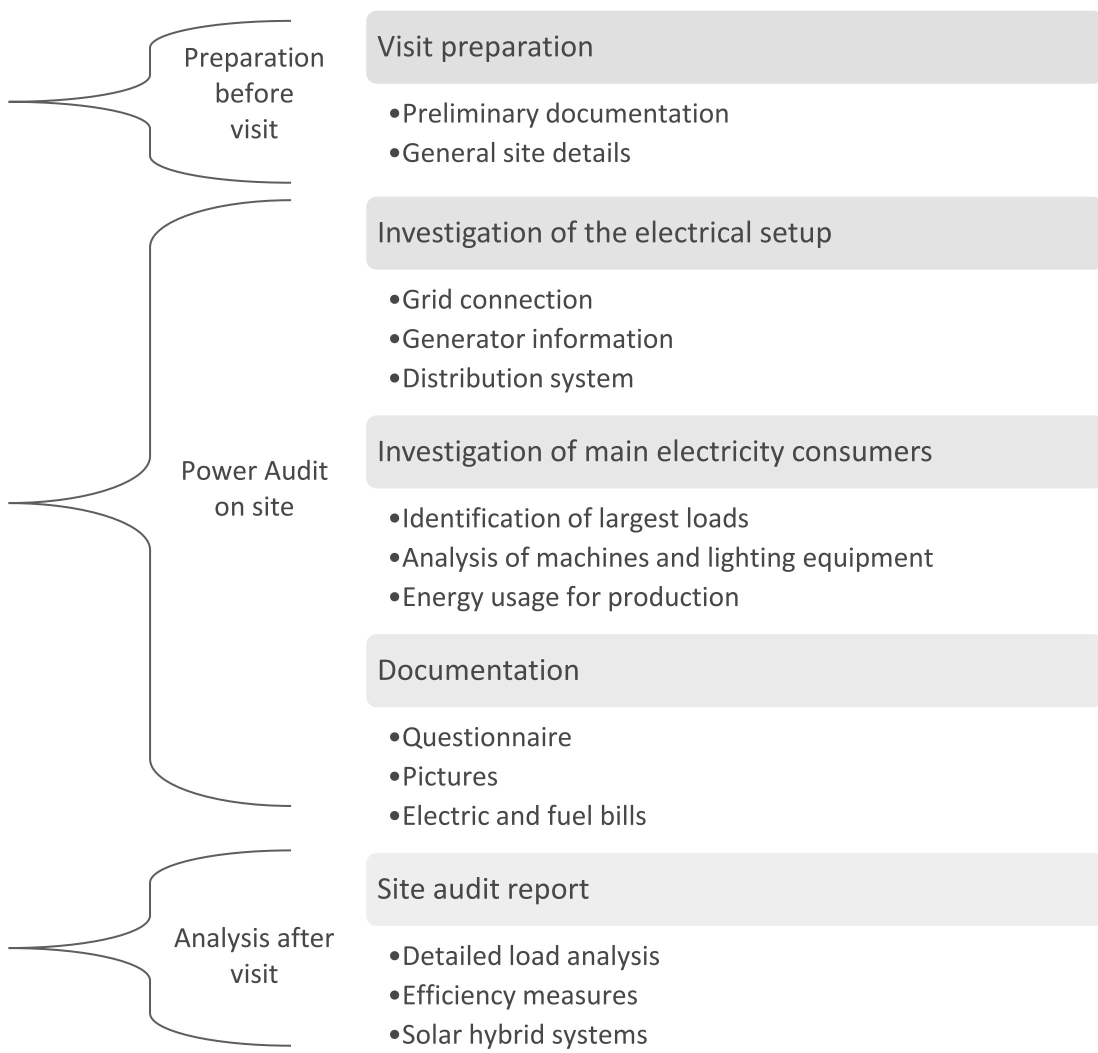
2. Site Visit Structure

2.1. Objective

To understand and document the power demand and electrical setup at Givanas cosmetics factory through the implementation of power audit procedures as well as the installation of a data collection system to provide detailed measurement data.

2.2. Approach

The following diagram shows the OneShore procedure with a list of key deliverables for each step.



2.3. Procedure

The site visit took place on the 25th of September 2017 with the assistance of site personnel and Nigerian solar company Solarmate. As part of the site visit, the following items were actioned:

1. Site inspection at Givanas factory
    a. Inspection of the grid connection and generator setup
    b. Identification of key electrical consumers
    c. Creation of a schematic of the electrical system
    d. Assessment of roof space and suitability for solar PV
    e. Visit through factory and quick identification of potential energy-saving measures
2. Installation and commissioning of a OneAnalyser load measurement device at the main electrical switchboard

2.4. Documentation

The information collected for the electrical setup, power demand and production is summarized as part of the OneShore questionnaire. The following documents have been created during the site audit or been made available by the site for further analysis:

- ☑ Questionnaire
- ☑ Site plan drawing
- ☑ Electrical diagrams

3. DETAILED POWER AUDIT

3.1. LOCATION

Givanas is located in Lagos' port area Apapa. Due to heavy traffic in and out the area the site is not easily accessible which needs to be considered for any measures to be carried out. The factory consists of several interconnected buildings for different cosmetics production lines.

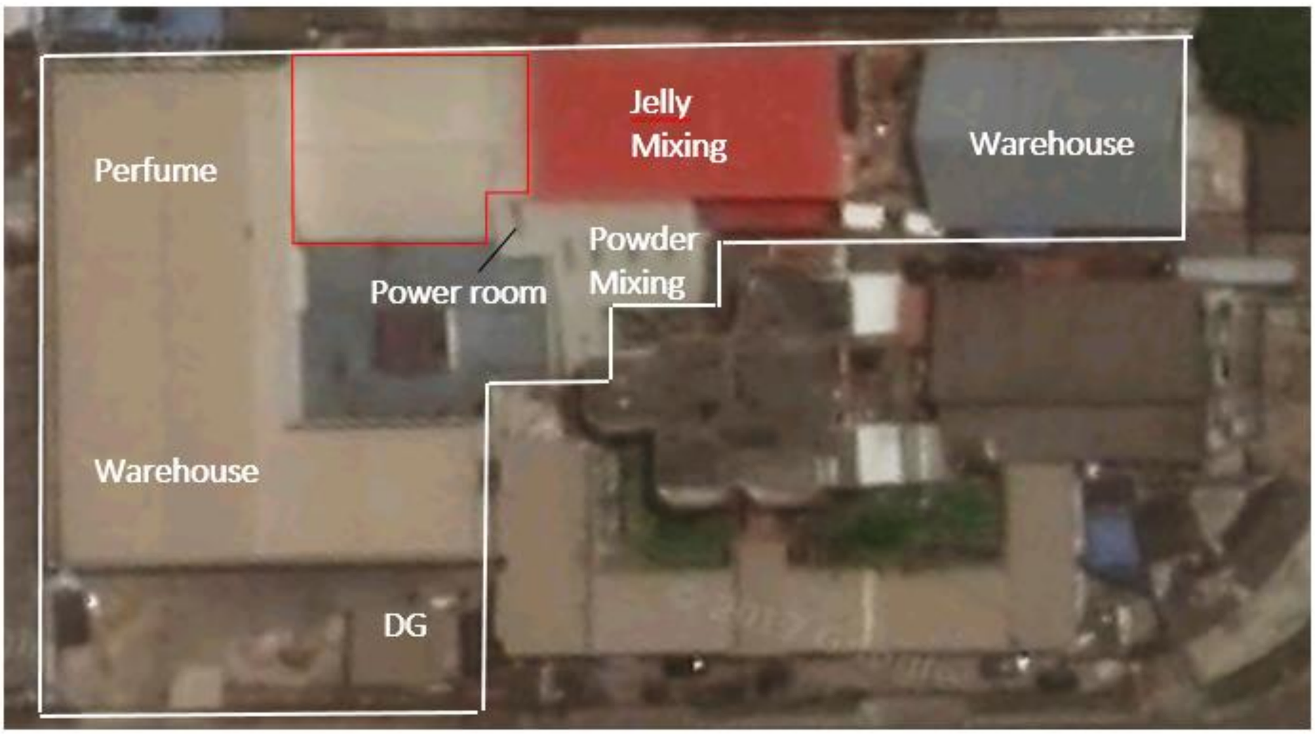


Figure 1 - Map and plan of Givanas factory

There is available roof space of approximately 1600 m^2 on the main production hall where a PV system could be installed. This includes the roof for the perfume and jelly production and the warehouses. The roof space delimited with a red square in the picture would not be suitable as it is a lower section of the roof and hence PV panels would be affected by shading. A stability analysis of the 45-year-old buildings has been carried out recently and shed doubts whether the structure can support the additional weight of solar modules. Whereas the roof appears to be robust, the pillars that support it have limited strength. Additional analysis will be required to confirm sufficient stability before planning a PV system.

3.2. Site Description

Givanas produces a range of cosmetics products such as perfume, jelly and powder. The factory has 3 main production lines with the following processes:

- **Perfume line**

Ethanol Tank → Mixer → Cooling → Filling → Packaging

- **Jelly line**

Heating → Mixer → Cooling → Filling → Packaging

- **Powder line**

Filling → Packaging

Perfume ingredients are mixed together and then need to rest at low temperatures in an air-conditioned room before the filling process.

In the jelly line product is heated up in the mixer using steam supplied by a diesel fired boiler. The steam is circulated through a closed loop and the heat is delivered to the tanks by a heat exchanger that brings the temperature up to 80 degrees. The condensate is recovered by returning it directly to the diesel boiler. Jelly is cooled through a chilling line before filling.

The powder production involves mainly manual processes, hence there are only few steps where electricity is required.

Typical operating times of the factory are 06:00 to 18:00 from Monday to Friday. Normally the plant does not operate on the weekend. Production times for the three main products (jelly, powder and perfume) can vary significantly over the course of the year. Powder is mostly produced from May to September, whereas perfume demand is very stochastic and production planned as the market required. Jelly is mainly sold between October and February leading to the factory operating around the clock and partly on weekends during this time of the year.

3.3. Electrical Setup

3.3.1. Grid Connection

There is no grid connection to this site.

3.3.2. Diesel Generators

Electricity is provided by three diesel generators of 32.5 kVA, 197 kVA and 500 kVA respectively (prime rating). The largest gensets are used during factory operation. They cannot be synchronised, i.e. they cannot be running simultaneously. The appropriate capacity to be operated is based on the power demand of the factory. When switching from one unit to another there is always a short power cut. The small generator is dedicated to security lighting and only operated during the night and on weekends. All generators already have been fairly old with a lot of running hours.

The diesel generators have the following technical specs:

	Generator 1	**Generator 2**	**Generator 3**
Manufacturer:	Caterpillar	SAKR Power Systems	Falcon
Model:	Unknown	DG50222	544 LB
Operating Mode:	Prime	Prime	Standby
Apparent Power:	500 kVA	197 kVA	32.5 kVA
Real Power:	400 kW	157.6 kW	26 kW

Figure 2 - Diesel Generator Nameplates

The maximum diesel consumption is on average 600 to 650 litres a day during the season when jelly is produced and operation takes place during 24-hour. Every three weeks fuel is delivered to site and stored in a 25,000-litre tank. Fuel is then transferred in batches to a 540-litre tank that supplies the main generator. The price of diesel fuel is 170 Naira (0.47 USD) per litre including transport and additional costs (e.g. taxes).

3.3.3. Distribution Setup

The electrical setup at site is neat and professionally installed. Two incoming cables from the large diesel generators at the top are led through circuit breakers and interlocked contactors to a busbar and from there distributed to the loads. The small diesel generator is connected to a separate cabinet, where it can be connected to security lighting and other critical loads without supplying the rest of the factory.

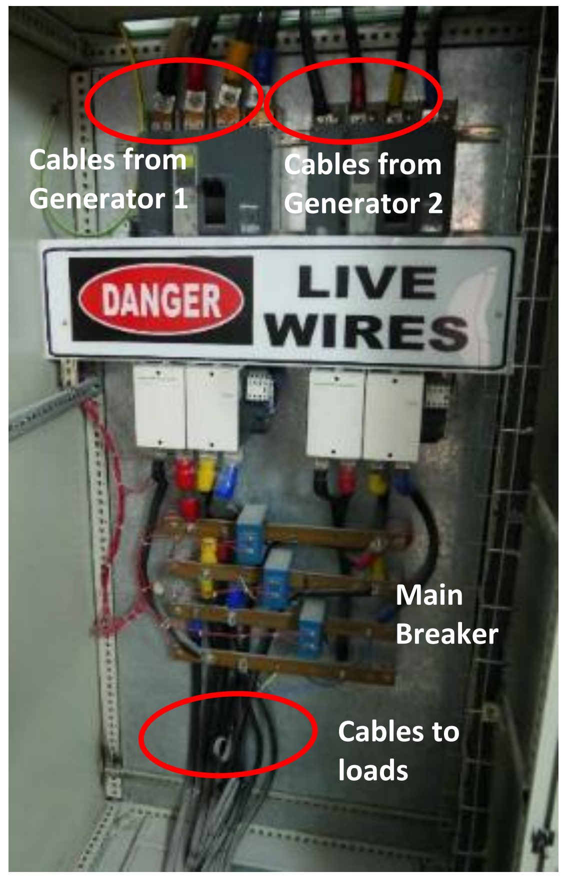


Figure 3 - Main Incomer panel

During the power audit, a OneAnalyser was installed to capture the electrical consumption on site. The measurement device was installed to capture the total consumption of the factory on a minute base. A relay signal allows to detect which of the two large gensets is being operated. The smallest generator, which operates only during weekends and non-production days, is not measured with this device. The single line diagram (SLD) below that was created based on the information gathered on site depicts the electrical layout of the site (see next page).

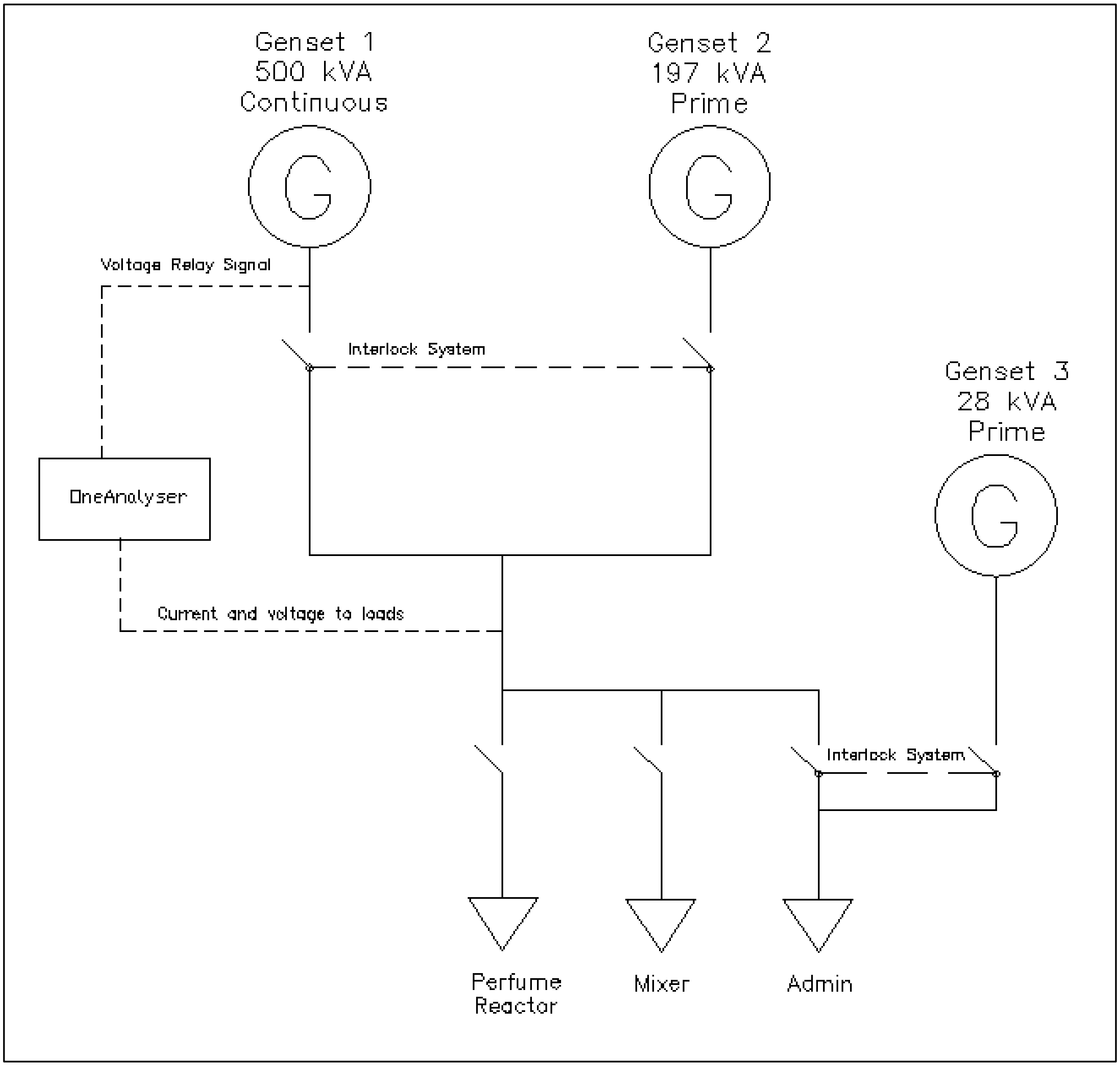


Figure 4 - SLD Givanas Factory

3.3.4. Electrical loads

Major loads of the factory are several mixers for perfume and jelly line as well as cooling, heating and conveyor units. The single largest load is the cooling on the jelly production line.

Lighting is composed mainly of energy-saving lamps, CFL type with wattage equivalent to 85 to 130 Watts traditional incandescent lamps. There are at least 80 lamps of this type in the factory.

3.4. Power Demand

3.4.1. Load Profile

The load profile of the site can be obtained through the measurements from the OneAnalyser installed on site. It captures the current running through each of the wires as well as the voltage on each phase. This provides an accurate measurement of the power demand in each time of 1 minute.

Based on this measurement, the following figures can be determined:

- Load profile during week days
- Load profile during weekends
- Load profile during jelly season
- Load profile outside jelly season
- Energy consumed from Generator 1
- Energy consumed from Generator 2

Below is an example of the load profile during the jelly season, which this year began at the end of October. The consumption increases significantly with 24/7 operation compared with the usual 06:00 to 18:00 production.

The 500 kVA generator (Generator 1) is used as the main power supply for periods of higher demand during production while the 197 kVA generator (Generator 2) covers the night shifts. In this way, the site is matching the load demand with the most appropriate generator so that they run at a higher loading.

It is clear through the measurements that during this season there is no usage of Generator 3 as only one generator can be running at a time.

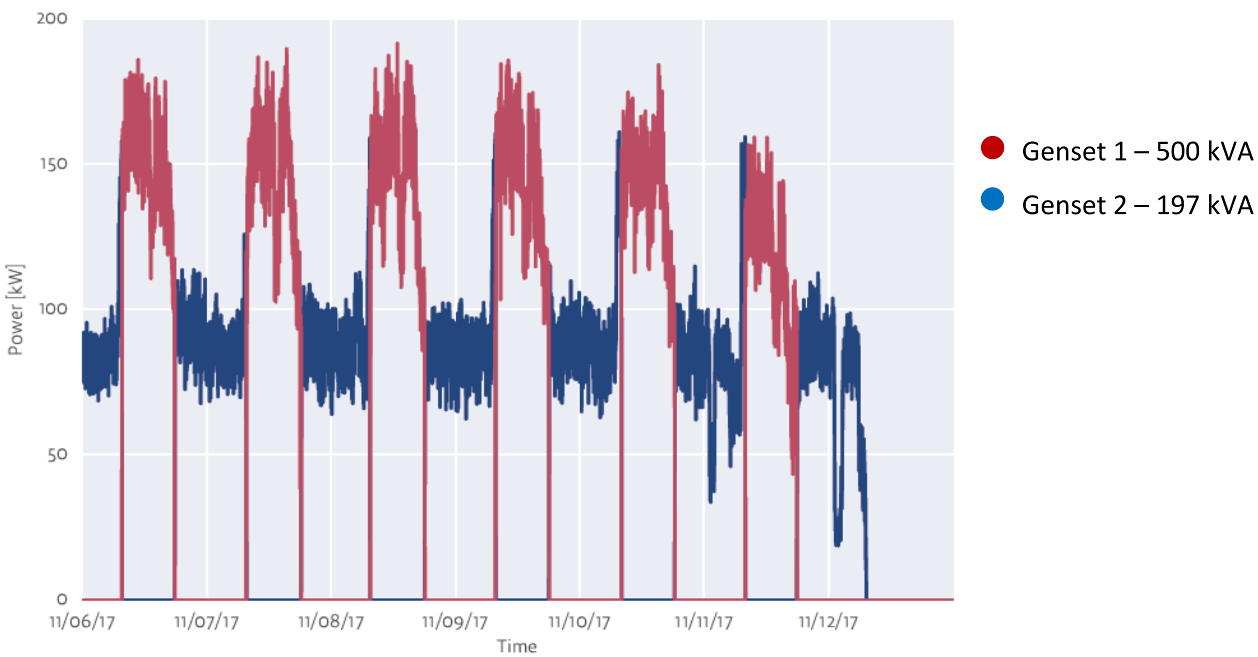


Figure 5 - Reference week during Jelly production

Outside the jelly season the site only operates during main production times and has no production on the weekends. Generator 2 is operated as the main power supply to cover an average power demand of 130 kW, which translates into an average of 52% loading for the generator. From the measurement data beginning on the 29th of September, Generator 1 was only being ran, as seen below, for a few hours on one day in the week. It is common practice among operators to run generators for a few hours every week so they are ready to be brought into operation when required.

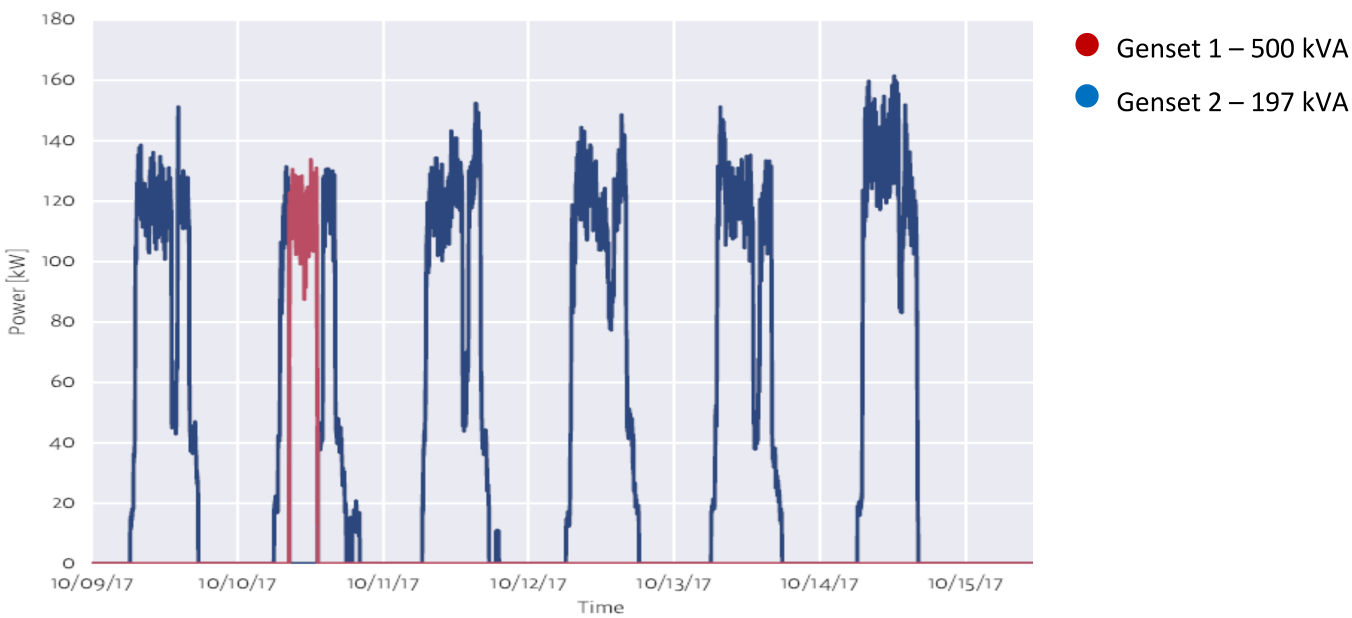


Figure 6 - Reference week during Powder production

During the weekend and evenings there could still be power demand on site, for non-production related loads. In this case it would be covered by Generator 3 (32.5 kVA) which is rated to be operated only as a backup power supply. Based on the measurements, the maximum load measured on site was 173 kW during the jelly season. Outside the jelly season it only reaches about 140 kW.

The annual load profile for the site is simulated through the extrapolation of data for production during the week and weekends for both jelly and powder seasons based on the measurements obtained from the OneAnalyser devices so far. There is no clear consumption related to the perfume production, hence only the main two production seasons are considered.

3.4.2. Electricity Consumption

During the measurement period (30/09/2017 until 09/11/2017) that this report is based on the following consumption was measured:

Total generator consumption:	56,281 kWh
Generator 1 share:	34 %
Generator 2 share:	66 %

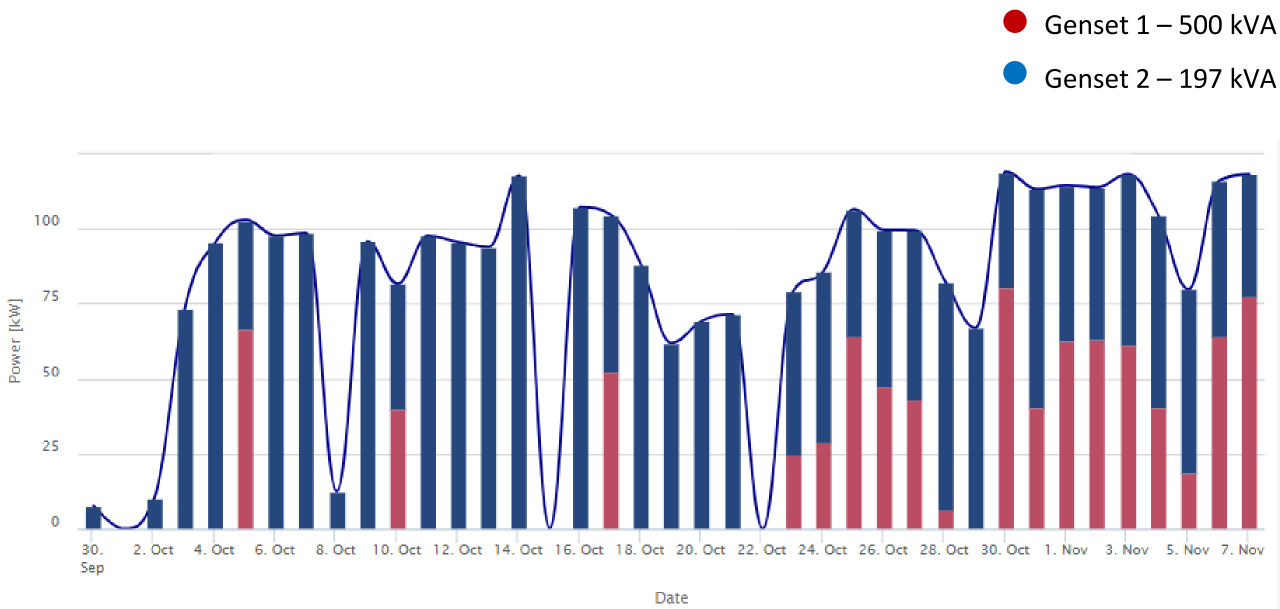


Figure 7 – Load profile in Givanas from OneAnalyser measurement data

The data measurements are extrapolated based on the known seasonality of the site for an entire year, which gives the total electricity consumption values for each generator and the total consumption for the site:

Annual Generator 1 consumption:	134,801 kWh
Annual Generator 2 consumption:	358,391 kWh
Annual consumption*:	493,192 kWh

*Note that the annual consumption only applies to production days as the consumption from the 3rd generator which provides power to the offices during the weekend is not measured. The non-production loads during these times have only a small effect in the total annual consumption of the site compared to the main large loads operated during production.

3.4.3. Diesel Consumption

A measurement sensor was installed in the fuel tank for the large 500 kVA generator to measure the level of the tank. This data allows to derive fuel consumption of the generator and through a comparison with its loading, assess its fuel efficiency. The fuel level can also be used to plan the refilling of the tank and most importantly, be used to monitor diesel theft. The TIM24 device is connected to the OneAnalyser to provide 1 hour measurement data of the tank level.

Figure 8 - Installation of TIM24 Fuel Measurement Sensor

The graph below shows the level of the fuel tank during an example measurement day. It starts with a steady tank level until approximately 06:00 where the tank is refilled. When the large generator starts at 14:00, the tank level steadily decreases as well as its loading, as it can be seen on its load measurement profile below. The relationship between the electricity generation and fuel consumption can be derived from this graph and results in an average specific production of 2.8 kWh /litre.

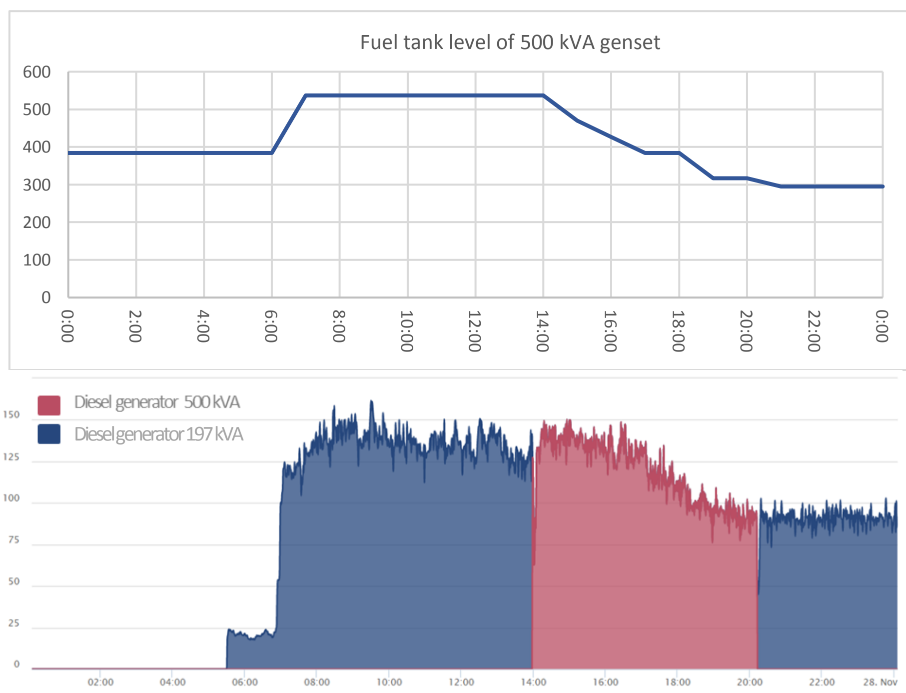


Figure 9 - TIM24 Fuel tank level measurements compared to load measurements

4. Energy Efficiency Options

In its goal to reduce the power demand at Givanas factory, various options can be considered. Below a list of these energy-savings or on-site generation options to reduce the electricity bill are presented in more detail. All options are compared after this chapter, with regards to their energy-savings and the attached cost.

4.1. Replacement of equipment

Lighting on site is provided mainly by Concentrated Fluorescent Lighting (CFL), one of the most efficient types of lighting in the market. Lightbulbs used at site have a lighting temperature of 6,400 Kelvin, equivalent to the daylight spectrum. Higher efficiency lighting (LED technology) is usually used for lower temperatures and becomes more expensive than CFL at these ranges. Therefore, a downgrading of the lighting conditions to 5,000 Kelvin, still in the region of daylight spectrum, is considered in order to make a viable proposal for the replacement of CFL with LED technology. With these conditions about a year payback would be feasible – see table below for 80 lamps operating 24/7. The electricity cost is assumed to be 0.17 USD/kWh as electricity on site is supplied only through the diesel generators (fuel price of 0.47 USD/litre with a 2.8 kWh/litre specific production).

Annual Savings	$ 590
Total Savings (expected lifetime of LED)	$ 1,010
Implementation Cost	$ 719
Simple Payback	1.2 years

A detailed lighting audit would be required to provide verifiable savings and confirm the quantity and type of the existing lightbulbs. As the current lighting is already efficient, expected savings are not very large, especially in comparison with the annual electricity consumption. Given a payback of only about a year it is an option still worth considering.

	CFL lighting	**LED lighting**
Brightness	1,650 lumens	1,600 lumens
Temperature	6,500 k	5,000 k
Lamp Wattage (equivalent for 100W traditional lighting)	23 W	16 W
Lamp Cost	$ 4	$ 10
Expected Lamp lifetime	12,000 hours	15,000 hours

4.2. REPLACEMENT OF DIESEL GENERATOR

There are currently two gensets on site which are used depending on the power demand, with the largest generator of 500 kVA operating during high demand periods such as daily production times during the jelly season. According to the measurement data, the highest peaks in this period are lower than 200 kW. Therefore, the generator is working mainly around 30% - 36% loading and could be much better utilized – see below a histogram of its loading during the measurement data period. As a prime generator it is designed to work as the main power supply at an average loading of 70-80%.

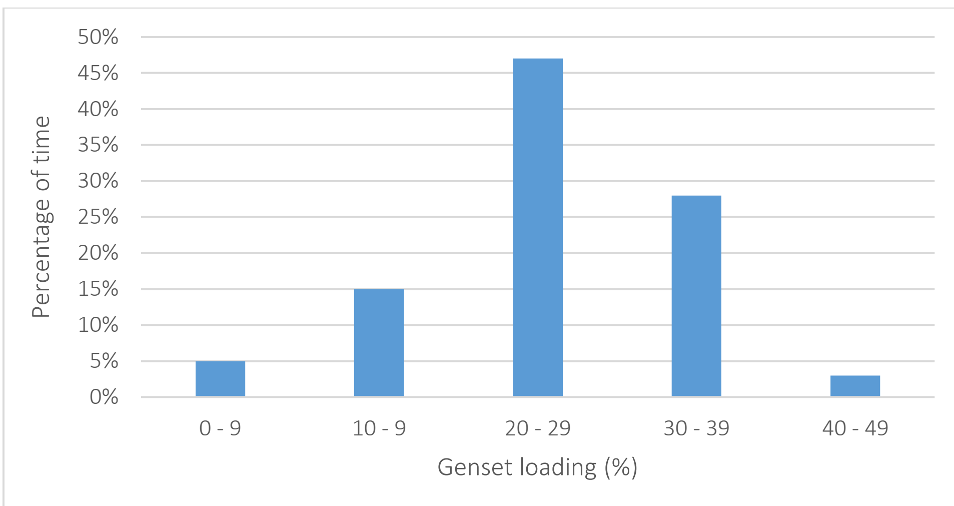


Figure 10 - Genset loading distribution

The 197 kVA generator is scheduled to cover lower demand periods and it is well sized to do so, running at an average 54% loading. Sometimes it runs on overcapacity, but this has been observed in the measurements only in a few occasions – i.e. less than 1% of the time during its operation.

The large 500 kVA generator could be downsized by approximately 45% to 275 kVA, with a 10% buffer capacity to deal with peaks of demand above 200 kW. The CAPEX for a new diesel generator would lie around 48,000 USD including shipment and installation compared to anticipated cost of 75,000 USD for the large genset. Hence, replacement cost can be reduced by 27,000 USD.

After a replacement a 25% in fuel savings could be achieved annually, considering the average loading and the fuel consumption efficiency of the old and new generator. For an average power demand of 150 kW and 1,340 operational hours (considering the operation during the high and low seasons), the savings would amount to approximately 7,000 USD per year. The larger generator is used mainly during the jelly season which means that the savings are limited as the fuel savings are directly related to the number of operational hours – i.e. the less the generator is used the lower the fuel savings that could be achieved.

The replacement would yield around 49,000 USD total savings over a typical expected lifetime of 7 years. No maintenance costs have been included in this calculation although OPEX savings would also be expected, due to the operation closer to the optimum design point of the engine. Generator downsizing should be considered when the current large generator needs to be replaced, or if there is either a possibility to sell the old engine or use it at a site, where it is more suitable for the load.

Another option would be to use the existing smaller 197 kVA generator in synchronisation with another small generator of around 100 kVA that would be started to provide additional power during times of high demand (and could also be used instead of the 197 kVA generator when demand is low). This would lead to an even lower investment for the generator and future replacements, but require the addition of synchronising equipment and a control system. An automated system would also prevent generators from being run in overload as it dispatches the gensets automatically according to the demand to prevent this situation. This option can be considered and evaluated further when there is an opportunity or need to replace the large generator.

4.3. SOLAR DIESEL HYBRID SYSTEM

The maximum PV power that can be safely integrated alongside the diesel generator and without a battery is 90 kW due to the operational limits of having two diesel generators. With this scenario, the shortest payback that can be achieved is 6.3 years. Investment cost for this system are 127,000 USD, contributing towards covering the electrical demand with an energy share of 22%. See the table in page 18 for a summary of the key financial indicators for this project.

The PV system relies on the operation of the generators to be able to generate electricity. This means that the savings are limited and larger PV systems would not bring additional savings as the energy could not be utilized and the increased investment would result in a longer payback. Additional savings could be achieved if the large generator was sized appropriately.

Payback is not the only key indicator describing the financial attractiveness of the system. With an assumed lifetime of 20 years it is worth looking at the total savings over this period. As fuel costs will further increase due to shortage of fossil fuels, annual savings and benefits from the system are likely to increase over the years.

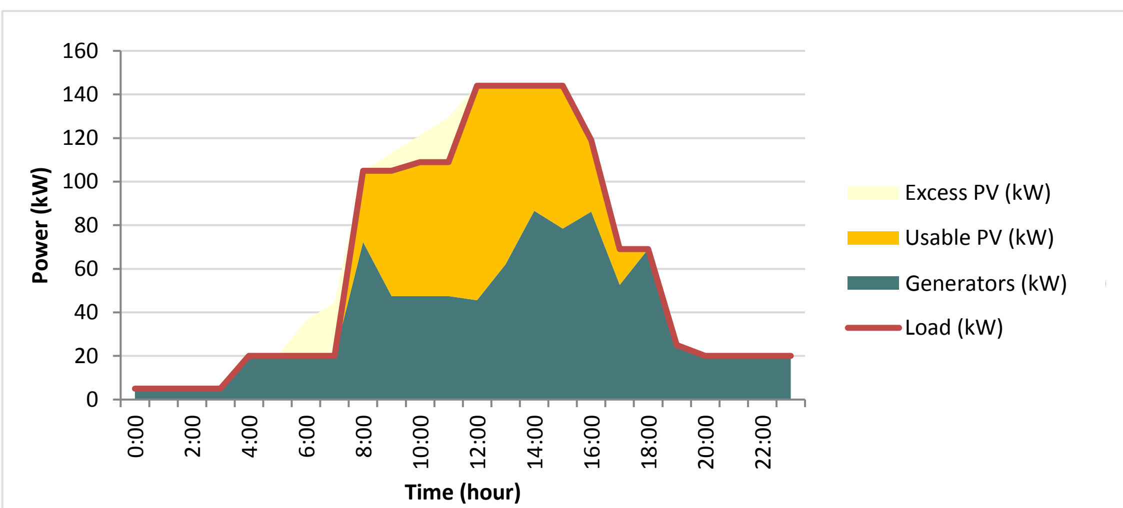


Figure 11 - Example of PV operation along with diesel generators

4.4. SOLAR DIESEL BATTERY SYSTEM

The addition of batteries to the setup with PV and diesel allows to raise the share of solar energy by enabling the integration of larger PV systems. Any PV power that cannot be directly used can be stored in the battery and discharged later. It is required to use a battery inverter that is grid forming, allowing the PV and the battery to operate on their own without having to run the diesel generator in parallel. The battery also allows for less operation of the generators, to the point that the smaller 197 kVA generator along with the PV system are sufficient to cover the demand during the entire year. This highlights the fact that the larger generator is oversized for the demand and that the second generator can be operated efficiently with a PV system to replace it completely.

Technical simulations showed that a battery capacity of 100 kWh is sufficient to reduce generator running hours significantly. This leads to a total share of 39% of annual consumption of the site being supplied by solar energy.

Compared to the PV diesel scenario this system is larger, more complex and more expensive. However, it also offers a greater benefit, with higher fuel savings thanks to the better utilization of the PV system through energy storage. Compared to the simple PV diesel hybrid system, this system offers a longer payback of 7.5 years. Nevertheless, higher total savings can be generated over the system’s lifetime thanks to its increased solar energy share.

	Base case	PV with diesel	PV with diesel and battery
Size diesel generator 1	400 kW	400 kW	400 kW
Size diesel generator 2	158 kW	158 kW	158 kW
Size PV	-	90 kW	140 kW
Size battery	-	-	100 kWh
Solar energy share	-	22 %	39 %
Investment cost	-	$ 127,000	$ 256,000
Annual diesel cost	$ 82,785	$ 65,000	$ 57,500
Annual fuel savings	-	$ 17,800	$ 25,300
Total Savings	-	$ 446,187	$ 634,000
Payback	-	6.3 years	7.5 years

5. CONCLUSION

5.1. COMPARISON OF ENERGY EFFICIENCY OPTIONS

Several energy-saving measures and solutions have been investigated in this report. A list of the recommended options that should be further analysed are presented in the table.

Case	Total Savings (USD)	Total Investment (USD)	Simple payback
Lighting replacement	$ 1,010	$ 719	1.2 years
Replacement of large generator	$ 49,000 (fuel) $ 27,000 (replacement)	$ 48,000	n.a.
PV with diesel generators	$ 446,187	$ 127,000	6.3 years
PV with battery and diesel generators	$ 634,000	$ 256,000	7.5 years

The payback indicates the time required to obtain enough savings from the system to pay off the initial investment. As such, it gives a good overview of the project feasibility and can be used for comparison between different projects. However, other parameters such as total savings over the lifetime of the system should be considered for a complete assessment of the projects´ viability. For example, the replacement of lighting has a very low payback but also brings very low savings. This is an energy efficiency measure that tackles small electricity consumers and hence does not decrease the overall electricity demand significantly.

Another option to replace current equipment is to downsize the large 500 kVA generator which is currently being used to cover the power demand during high season. An appropriately sized generator would bring fuel and OPEX savings which makes this an interesting option. However, this project would only be economically viable when the generator needs to be replaced.

Finally, two options for the installation of on-site PV hybrid generation systems are simulated and analysed. The initial investment for these systems are considerable but so are the potential savings that they could deliver. A PV system can inject more energy into the grid when energy storage is available, however, this also increases the required investment. This considers that a scheme would be in place to provide payments for exporting solar energy into the grid.

The battery also allows to utilize the output of the PV plant to the point that the large generator is no longer required. Small generator, PV and battery are able to cover the entire load any given point of time during operation. This would have a great impact in terms of fuel savings, as it avoids the inefficient operation of the large generator completely, which would function merely as backup generation.