Power Audit Report

DeveloPPP Project: WP2 Power Audits

Power Audit at Soulmate Factory

Lagos, Nigeria

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1. EXECUTIVE SUMMARY

Soulmate 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 there are 680 m^2 of roof space available at Soulmate factory which could be assessed for PV installation. A OneAnalyser measurement device captured the electricity consumption from the grid and the two main diesel generators on site. Production times are mainly in shifts on weekdays from 07:45 to 18:00 with a relatively low average power demand of 22 kW during operation with peaks up to 40 kW. Non-production times especially during the weekends and at night, have a minimal power demand (less than 5 kW). The site operates for longer hours from October to January and periods of higher power demand occur when large orders are placed. Diesel generators are deployed to cover the demand during grid outages and critical stages of production, where stable and constant power supply is crucial.

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 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 viable energy savings opportunities investigated in this report and their financial key indicators:

Case	Total Lifetime Savings (USD)	Total Investment (USD)	Simple payback
Lighting replacement	$ 756 over 4.6 years	$ 539	3.3 years
Replacement of large generator	$ 22,281 fuel savings over 7 years $ 23,660 additional revenue from large genset sale	$ 19,500 for a 66 kVA generator	Immediate with sale of large genset
PV with diesel generators	$ 56,838 over 20 years	$ 40,000	10.4 years

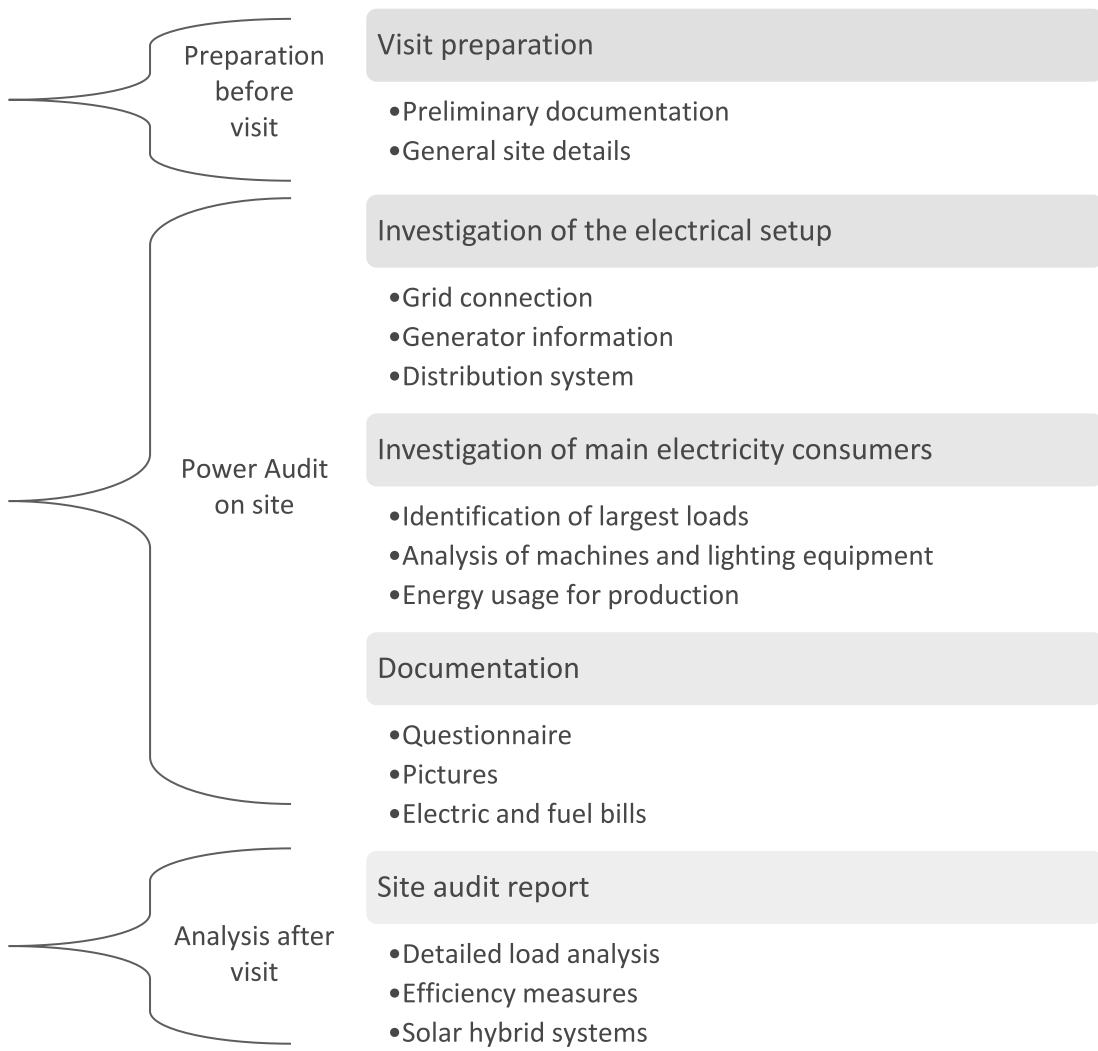
2. SITE VISIT STRUCTURE

2.1. OBJECTIVE

To understand and document the power demand and electrical setup at Soulmate 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 26th 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 Soulmate 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

The Soulmate factory produces cosmetics, mainly hair care, for the Nigerian market and is located in Lagos.

There is a rooftop space of around 200 m^2 on three different buildings (warehouse, production and administration). There is a total roof area of 680 m^2 that could be used for the installation of PV rooftop modules. A detailed analysis will be required to confirm sufficient stability before planning a PV system.

Figure 1 - Site map of Soulmate factory

3.2. SITE DESCRIPTION

The site operates typically from 07:45 to 18:00 with one hour break at 13:00. There is no operation at night and over the weekend. The only electrical consumption at this time is for security systems and lighting. There is a main production season from October to January when they produce for longer hours. The output of the site is very dependent on orders; hence it is difficult to predict the electrical consumption for a year with a high degree of certainty.

There is a main production line where electricity is mainly used for the mixer (including pumps and motors) and the filling and packaging stages.

- **Example production line**

Mixer → Heating → Filling → Packaging

On the packaging line, a 3-phase electric heater for attaching labels onto the products has a rating of 30 Amps per phase. A cooling tower is used as a natural heat exchanger to provide cooling to mixer and the motors in the production hall. Pumps are required for this system and are hence part of the loads in the production hall. No more details into the production process could be provided by site during the visit.

3.3. Electrical Setup

3.3.1. Grid Connection

There is a connection to the main electricity distribution network. The grid is generally too unreliable to maintain planned production every day which is why the site relies almost entirely on the use of diesel generators to provide power. There are also issues with the power quality, for instance voltage sags and swells, that affects production as some equipment cannot safely operate under these power conditions. This decreases even further the reliability of the grid as the site cannot consume electricity sometimes from the grid even in the time windows that is available. The site and has an electricity contracted tariff for D2 industrial category with the Eko Electricity Distribution Company and amounts to 33.05 Naira (0.11 USD).

Power outages were modelled to assess the impact of grid unavailability on the savings options proposed. It is assumed that outages occurred during the periods during production times and when the generators are in operation.

3.3.2. Diesel Generators

There are two main generators used during production, a small CAT Olympian 100 kVA and a large CAT 200 kVA. Both generators are relatively new (2013 and 2007 respectively) and are serviced several times a year. An additional 75 kVA generator supplies power during low demand, at night and weekends. However, it is not working at the moment and needs to be repaired. At the time of the visit it had not been used for the previous two months. During production, the small 100 kVA generator is the main power supply when the grid is not available throughout the low season providing 39% of the demand. The large 200 kVA genset is used during high season or when the site receives large orders.

As seen in the SLD shown in section 3.3.3, there are two changeover switches that need to be operated in order to route the power to the loads. When the grid is available or the large generator is to supply power, the changeover next to the loads must be selected for this circuit. When the grid is not available or the small generator provides the power, then the changeover switch is selected for the small genset circuit. These switches are manual levers operated by the site electrician.

The diesel generators have the following technical specs:

	Generator 1	**Generator 2**
Manufacturer:	Caterpillar	Caterpillar/Olympian
Model:	GEH220-4	GEP110
Operating Mode:	Prime	Prime
Apparent Power:	200 kVA	100 kVA
Real Power:	160 kW	80 kW

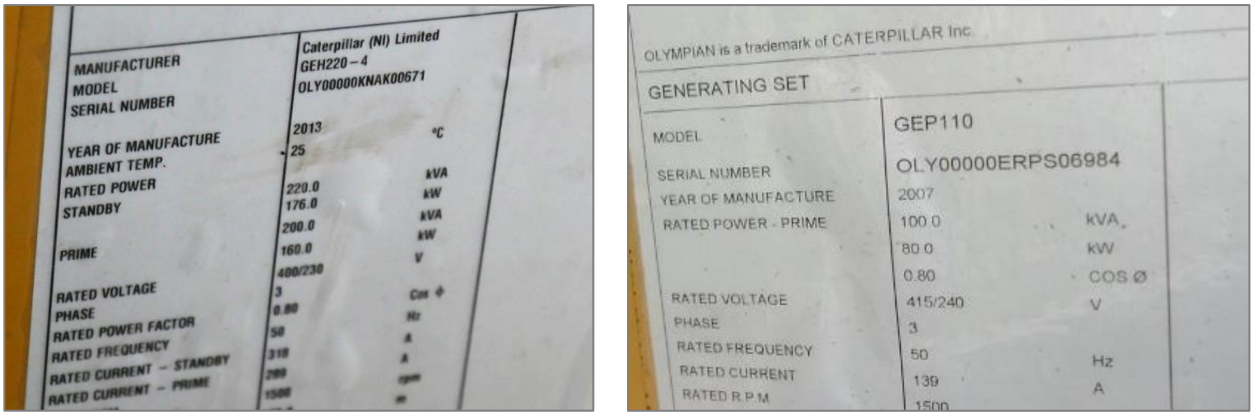


Figure 2 - Diesel Generator Nameplates

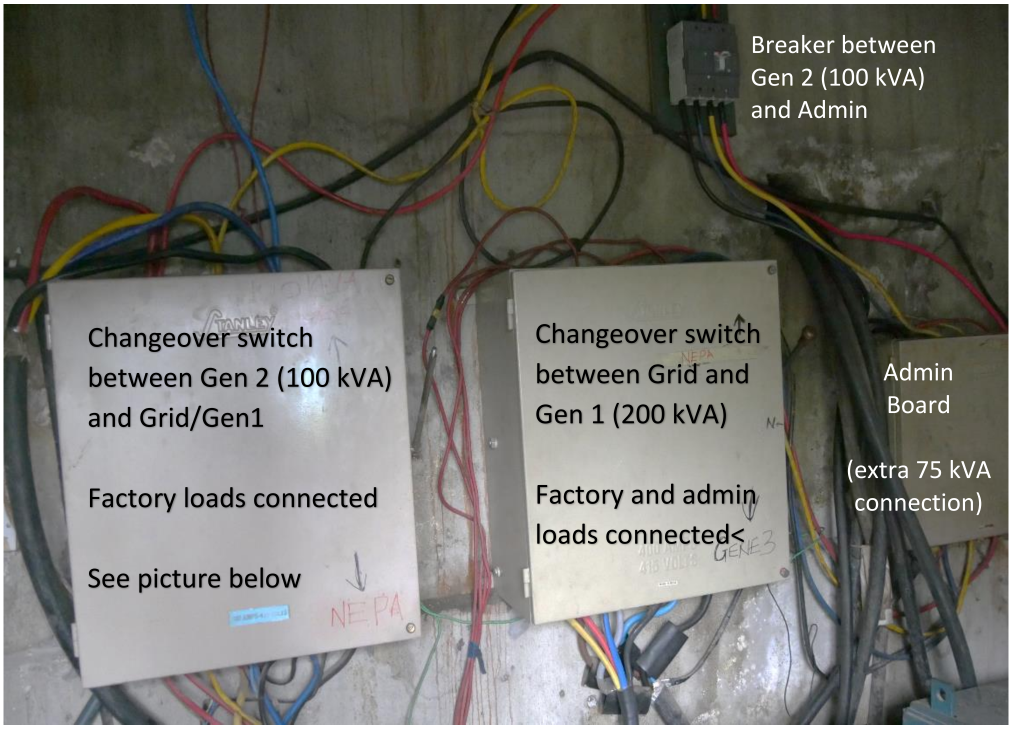
It is estimated that the generators consume 150 – 180 litres a day during normal operation season. It is not recorded however how the consumption increases during higher production times.

The fuel is delivered by an outside contractor to the large 10,000 litre tank. From there the gensets' base tanks are refilled, but diesel is also used for company vehicles and to power the managing director's house. The price of diesel is between 200 Naira (0.5 USD) per litre and includes transport costs.

3.3.3. Distribution Setup

During the power audit, a OneAnalyser panel was installed to capture the electrical consumption on site from the grid and the large diesel generators. The distribution panel and the connections to the OneAnalyser are shown in Figure 3.

The measurement device was installed to capture the consumption from all the production loads and a reference voltage measurement to distinguish whether the small generator or the large generator / grid are supplying electricity. A Single Line Diagram (SLD) of the system is shown in Figure 4.



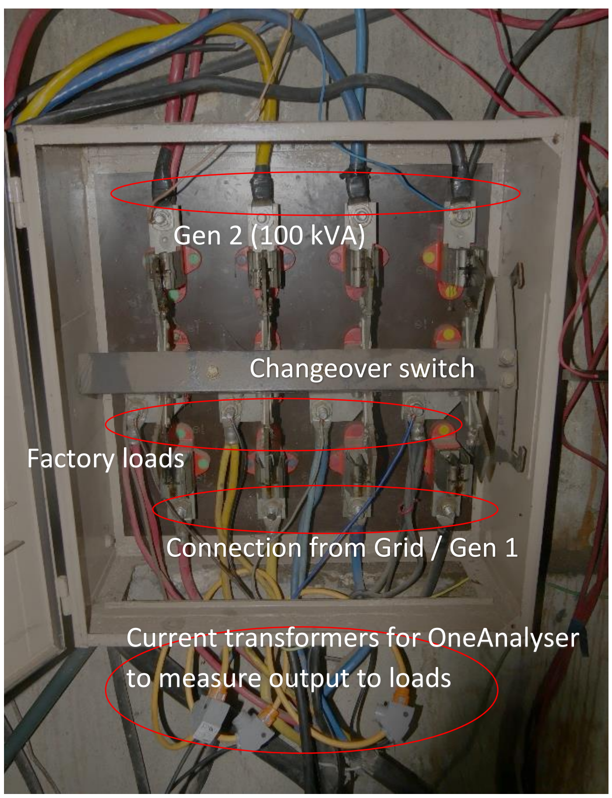


Figure 3 - Electrical distribution and OneAnalyser connections

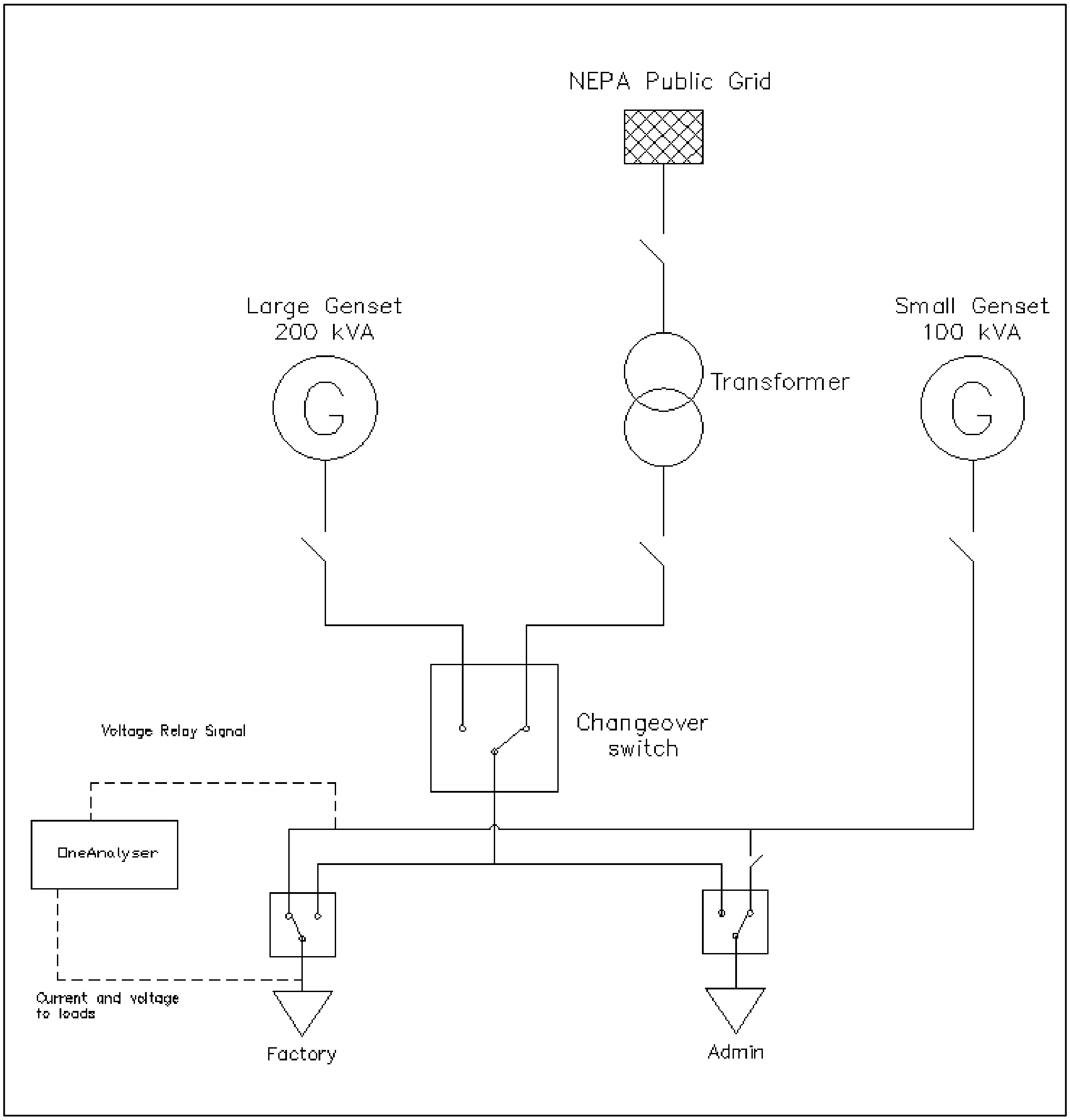


Figure 4 - SLD Soulmate Factory

3.3.4. Electrical loads

The largest electrical loads on site would be the mixer and packaging in the production process. No datasheets or documentation with information on the ratings of the loads could be provided during the visit. Lighting is composed mainly of energy saving lamps, CFL type.

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:

- Energy consumed from the public grid
- Energy consumed from Generator 1 (200 kVA)
- Energy consumed from Generator 2 (100 kVA)

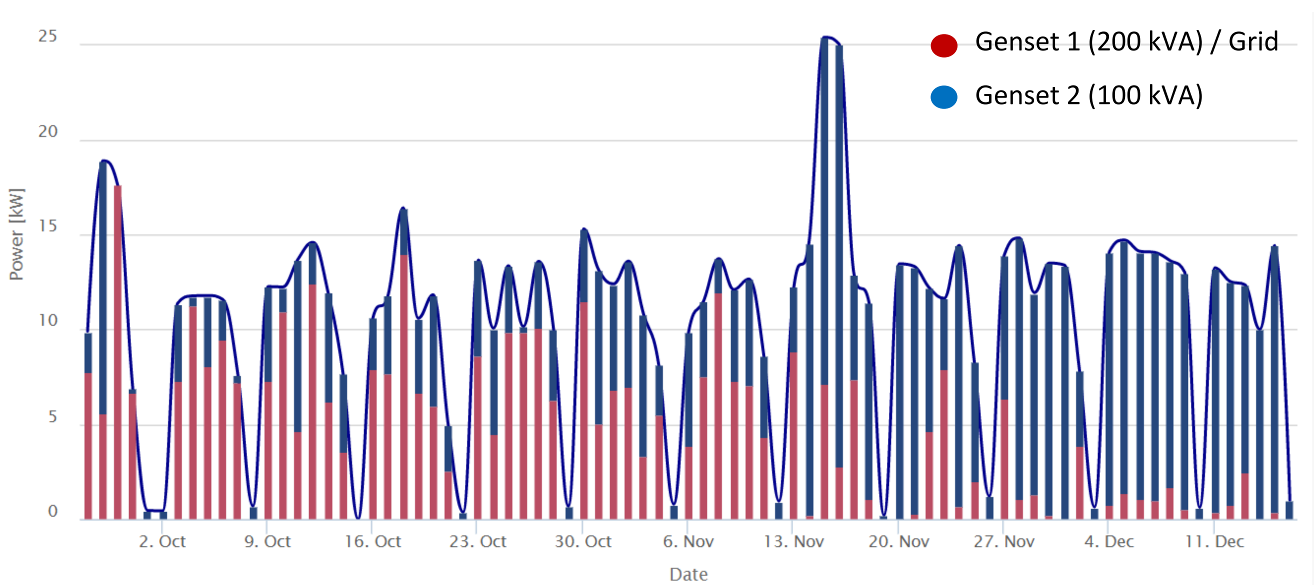


Figure 5 - Load profile in Soulmate from OneAnalyser measurement data

During the measurement period shown in the previous page (30/09/2017 until 10/12/2017) that this report is based on, the following consumption was measured:

Total consumption:	14,603 kWh	
Generator 1 consumption:	3,534 kWh	24%
Generator 2 consumption:	6,409 kWh	44%
Grid consumption:	4,660 kWh	32%

The changeover switch at this site selects between either generator 2 or the grid and generator 1. This means that the consumption between genset 1 and the grid had to be differentiated through further analysis of its power characteristics. The phase voltages supplied by the generator are very stable, i.e. the deviation between the phase voltages is close to 0. In comparison, the public grid is connected to a large electrical network which results in more variable phase voltages.

From the measurements collected from September it was possible to obtain data for a lower and higher season, with higher demand beginning at early December. The smaller 100 kVA genset is used as the main power supply during the grid outages during the lower periods of power demand.

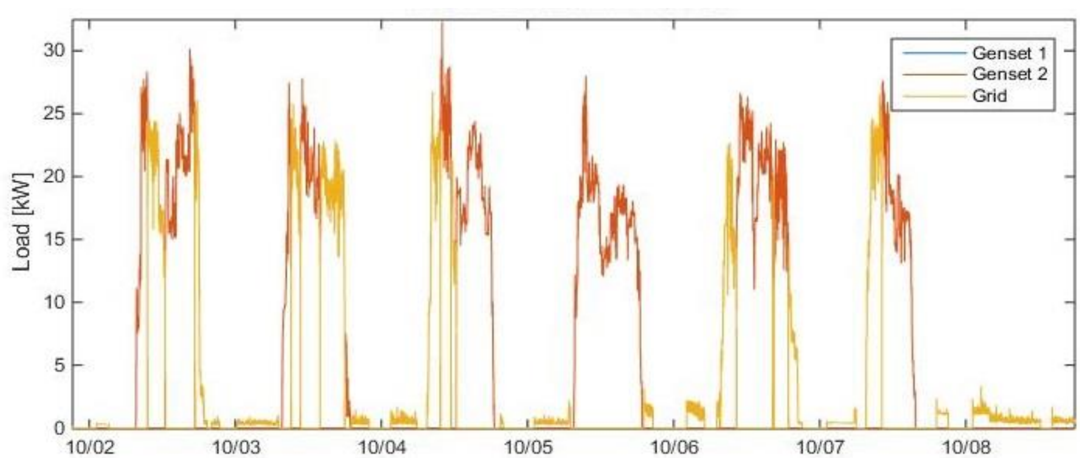


Figure 6 - Example of Soulmates consumption weekly profile during lower demand periods

As seen below, the large 200 kVA generator is used more often during the high demand period. The most marked difference between the two seasons is how the generators are deployed rather than a significant difference in the power demand. The maximum power demand during the high season can reach 40 kW, barely 6kW higher than the low season and the average power is 22 kW, compared with 20 kW for the low season. The overall consumption however is higher in average because the site operates for longer hours in the evening.

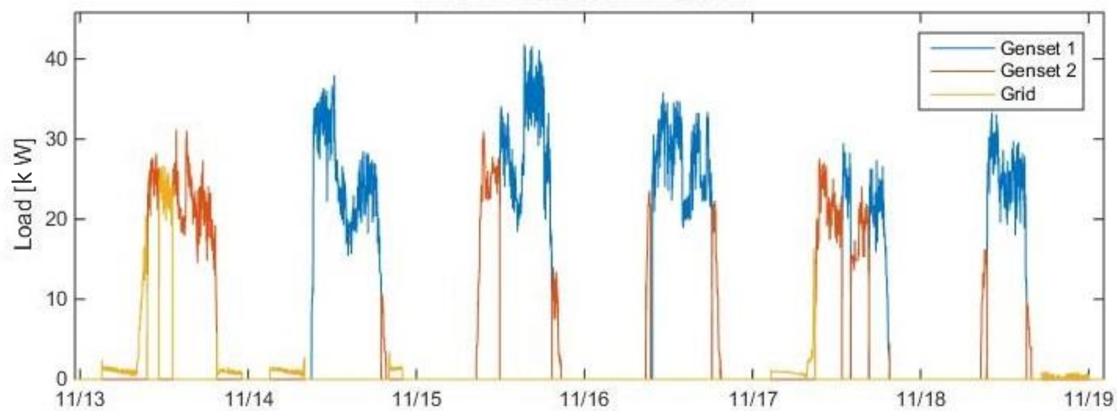


Figure 7 - Example of Soulmates consumption weekly profile during high demand

3.4.2. ANNUAL ELECTRICITY CONSUMPTION

The data measurements were extrapolated based on the anticipated seasonality of the site for an entire year so that the system can be modelled to assess the feasibility of energy solutions. From the lower and higher demand periods captured by the OneAnalyser device, an estimated annual consumption using both periods was simulated. The higher season was considered to run for around 4 months from early December until end of March.

The following table presents the total electricity consumption values for each generator, the grid and the total for the site for a year:

Annual consumption*:	70,721 kWh	
Annual Generator 1 consumption:	14,694 kWh	21%
Annual Generator 2 consumption:	29,781 kWh	42%
Annual Grid consumption:	26,245 kWh	37%

*It is assumed that the demand is covered completely by the generators 1 and 2 as well as the grid. The 3rd generator of 75 kVA currently unavailable is not considered for the analysis.

4. ENERGY EFFICIENCY OPTIONS

In its goal to reduce the power demand at Soulmate factory, various options have been 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 their related costs.

4.1. REPLACEMENT OF EQUIPMENT

Lighting on site is provided mainly by approximately 60 Concentrated Fluorescent Lighting (CFL) lightbulbs, one of the most efficient types of lighting in the market. A replacement of these lights with LED lighting would be possible to further reduce electricity consumption.

	CFL lighting	**LED lighting**
Brightness	1,650 lumens	1,600 lumens
Lamp Wattage (equivalent for 100W traditional lighting)	23 W	16 W
Lamp Cost	$ 3	$ 9
Expected Lamp lifetime	12,000 hours	15,000 hours

The electricity cost is assumed to be 0.16 USD/kWh, a compounded value from a 30% grid costs of 0.11 USD/kWh and 70% of 0.18 USD/kWh for diesel derived from a fuel price of 0.50 USD/litre with a 2.6 kWh/litre specific production. From the replacement, annual electricity savings of $ 3.8 saving per lightbulb can be expected. For a replacement of 60 lamps the following savings (including replacement savings) could be achieved:

Annual Savings	$ 164
Total Savings	$ 756
Implementation Cost	$ 539
Simple Payback	3.3 years

Total savings are calculated based on the lifetime of the LED lighting with the same operating hours, in total 4.6 years. The payback of 3.3 years is relatively large for a small investment project. This is because of the limited use of lighting which has been assumed that is only operational during production, yielding 3,250 hours of operation in a year. Other lighting used outside of core production times would be used for security and its electrical consumption is negligible. A more in-depth lighting audit would be required to find detailed information about the current lighting system and exact number of bulbs that can be replaced.

4.2. REPLACEMENT OF DIESEL GENERATOR

There are currently two diesel generators on site which are used depending on the power demand, with the largest generator of 200 kVA operating during high demand periods. According to the measurement data, the highest peaks in this period do not exceed 40 kW. This means that in fact both the 100 kVA (80 kW) and the 200 kVA (160 kW) generators are oversized for the current demand.

As seen in the histogram below the large generator was working mainly around 20 to 30 kW loading for 60% of the time during the measurements. This loading in kW translates into a 26% loading on average. As a prime generator, it is designed to work as the main power supply at an average loading of 70-80% which shows how it is not running at its most efficient conditions.

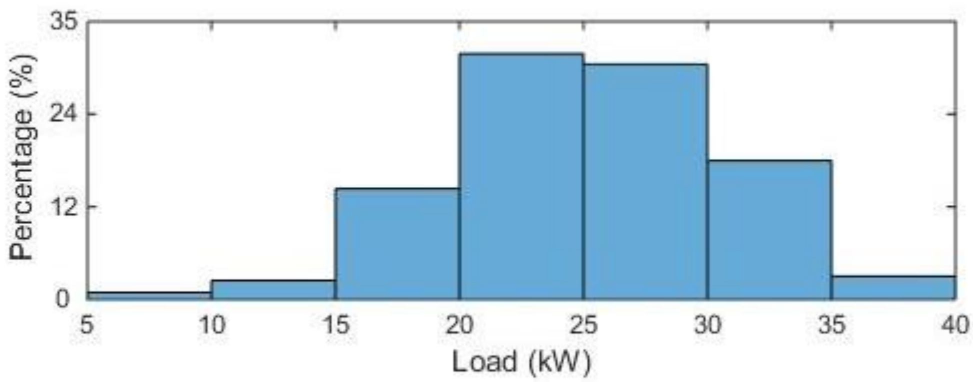


Figure 8 - Genset 1 (200 kVA) load histogram

Similarly, the smaller 100 kVA generator covered loads between 15 kW and 25 kW, 79% of the time. These loads translate into an equivalent loading of 53% for the generator. This generator is better utilized and could cover the entire demand if required.

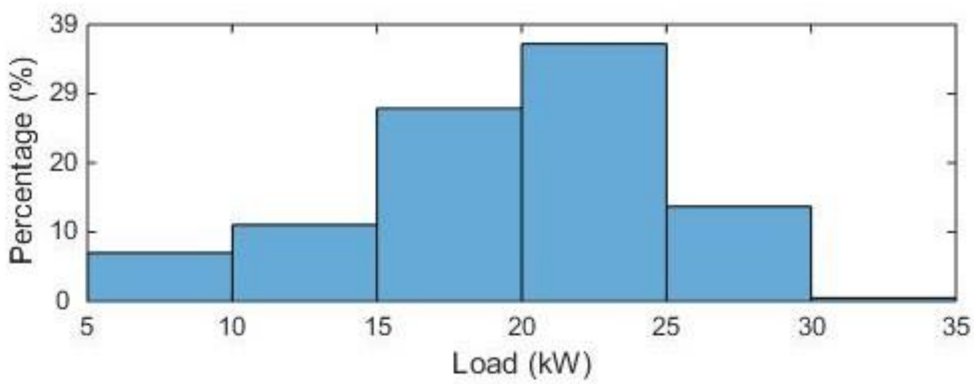


Figure 9 - Genset 2 (100 kVA) load histogram

Different possibilities could be explored to use the current assets more efficiently. The current power demand on site could be covered by the small 100 kVA generator as a prime generator. The 200 kVA generator would not be longer required; already the measurements showed that it was only used 21% of the time with maximum loading around 26%. Although the 100 kVA generator could be used as the main power supply, it would be cautious to have a backup generator such as the third 75 kVA generator. This genset had been previously used as a backup generator for low power demand periods, however, it was out of order at the time of the visit. More details about the state of the generator and the requirements from site would be required to assess whether this equipment should be used.

A possible sale of the large generator would yield around 23,000 USD. This capital could be used towards the investment of a new smaller generator that would function as the prime power supply. The CAPEX for a new diesel generator of 66 kVA, sufficient to cover high demand, would lie around 20,000 USD including shipment and installation. The system would be paid back immediately and savings would be accumulated from the start of the operation of the new generator.

The 100 kVA generator could be kept as a backup generator, which means that the site would have the security of having a backup in case the main generator (now 66 kVA) was not available. The fuel savings from replacing the operation of the 100 kVA and the 200 kVA by the 66 kVA generator would amount to approximately 3,200 USD annually over a typical expected lifetime of 7 years. An additional benefit of having a smaller generator would be that future replacement costs would be much lower than for the current large 200 kVA system.

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.

4.3. Solar Diesel Hybrid System

The current power system with oversized diesel generators means that the generators run always inefficiently. To ensure grid stability, the gensets must provide a baseload because solar energy cannot be always guaranteed. The capability of the system to incorporate a PV plant is highly constrained due to the minimum operating requirements for the generators when running along a PV. It is not possible to efficiently integrate the PV system with the present diesel generator setup. For this reason, it is a prerequisite to downsize the generators (see section 4.2) so that a PV system can be integrated and become an economically viable energy solution.

A PV system is well suited to the load profile of the site, as the highest demand occurs during daylight hours. There is only marginal power demand of less than 5 kW after production times, after 18:00 during the lower season and often 20:00 during the higher season. There is no domestic load that increases the consumption during the evening. The power demand on site however is very low, with an average of 22 kW during production which limits the sizes of PV that could be proposed for an economical energy solution.

With this scenario, the shortest payback that can be achieved is around 10 years for a system of 20 kW. Already with this smaller system, it can contribute towards 31% of the total annual electricity consumption. Larger systems would increase this solar share which could destabilize the system without the addition of energy storage. Investment cost for this system are around 40,000 USD and would bring total lifetime savings of 56,838 USD. See table below for a summary of the key financial indicators for this project.

	Base case	PV with diesel
Size diesel generator 1	160 kW	66 kW
Size diesel generator 2	80 kW	80 kW Backup
Size PV	-	20 kW
Size battery	-	-
Solar energy share	-	31 %
Investment cost	-	$ 40,000
Annual grid cost	$ 4,014	$ 2,661
Annual diesel cost	$ 6,688	$ 4,876
Annual savings	-	$ 3,085
Total Savings	-	$ 56,838
Payback	-	10.4 years

Due to the low demand from this site on the weekends, the utilization of the PV system is only around 70%. This means that energy produced by this system cannot always be consumed, which reduces the annual savings and has an impact in the overall return of the project. For a significantly greater utilisation the system size would become very low and therefore its impact would be only marginal. Additionally, the small size of the PV system means that the project does not benefit from the economy of scale for PV technology.

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.

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 or grid in parallel. Since the generators will be switched off during PV production, in this scenario the resizing (according to section 4.2) is not a critical prerequisite.

Simulations were carried out with a range of battery capacities from 10 kWh to 80 kWh. Compared to the PV diesel scenario this system is larger, more complex and more expensive. For this site, the benefits of having a battery to increase the amount of PV energy does not bring enough increased revenues to justify the investment on energy storage. A configuration of 30 kW PV system in combination with an 80-kWh battery would be an appropriate technical solution for this site, providing a renewable share of more than 50%. However, the system would not be financially viable given the current cost of electricity.

4.5. 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 Lifetime Savings (USD)	Total Investment (USD)	Simple payback
Lighting replacement	$ 756 over 4.6 years	$ 539	3.3 years
Replacement of large generator	$ 22,281 fuel savings over 7 years $ 23,660 additional revenue from large genset sale	$ 19,500 for a 66 kVA generator	Immediate with sale of large genset
PV with diesel generators	$ 56,838 over 20 years	$ 40,000	10.4 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, typically the replacement of lighting has a low payback but also brings low savings.

Another option to purchase a 66 kVA diesel generator to become the main power supply during outages and replace the usage of the 200 kVA and 100 kVA generators during the main production. The 100 kVA could be kept as a backup. Among the recommended energy saving options, this brings the greatest benefit to the site as the current generators are oversized for the current demand which results in higher annual fuel expenses. Additional revenue from the sale of the large generator would cover easily the investment for a new 66 kVA generator. In addition, an appropriately sized generator would also bring annual fuel and OPEX savings.

Finally, two options for the installation of on-site PV hybrid generation systems were simulated and analysed.

A small 20 kW PV system is suggested for a pure PV and diesel hybrid solution. This system would not demand a large investment from the site and could have a high penetration of 31% into the system. The low demand of the site however means that the system would require a long payback (around 10 years) due to the low annual savings that can be achieved in comparison with the investment required.

A second PV hybrid option with energy storage was also discussed in this report. Although this system would allow an even higher renewable share, the required investment would not increase the annual savings for the site significantly to justify the investment. Even though technically feasible, it would not be a financially viable solution especially with the actual costs of electricity.