ARUP

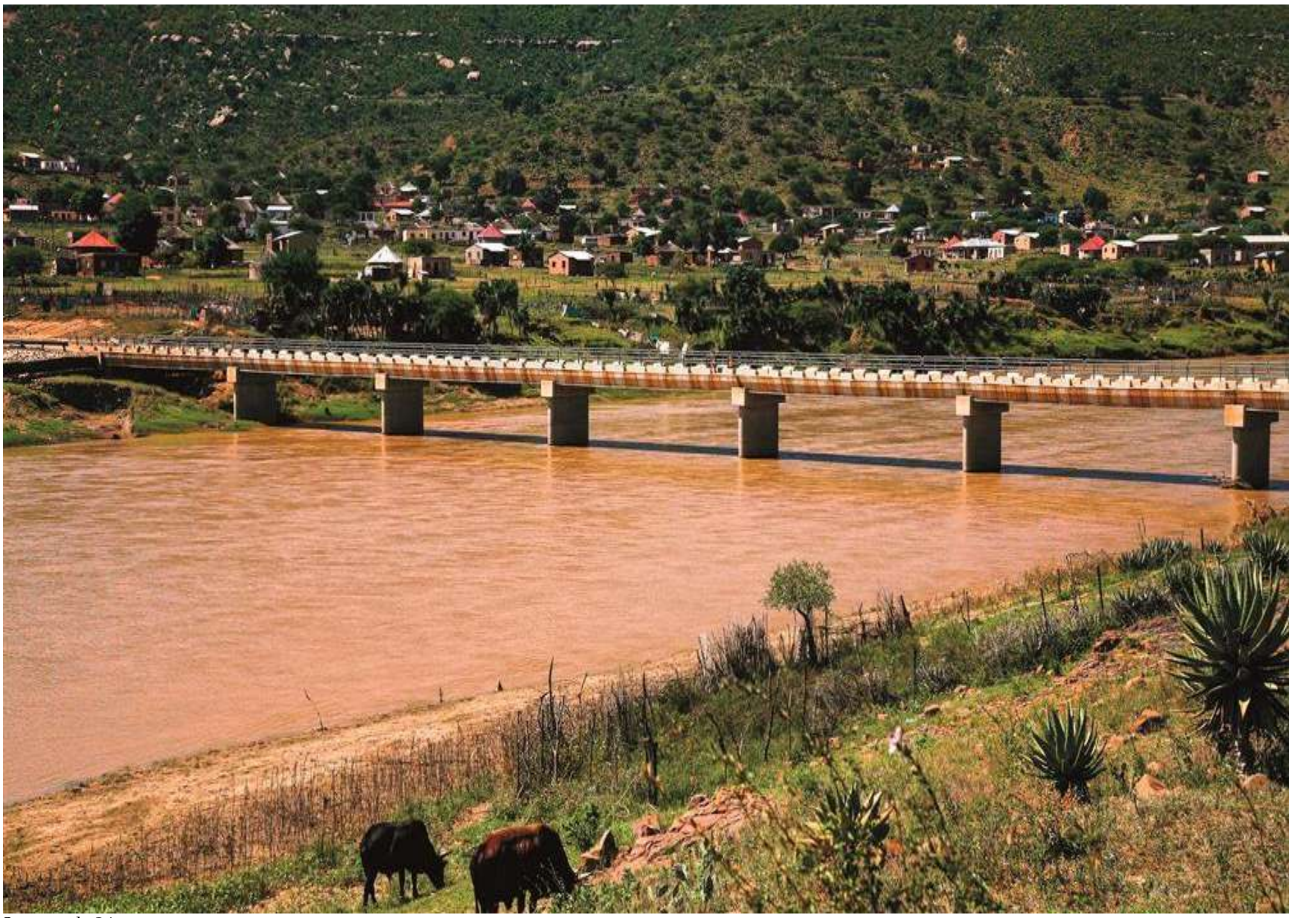
Vuthela iLembe Municipality

VILP/I/036 - Vuthela iLembe LED Programme

Sundumbili Water Treatment Works: Improving Energy Management and Efficiencies

Reference: IDM-01

Issue | 07 October 2022



Source: cdn.24.co.za

Job number 287865-00

Arup (Pty) Ltd
2nd Floor 6 Parks Boulevard
Oxford Parks Corner Oxford Road and Eastwood Road Dunkeld
Johannesburg
2196
South Africa
arup.com

Contents

Tables

Figures

Glossary of Terms

Documentation Reviewed	Version / Date
BMS	Building Management System
CT	Current Transformer
H&S	Health and Safety
IDM	iLembe District Municipality
kV	Kilovolts
kVA	Kilo Volt-Amps
kW	Kilowatts
KZN	KwaZulu-Natal
LED	Light Emitting Diode
NMD	Notified Maximum Demand
NRS	National Rationalised Specification
PFC	Power Factor Correction
PME	Power Monitoring Expert
POS	Ponit of Supply
POS	Point of Supply
PV	Photovoltaic
R	South African Rand
SA-LED	South Africa Low Emissions Development Program
SCADA	Supervisory Control and Data Acquisition
TOU	Time of Use
VT	Voltage Transformer
VSD	Variable Speed Drive
WTW	Water Treatment Works

Risk Categorisation

The following risk definitions have been used in this report. Each item is classified into a risk area with regards to the impact on the plant operation and long-term implications.

Risk Level	Interpretation
Low [L]	Risk not anticipated to have an adverse impact on the development and operation of the Project.
Medium [M]	The document/clause under review proposes a condition that leaves some level of residual risk with the Project which is not considered to be critical to the successful development or operation of the Project; or is missing detailed information that could reasonably be expected not to have been finalised at this stage of Project development and when provided is not expected to provide a significant residual risk.
High [H]	The document/ clause under review proposes a condition that is not in-line with Industry good practice and has the potential to leave significant residual risk with the Project; or key information is missing that should have been developed and included for review.
*	A risk level noted with an asterisk (e.g., M*, H*) indicates that incomplete or insufficient documentation has been provided for review.

Executive Summary

This report outlines opportunities for the iLembe District Municipality (IDM) to improve energy management and efficiency at the Sundumbili Water Treatment Work (WTW) plant. A site visit was conducted on the 14th of June 2022 where a visual inspection was conducted to determine the functionality, condition and appropriateness of the electrical infrastructure installed at the plant. Overall findings are listed below followed by recommendations on the next page.

Energy efficiency: During the site visit a review was conducted of the lighting, heating and cooling systems installed at the plant buildings and administrative buildings. The lighting systems installed at the plant are already energy efficient and the plant does not utilize a centralized heating and cooling system or a building management system (BMS), therefore there are no further efficiency measures that can be incorporated at this stage. Energy efficiency regarding plant operations however can be improved by employing the recommendations set out in this report.

Electricity meters: Electricity meters enable plant operators to monitor and evaluate a plant's electricity consumption, electrical data and compare this data against billing data. Energy management can be improved by the installation of digital meters to monitor the plants consumption and the efficiency of the plant motors. The plant site visit confirmed that there were no digital electricity meters currently installed on site. Based on a review of the plant operations, a recommendation is made to install 8 electricity meters, which is estimated to cost approximately between **R 395,723.11** and **R 743,927.00.** Appendix A1.1 details a breakdown of the metering quotes received from three companies.

Notified Maximum Demand: A previous study funded by the USAID South Africa Low Emissions Development Program (SA-LED) [1] in 2016 indicated that the plant was not on Eskom's correct Notified Maximum Demand (NMD) billing threshold and as a result the plant was incurring significant penalties. The plant is metered on two separate accounts as it has two points of supply for the internal water works and the raw water works. A review of the plants NMD was conducted, and it was confirmed that the internal water work's NMD was increased from 500kVA to 1,000kVA in October 2021 whilst the raw water works NMD was kept at 400kVA. The plants electricity consumption and NMD are to be monitored going forward to avoid exceeding the threshold. No further action is required at this stage.

Loadshedding status: A loadshedding exemption assessment was conducted for the plant as it provides a critical service (potable water supply) according to the NRS 048-9-2019 – Quality of Supply standard. It was concluded, via engagement with Eskom, that due to the current state of national electricity supply, loadshedding provincial targets would not be met if water treatment plants are excluded from the loadshedding schedule. Based on Eskom's assessment the Sundumbili WTW plant is not eligible for exemption based on the plant feeder loads.

Recommendations

Based on the above findings, the recommendations listed in Table 1 below are presented for the Municipality to take forward.

Table 1: Summary of recommendations

Item	Recommendation	Enablers	Lead
Energy efficiency	• No action required at this stage. Installation of new equipment to be monitored.	Funding for purchase of new efficient equipment if required.	Makhosonke Sikhosana Sifiso Zulu
Electricity meters	• Proceed with installation of digital metering systems.	Funding for appointing of meter contractors.	Makhosonke Sikhosana Sifiso Zulu
Notified Maximum Demand (NMD)	• No action required at this stage. • Continue to monitor NMD based on the electricity consumption to ensure correct tariff structure is in place and penalties are avoided.	Engagement with Eskom Customer Executive.	Xolelwa Mazibuko
Loadshedding	• Application for exemption is not possible. • Plan water treatment in conjunction to loadshedding schedules. • Proceed with renewable energy system to provide plant with resilience against loadshedding and other unexpected power loss events.	Funding required for construction and installation of renewable energy system.	Xolelwa Mazibuko Sifiso Zulu

1. Introduction

The iLembe District Municipality (IDM) owns and operates the Sundumbili Water Treatment Works (WTWs) located near the towns of Mandeni and Sundumbili in the province of KwaZulu-Natal. The plant is located on the northern bank of the lower Tugela River. It abstracts water from this river, treats the water and pumps it to remote bulk storage reservoirs which then supply potable water to the central and northern areas of Mandeni, Ndulinde and its surrounding areas. In 2011, the Sundumbili WTWs was upgraded to 40 Ml/day. As of 2022 the plant provides between 25-30 Ml/day of potable water, servicing 16 Wards and approximately 100,000 people.

1.1 Site Details

The Sundumbili WTW site is approximately 2.6 hectares, of which an estimated 1.4 hectares are occupied by the WTWs, buildings and ancillary components. See Figure 1 on the next page for the site overview. According to the August 2020 State of Municipal Water, Sanitation and Electrical Infrastructure study conducted by LTE Consulting, the Sundumbili WTWs was listed to be in poor condition, requiring extensive refurbishment. From the site visit assessment undertaken in June 2022, we can confirm that this is still the case for the older parts of the plant.

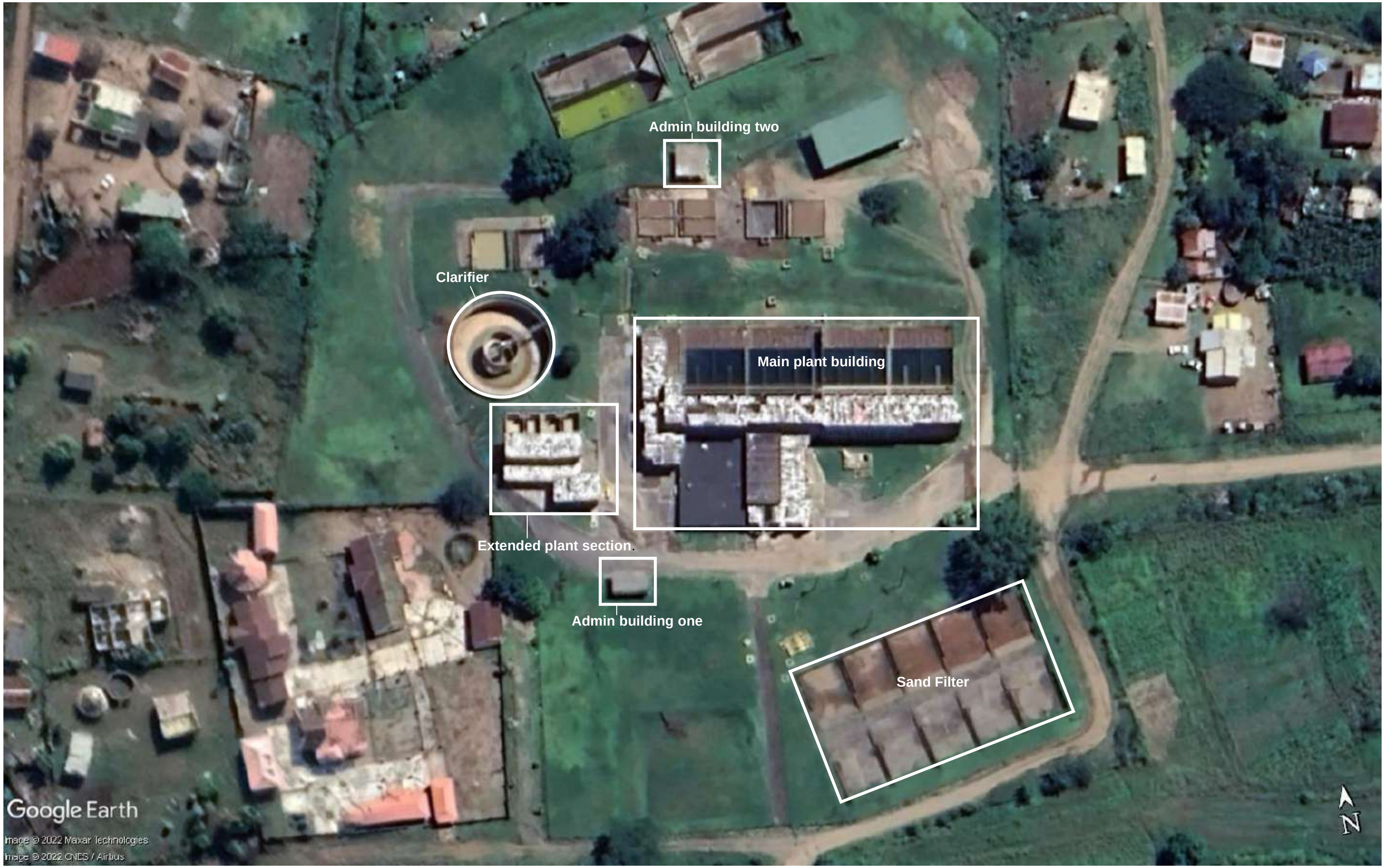


Figure 1: Sundumbili WTW plant layout (Source: Google Earth)

1.2 Status Quo Assessment

An assessment was conducted to determine the overall state of the plant's operation and maintenance as specific areas were previously highlighted for intervention by previous studies. Table 2 below highlights Arup's overall findings and updates to the SA-LED 2016 findings. IDM has also been engaged with regards to the contents of this report and their inputs have been incorporated below and throughout the report.

Table 2: Update of findings at the Sundumbili WTW [2]

Item	SA-LED 2016	Arup 2022 assessment	Risk	Recommendation
1.	The physical plant documentation provided is in good order and reflective of the plant operations.	The plant documentation viewed at the site visit was in good order and up to date. The initial findings are valid.	**L**	Continue to maintain up to date records. Maintenance records could be uploaded and saved to a server for record keeping purposes.
2.*	The State Of Municipal Water, Sanitation And Electricity Infrastructure Report from August 2020 reflected the following findings [3]: • Sundumbili abstraction works was found to be in a fair condition. • Sundumbili WTW found to be in a poor condition and in need of refurbishments which are estimated at ~R 3 million.	Some of the older electrical and building infrastructure of the plant is damaged and non-operational. The newly added pump works infrastructure is still in good condition. The initial findings are valid.	**L-M**	An upgrade of the plants old electrical and mechanical systems would be ideal to improve energy management and efficiency which could lead to reduced electricity consumption.
3.	All pumps are level controlled and no variable speed drives are utilised. The only efficiency improvement would be to ensure the pump is being correctly utilised by running at its optimal pumping point.	The pumps are manually controlled by the operator. The soft starters for the 90kW and 355kW pumps are still functional.	**L-M**	An operation controller is recommended for the plant as this would improve energy efficieny and management at the Sundumbili plant by controlling the duty cycle of the plant comapred to having the operator manually switch the plant on and off which is currently the case in 2022.
4.	Power factor correction used at both the river pumps and main pumps.	Power factor correction is no longer functional for both river pumps and main pumps.	**M-H**	Power factor correction reduces excessive reactive power drawn from the utlity network. This in turn reduces the overall demand charge which leads to improved energy management and thus a reduction in the plants utlity bills.

Item	SA-LED 2016	Arup 2022 assessment	Risk	Recommendation
5.	There are no meters in place to obtain the load profile as to when, how and where energy is used. Analogue energy meters are included on all control panels for each pump system. Technicians do not take regular records to establish actual daily energy consumption. This highlights the need for automated meter reading (AMR).	The meters used on site are analog meters and some meters are no longer functional. Thus, consumption can not be tracked accurately for control purposes and cannot be compared against Eskoms metering. The initial finding is still relevant.	**L-M**	The installation of digital meters is recommended at key points in the plant i.e. the points of supply (POS), the river pumps and the internal pumps. Estabishing check metering is also recommened at the POS in order to verify Eskoms metering and monthly utlity bills. Quotations for these meters is given in Appendix A1.1.
6.	It was not possible to access either of the Eskom meters to confirm the bill as the Eskom owned meter cubicles were locked.	The Eskom cubicles were locked and were not accessible. The initial finding is still relevant.	**L-M**	It is recommened that a check on meter class as well as Current Transformers (CTs) and Voltage Transformers (VTs) ratios as well as class be done to ensure that consumption measurements are as accurate as possible.
7.	The main plant and river pumps are on two separate Eskom accounts and should be consolidated.	The river pumps and the internal works pumps are still on two seperate accounts. Engagements with Eskom have been undertaken to determine the most feasible tariff configuration for the plant.	**L-M**	Consolidating the two consumption bills could potentially lead to monetary savings as the entire plant would be on one tariff instead of two. The costs associated with one tariff could potentially be lower. The outcome of this is covered in section 3.1.
8.	Central energy management system recommended for installation with remote metering to optimise operations by identifying operational gaps and tariff optimisation.	There is no central management system on site and all equipment is managed manually. The initial recommendation is still relevant.	**L-M**	A remote monitoring system, linked to the plant electricity meters, is recommended to monitor and optimize the operations of the plant. This will allow electricity consumption patterns to be monitored and operating times could be planned and scheduled to avoid operating during peak periods as well as to facilate operations to mitigate the impacts of loadshedding.

*Additional information not from SA-LED report.

2. Key Findings

2.1 Site Visit

A site visit was conducted on the 14th of June 2022. Arup's Engineer, Derrick Makhathini, was taken around the Sundumbili WTWs by Sifiso Zulu (Plant Supervisor) and Sithembiso Dlamini (Plant Operator) who shared information about the current and past operations of the plant. Table 3 below provides an overview of the site visit findings.

The overall risk level of the site visit findings is set at **Medium-High,** as the plant is operational and providing water on a regular basis to its constituents; however, there are areas that have been identified that require maintenance, and/or refurbishment to allow the plant to continue to function optimally and avoid further deterioration.

Table 3: Site visit findings

Item	Commentary	Risk	Recommendation
Site access	Site access was sufficient. All plant administrative buildings and plant rooms were accessible. The only area that was not accessible were the Eskom meter cubicles. Prior arrangements are required to be made with Eskom in order to gain access to the meter cubicles. The risk is set to **Low.**	**L**	No mitigation required.
Infrastructure	The plant's building and electrical infrastructure is extremely dilapidated with some of the control and monitoring equipment systems not working, such as the power factor correction panels and electricity meters. The risk for this item is set to **Medium to High.**	**M-H**	Maintenance and refurbishment of the plant infrastructure is highly recommended to prevent further disrepair.
	During the site visit, water leaks were present, indicating that maintenance is in need of improvement. Information provided by the Plant Operator indicated that a transformer exploded in the High Lift Pump Room in April 2022, causing a fire and damage to equipment. A root cause analysis of what caused this explosion is currently being conducted. The risk is set **Medium to High**	**M-H**	Maintenance of motors and motor piping needs to be properly implemented as the leakages noted in the high-lift pump room could cause hazards such as slips and falls and electrocution should any of the live motor cables be in contact with the water.

Item	Commentary	Risk	Recommendation
	as the plant is operational; however, mitigations are recommended.		
Electricity consumption – Administrative Buildings	The plant and administrative offices mainly utilise fluorescent lighting indoors and LED lighting outdoors. The major power consumers in the administration buildings is the one air-conditioner and fridge. The air conditioner mainly operates at night for approximately 8-hours for heating purposes during winter and cooling purposes during the summer. There are no immediate areas for energy efficiency measures to be implemented with regards to the lighting, heating and cooling systems. The risk is set to **Low.**	**L**	No mitigation required.
Electricity consumption – Plant Buildings	The only major power consumers in the plant buildings are the motors. See Appendix A1.2 for site visit images of the plant and installed equipment. The risk for these is set Medium-High.	**M-H**	Recommendations for efficient operation of the motors and the overall plant are made in section 3 of this report.
Metering	The existing meters on the electrical enclosures are analogue meters and thus do not have the capability of storing electrical data for evaluation. See Appendix A1.2 for site visit images. Arup's recommendation would be to install digital meters for the plant in order for the plant operators to be able to monitor and evaluate the plant's electrical consumption and compare this data against Eskom's electricity bills. Check metering could also be installed alongside Eskom's metering to check and verify the power supplied to the plant. Arup has sourced metering options from different	**L-M**	Installation of digital electricity meters are recommended.

Item	Commentary	Risk	Recommendation
	providers and quotes are provided in Appendix A1.1. The risk is set **Low to Medium** as the plant is operational; however, mitigations are recommended.		
Water loss	During the site visit the raw water piping as well as piping in the high-lift pump room appeared to have water leaks; however, according to information provided by the Plant Operator, the water loss was due to gland packings which needed replacement. A gland packing is a seal that prevents fluid loss from around the shaft of the motor and is essential for the efficiency of pumps and valves. The gland packings have since been replaced. See Appendix A1.2 for site visit images. Excessive water loss can result in the reservoirs taking longer to fill up, which leads to prolonged operation resulting in wear and tear of the motors and pumps and an increase in energy consumption. Raw water and high-lift stand-by pumps were removed for repair at the time of the site visit and were not able to be inspected. Maintenance schedules and maintenance to be monitored going forward. The risk is set **Low-Medium** as maintenance needs to be kept up to date to avoid water loss and maintain overall system efficiency.	**L-M**	Maineance schedules and maintenace to be monitored going forward to avoid any areas of water loss resulting in decreased system efficency.

2.2 Sundumbili WTW Loadshedding Exemption

An investigation was conducted to understand the impact of loadshedding for the Sundumbili WTW. According to information provided by Eskom's Key Customer Executive and Head of Eskom Municipal Engagements in a telephonic conversation on 26.07.2022, Eskom exemptions to critical services such as potable water supply, are only done where possible, and on a case-by-case basis (see NRS 048-9-2019 - Quality of Supply - Reduction of Load).

Due to the current state of national electricity supply available, if the WTW plants are not included in the loadshedding schedules, Eskom would be unable to meet their provincial required load reduction targets. In the case of KZN, there are several WTW plants in the province, and an assessment was completed by Eskom to determine which WTW plants could be exempt, based on their loadshedding requirements. Based on this assessment, the Sundumbili WTW plant was found to not be eligible for exemption. This item should be monitored on an on-going basis should there be any future changes to this outcome.

Arup's recommendation to mitigate the effects of loadshedding would be for the plant operators to be aware of the loadshedding schedules and take precautions by adjusting operation prior to being switched-off to ensure the reservoirs are filled enough to supply the community for the periods when the loadshedding would be in effect. This is, however, dependent on the loadshedding stage the area would be experiencing and advance notice. An alert system with regards to water levels during loadshedding for consumers can also be considered where a short message can be sent to consumers alerting them on water levels. The reservoirs would need an alert system for this which can be done via the reservoirs SCADA system. This will, however, need to be investigated further.

2.3 Notified Maximum Demand (NMD) Review

The Notified Maximum Demand (NMD) is a contractual value of load demand which binds Eskom and the customer. According to the agreement, Eskom is required, at all times, to have the contracted capacity available, and in turn the customer need not exceed this capacity. If the customer does exceed their NMD, Eskom imposes an NMD penalty [4]. The one point of supply (internal water works) has been on an NMD of 500 kVA before this was changed to 1,000kVA in 2021. According to an energy audit commissioned by the South Africa Low Emissions Development Program (SA-LED), this section of the plant was incurring NMD penalties, which were estimated to reach R1.25m by December 2016. This was due to the fact that at the time of the investigation, the internal water works point of supply was on an NMD threshold of 500kVA, whilst reaching an average monthly maximum demand of ~735kVA, according to the Sundumbili WTW consumption data provided by Eskom. The raw water works however, was not incurring NMD penalties as it has an NMD of 400kVA and this was not being exceeded. The other point of supply (the raw water works) is currently only reaching an average maximum monthly demand of ~125kVA.

A review was conducted on the most recent consumption billing data, ranging from July 2021 to July 2022 for the Sundumbili WTW. It is noted that the NMD for internal water works was changed in October 2021 to 1,000kVA, thus eliminating the penalties that were being incurred. The NMD for the raw water works remains at 400kVA as it is anticipated that the maximum demand for this section of the plant will increase due to the plant supplying more areas with water going forward [3]. Table 3 below compares the 2016 SA-LED's consumption study to Arup's 2022 findings with SA-LED's.

Table 4: Sundumbili energy usage [2]

Plant area	SA-LED Review 2016			Arup Review 2022			
	Tariff	NMD (kVA)	Actual Demand 2016 (kVA)	Tariff	Average Demand 2022 (kVA)	NMD 2022 (kVA)	Recommendation
Internal Water Works	Nightsave Urban kVA Interval.	500	<1,011	Miniflex	~735	1,000	The current highest maximum demand reached was ~1098 kVA in December 2013. However, the average maximum demand for 2012 to 2022 is ~875kVA. It is important to note that the utilized capacity of the internal water works has decreased as the two sludge pumps, rated at 30 kW each, have ceased being used since ~2012 according to information provided by the Plant Operator. In place of the sludge pumps, a gravity fed valve is being used to get rid of sludge. Thus, this new NMD should be sufficient for the current operations of the plant. The maximum demand should however be investigated prior to increasing the plant's capacity to supply more areas. It is recommended that this is done at the design stage of the project to identify any potential issues.
Raw Water Works	Nightsave Urban kVA Interval.	400	<150	Nightsave Urban kVA Interval.	~127	400	This NMD is sufficient for the current operations of the plant. The highest maximum demand this section of the plant reached was ~255kVA in June 2022. The average maximum demand since 2012 to 2022 is ~147kVA. Thus, the raw water works is still within limitations however, close monitoring of the maximum demand is crucial when the plant starts to supply more areas.

2.4 Energy Consumption and Costs

The electricity at the Sundumbili WTW is provided by Eskom. The plant's electricity consumption is split between the raw water works and the internal water works. The total combined consumption and costs amounted to approximately **5,281,169kWh** and **R 4,913,577.62** respectively, for the period August 2021 to July 2022. Please note that the July 2021 and April 2022 bills were not available for the internal water works and thus these totals exclude those periods. The raw water works pump consumption, and the internal water works consumption were **1,465,876kWh** and **3,815,293kWh** respectively for the same period. This usage is based on the Nightsave Urban kVA Interval tariff for the raw water pumps and the Miniflex tariff for the internal water works. Excess maximum demand charges amounted to **R 142,632.62** for August and September 2021 before the NMD was modified in October 2021. Table 5 below gives a summary of the major electricity consumers in the plant and the total load. The plant is currently running at **~62-75%** of installed capacity.

Table 5: Equipment list

Area	Type	Rating (kW)	Quantity	Total Rating (kW)
Raw Water Works	River Pumps	90	3	270
Internal Water Works	High Lift Pumps	355	3	1,065
	Blowers 1	30	2	60
	Blowers 2	7.5	2	15
	Backwash Pumps	15	2	30
	Backwash Pumps	50	2	100
			Installed Capacity (including spares)	**1,540kW**
			Maximum Utilised Capacity (based on consumption data)	**920kW**

3. Energy Saving Opportunities

3.1 Tariff Analysis

The purpose of this tariff analysis is to determine which tariff would be the most cost-effective configuration for the Sundumbili WTW resulting in electricity cost savings. Thus, this analysis seeks to determine the plant's current cost of electricity and compare it to the projected costs for the scenarios where the plant is on a single consolidated tariff, i.e., both meters are on the Nightsave Urban Small or Miniflex tariff for the year 2022/23 onwards.

3.1.1 Internal Water Works

The internal water works is currently on the Miniflex tariff. The Miniflex tariff is a Time of Use (TOU) tariff for urban customers with an NMD between 16 kVA and 5,000 kVA. TOU periods are typically peak, standard, and off-peak periods and they differ during high and low demand seasons. The cost of electricity is also dependent on the consumption during a specific period. See Eskom's TOU periods in Appendix A1.5. This tariff was changed in October 2021, from the Nightsave Urban Small tariff to the Miniflex tariff with an increase in the NMD to 1,000 kVA. This analysis caters for this change in tariff [5].

3.1.2 Raw Water Works

The raw water works is currently on the Nightsave Urban Small tariff. The Nightsave Urban Small tariff is a tariff suitable for customers with an NMD between 25 kVA and 1,000 kVA.

Using the current tariff configuration or base case scenario the consumption costs were calculated for 2021/22. The energy consumption cost for the two load centres combined for the year 2021/22 (Jun 2021 to May 2022) was determined to be ~R 7,097,894. Factoring in a tariff increase of 8.61% for years 2022/23 as announced by Eskom in 2022 [5], and assuming that the plant will consume the same amount of energy as year 2021/22, the energy consumption cost is estimated to be ~R 7,503,643 for year 2022/23, an increase of R 405,749. The graph in Figure 2 below gives a comparison of the consolidated tariff costs against the current configuration. This entails each tariff's energy costs and associated costs which include:

- Network Capacity Charge,
- Network Demand Charge,
- Ancillary Charges,
- Electrification & Rural Network Subsidy Charge,
- Service Charge, and
- Transmission Network Charge.

It is important to note that the raw water works Nightsave Interval Small tariff contains two additional charges compared to the Miniflex tariff and these are the energy demand charges and transmission network charges which equate to costs of approximately R203,355 and R63,753 per annum respectively for the raw water works (based on calculations using the new tariff rates and the plants recent consumption data).

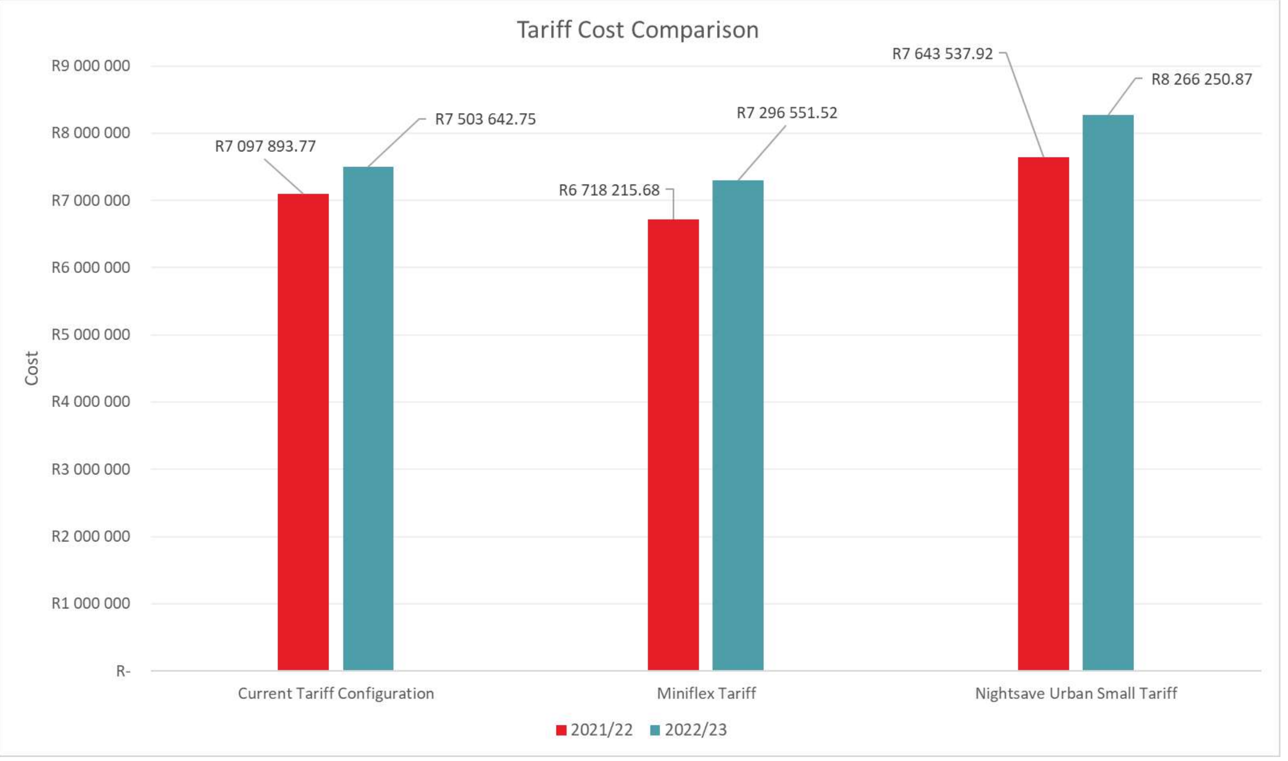


Figure 2: Tariff configuration cost comparison

Figure 2 above shows the comparison in energy costs for year 2021/22 and 2022/23. In the case where both load centres were to be changed to the Nightsave Urban tariff, the total electricity cost is estimated to be ~R 7,643,538 and ~R 8,266,251 for the year 2021/22 and 2022/23 respectively. When compared against the base case, the net loss for this tariff configuration would potentially be ~R 545,644 and ~R 762,608 for year 2021/22 and 2022/23, respectively.

If the plant were to be consolidated to the Miniflex tariff, the cost for year 2021/22 and 2022/23 is estimated to be ~R 6,718,216 and ~R 7,296,552, respectively. This shows an estimated net saving of ~R 379,638 and ~R 207,091 for 2021/22 and 2022/23 against the base case, respectively.

The highest costs are observed if the plant is consolidated to the Nightsave Urban Small tariff and a net loss of ~R 762,608 would be experienced if this were the case for 2022/23 onwards. Thus, the consolidating of the tariff configuration to the Miniflex tariff proves to be the most cost-effective configuration for the plant as it results in monetary savings. This is however dependent on the plant's energy consumption pattern during the period as the Miniflex tariff is a TOU tariff. See Eskom's TOU periods in Appendix A1.5.

Eskom also conducted an analysis in August 2022 to determine whether changing the raw water works tariff to Miniflex would be ideal for the plant and ultimately determined that the Miniflex is the most cost-efficient tariff as determined in the analysis above. See Appendix A1.3 for screenshots of Eskom's analysis.

3.2 Power Factor Correction

The power factor correction (PFC) for the raw water pumps and high-lift pumps is not operational. This results in the motors drawing reactive power from the grid which in turn increases the plants apparent maximum demand.

The purpose of PFC is to reduce excessive reactive power drawn from the utility network as it has the capability of producing reactive energy in opposition to the reactive power absorbed by loads such as motors. This in turn reduces the overall demand charge on apparent power or kVA which leads to improved energy efficiency and a reduction to the plant's consumption bill. Figure 3 explains the flow of power with and without PFC.

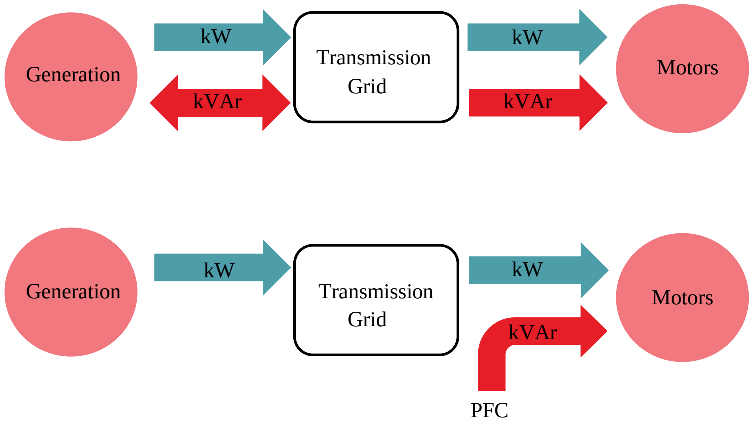


Figure 3: Power Factor Correction [6]

Figure 4 below, shows the combined maximum demands of both the internal and raw water works and illustrates the difference between the maximum active power (kW) demand and the maximum apparent power (kVA) demand with the highest difference being ~213kVA. This is due to the fact that reactive energy is drawn by the motors from the grid which thus raises the maximum kVA since kVA is a combination of active (kW) and reactive power (kVAr).

3.2.1 Cost Analysis

If the PFC was operational this would eliminate or reduce the reactive power drawn from the grid by the motors, by raising the power factor closer to unity at the point of connection, thus bringing the kVA demand closer to the kW demand resulting in a lower kVA demand charge. In addition, a saving on reactive energy (kVAr) charges will be achieved. The plant's raw water works is currently being charged at a rate of R31.96/kVA during the low demand season and R248.38/kVA during the high demand season. There is also a network demand charge of R49.98 based on the maximum kVA demand reached. This equates to a combined charge on maximum demand (kVA) of roughly R326,821 per year. This cost can be reduced by approximately 14% (assuming unity power factor after correction) if the PFC system was operational as this is the average difference in kVA and kW demand for the raw water works from 2020 to 2022. The Miniflex tariff charges a single demand charge of R34.60 based on the NMD and this results in total demand cost of R174,697 per year for a 400 kVA NMD (raw water works NMD) which is a much lower demand cost. It is also important to note that the raw water works is the only plant section with these charges as it is on the Nightsave Urban Small tariff. Thus, as mentioned in the section above, it may be beneficial to change the raw water works tariff to the Miniflex tariff as well.

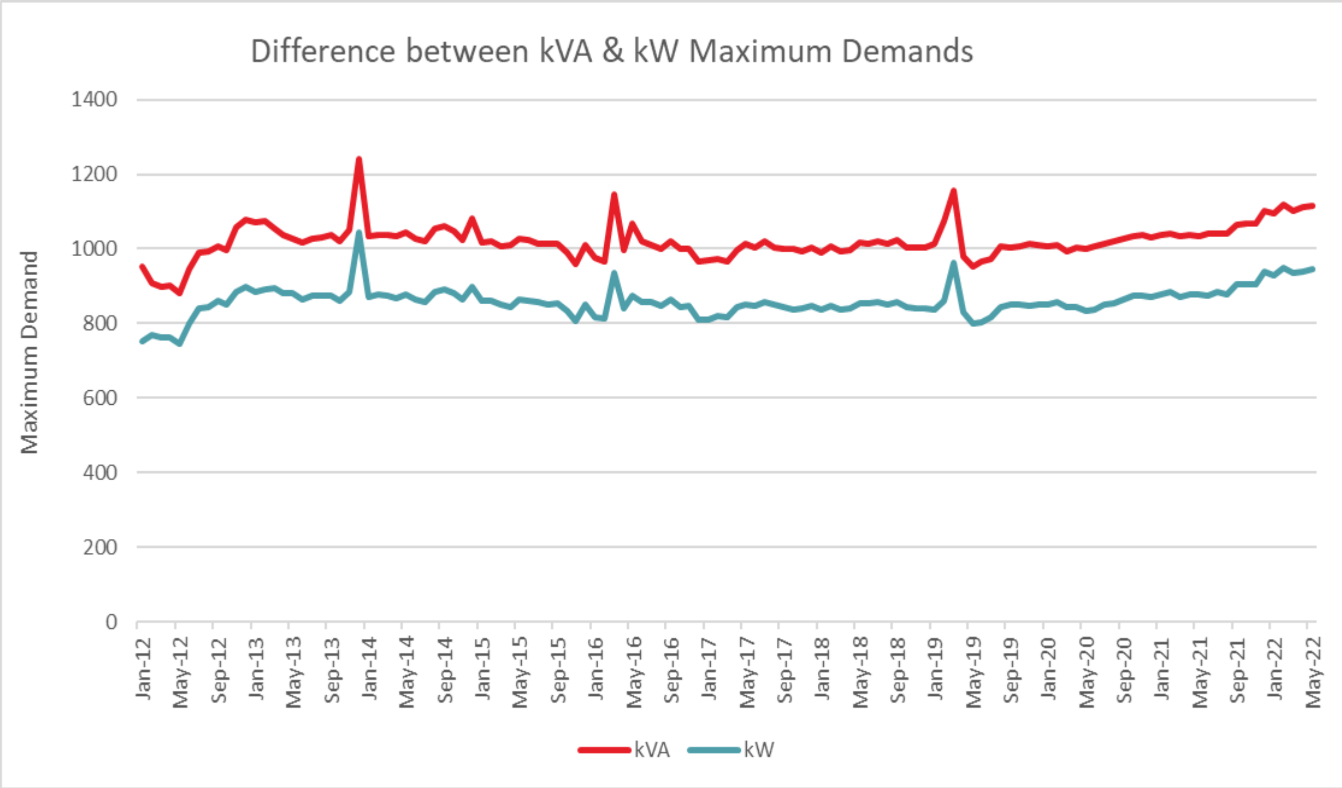


Figure 4: Graph showing difference between maximum kVA & kW for the Sundumbili WTW

It is thus recommended that the plant's PFC be repaired/renewed. The average power factor for the internal water works is currently 0.769 p.u. and 0.860 p.u. for the raw water works (determined from the plant's 2022 consumption data) which are relatively poor power factors. An alternative to repairing the PFC is that Variable Speed Drives (VSDs) could be installed on the motors to improve operating overall power factors and reduce load demand. The water pumps in the plant utilize IE3 induction motors which are fairly efficient. However, should any of the motors need replacing, Arup recommends that they be replaced with IE4 induction motors as these are slightly more efficient and have a higher operating power factor.

3.3 Administrative Buildings

The major energy consumers in buildings comprise of heating, ventilation, and air conditioning which consume ~35% of total building energy, lighting consumes ~11%, major appliances (water heating, refrigerators and freezers, dryers) consume ~18%, and the remaining 36% is consumed by miscellaneous items such as charging laptops and phones. In each case, there are opportunities to improve both the performance of system components (energy efficient lighting) and the way they are controlled or behaviour change[7].

The Sundumbili WTW administrative buildings have little to no major energy consumers. There are two administrative buildings and only one building contains an air-conditioner and a small fridge. These items operate at specific periods, thus requiring little to no management. The air-conditioner functions mainly at night for approximately 8-hours, for the purpose of heating and cooling. Two air-conditioners are planned to be installed in future. The fridge is rated to consume 341kWh/year depending on how it is used and where it is located. The buildings, and the plant overall, is fitted with LED and fluorescent lighting which are 80-90% more energy efficient than incandescent lights, and last for an extended period of time. The outdoor areas utilize LED lighting, and the indoor areas utilize florescent lighting. These lights are kept on throughout the night for approximately 12-hours as the plant operates 24-hours and operators are present during the night. These lights are switched off during the day. Motion sensors are not recommended for plant health and safety reasons as well as for general security purposes.

4. Conclusion

The Sundumbili WTW is a significant energy consumer, rated at 1,400kVA. It provides critical services to various areas in the region, ensuring that potable water supply is pumped to reservoirs. The plant presently provides between 25-30 Ml/day of potable water, servicing 16 Wards and approximately 100,000 people. The plant is operating well despite ageing infrastructure. Plans are in place for the plant to increase the number of areas it supplies water to. Maintenance and refurbishment of the plant equipment is highly recommended to ensure the plant can function optimally and continue to service the surrounding areas for many years to come.

The plant can improve its energy management and efficiency by pursuing the opportunities mentioned in this report, which would ensure long term optimal plant operation and a reduction in the plant's operational costs. The plants raw water and internal water works electrical equipment, such as the motors and control equipment, is old and refurbishment and/or upgrade of this equipment could improve energy efficiency.

Energy management can be improved by the installation of digital meters to monitor the plants electricity consumption and the efficiency of the motors. Check metering at the points of supply could be installed to monitor and verify Eskom's billing data. The plant is currently billed on two tariffs. A tariff consolidation has been noted to be beneficial from a cost point of view.

As exemption from loadshedding is not possible at this stage, Plant Operators need to plan around the loadshedding schedules to minimise the impacts of loadshedding and interruption to water supply for the surrounding communities. A longer-term solution would be the implementation of a renewable energy system which would allow the plant to minimise the impacts of loadshedding via the supply of backup power during outage periods and this study is the first step to this incorporation.

5. Bibliography

[1] D. E. (Ltd, "Energy Audit Report for the iLembe District Municipality Sundumbili Bulk Water Treatment Plant," USAID South Africa Low Emissions Developmen (SA-LED), 2016.

[2] iLembe District Municipality, "Energy Audit Report for the iLembe District Municipality Sundumbili Bulk Water Treatment Plant," DNA Economics (Pty) Ltd , 2016.

[3] ILEMBE DISTRICT MUNICIPALITY, "THE STATE OF MUNICIPAL WATER, SANITATION AND ELECTRICITY INFRASTRUCTURE," LTE Consulting (Pty) Ltd., 2020.

[4] Eskom, "THE NOTIFIED MAXIMUM DEMAND (NMD) AND MAXIMUM EXPORT CAPACITY (MEC)," 19 July 2022. [Online]. Available: https://www.nersa.org.za/wp-content/uploads/2021/01/The-Notified-Maximum-Demand-NMD.pdf.

[5] E. H. S. Ltd, "eskom.co.za," 1 June 2022. [Online]. Available: https://www.eskom.co.za/distribution/wp-content/uploads/2022/05/4756-ESKOM-Tariff-Booklet-2022-Final-Rev.pdf. [Accessed 24 July 2022].

[6] E. Apprentice, "Desgn and Installation," [Online]. Available: https://electricalapprentice.co.uk/power-factor-correction-what-is-it-why-is-it-required-how-is-it-achieved/. [Accessed 27 July 2022].

[7] DOE, "An Assessment of Energy Technologies abd Research Opportunities," March 2017. [Online]. Available: https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf. [Accessed 9 August 2022].

[8] DSO Electric Cooperative, 2022. [Online]. Available: https://www.dsoelectric.com/energy-saving-strategies. [Accessed 18 August 2022].

Appendix

A1.1 Plant Metering Quotes

One of Arup's recommendations to improve and manage the plant's energy efficiency included the installation of digital meters. These meters would have the capability of measuring and storing consumption data which can be used to monitor and analyse the plants energy consumption as well as verify Eskom's consumption measurements and billing data. Electricity meter quotes were obtained from three different suppliers. Based on communication with the IDM team, a total of eight metering points were considered as critical to monitor, see Figure 5 and Table 6 for an overview of these points. A single line diagram (SLD) provided by IDM is attached in Appendix A1.4. It shows all the pumps that require metering and how they are connected to the two points of supply. Please note that this is a roughly drawn hand sketch as the actual SLD drawings for the plant could not be located. Arup recommends that an electrical engineer/technician be contracted to develop a SLD that includes all main equipment ratings (voltage, current and short-circuit ratings) and cables sizes so that it can be kept on site for future use.

Table 7 lists the companies selected to provide electricity meter quotes A recommendation of the most feasible quote and company is listed further below.

Figure 5: Metering Points

Table 6: Metering requirement as depicted by the image above

Infrastructure	No. of meters required
Raw Water Pumps	1
High-lift Pumps	1
Blowers 1	1
Blowers (extended plant **section)**	1
Backwash Pumps	1
Backwash Pumps (extended plant **section)**	1
Point of Supply 1	1
Point of Supply 2	1
Total number of meters	**8**

Table 7: Overview of chosen companies and quotes

Company	About Company	Reason for Selection	Metering Quote (excl. VAT)
IST	A multi-disciplinary engineering business whose core capability is system engineering and integration.	They are an established company that Arup has worked with before on previous projects.	R 743,927.00
3-Core Electrical	Supplies electrical and buidling construction services.	They are the eletrical meter supplier for the eThekwini Municipality, based in Durban. They were recommended by the eThekwini Electrical Department.	R -
SEC Electrical	Electrcial services provider servicing the Isithebe area and surrounds.	Recommended by the IDM. They are situated in the vicinity of the Sundumbili WTW plant and they have performed electrical work on the plant previously and thus are familiar with the plant operations.	R 164,483.11

3-Core Electrical have still not provided a quote as requested.

These quotes are based on information such as the number of meters required, availability of Current Transformers (CTs) and Voltage Transformers (VTs), mounting space on the existing panels, communication requirements, system monitoring, etc.

Recommendation:

Arup recommends using SEC Electricals services as they have a working relationship with the Sundumbili WTW plant and are closer to the plant than the other suppliers. SEC Electrical have also conducted a site inspection to determine their quote which makes it more accurate as it includes only the required items compared to IST's quote. SEC Electricals cost however, does not include power monitoring expert (PME) and server costs which could cost approximately **R 96,588.00** and **R134,652.00,** respectively. This would bring their total cost to **R 395,723.11.**

The meters would be installed in an enclosure using the existing CTs in the main control panels for the raw water pumps, high-lift pumps, blowers and backwash pumps. Additional CTs and meter enclosure costs have been added for the two points of supply as it is not clear if the Eskom panels have existing CTs to connect to and if there is space to mount the meters.

A1.2 Site Visit Images

Table 8 below provides the images taken on site and a brief description.

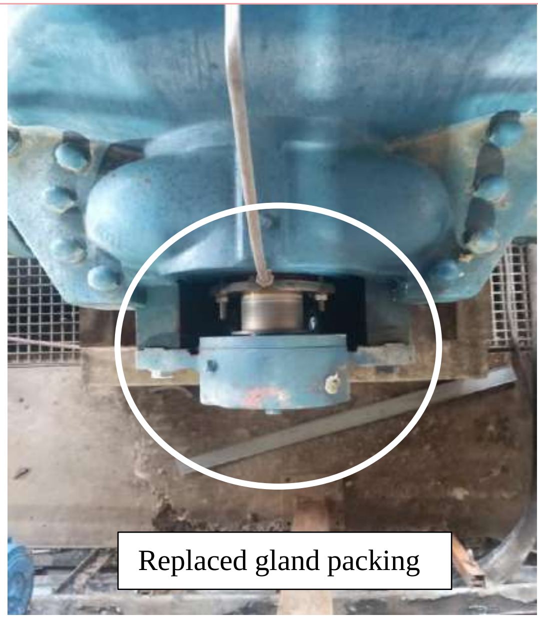
Table 8: Site visit review

Area	Description	Site visit image
Raw Water Pumps	Pumps used for raw water extraction rated at 90kW. Two pumps were operational with the standby pump removed for maintenance. Leaks were noted during inspection at the pump area as well as along the extraction piping. These leaks were due to valve and motor gland packings needing replacement. The power factor correction device was not working during the site visit. The Plant Operator indicated that it had operated for a long period. The meters for this section are analogue meters.	   

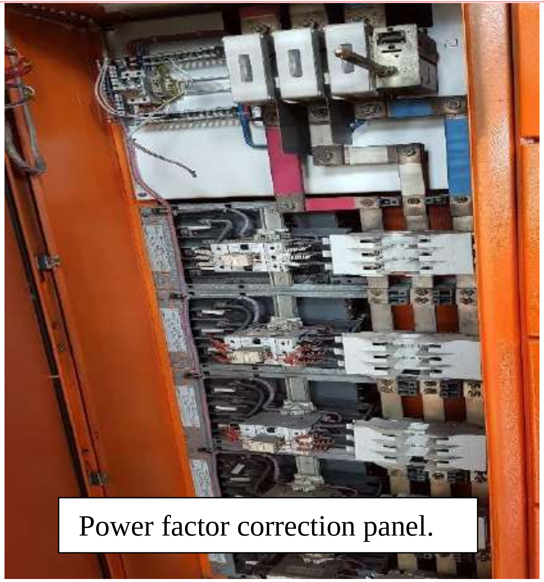

POWER FACTOR CORRECTION
BEFORE OPENING
DO NOT DEFEAT


RAW WATER PUMP

High-lift Pump Room	These are the pumps used for pumping water into the reservoirs once purification is completed. They are rated at 355kW. Two pumps were operational with the standby pump removed for maintenance. Leaks were noted during the inspection at the pump area. This may be due to the gland packings that needed replacement. The power factor correction equipment was not operational as the equipment was damaged by a fire caused by a transformer explosion in the control room. The cause of this explosion is unknown, and a root cause analysis is currently being conducted. Moderate flooding is a result of the leakages occurring in this room. The Operator has noted that this has been fixed as a result of installing new gland packings on the motors and valves. The soft starters for these motors are still functional. Soft-starters ramp up the voltage applied to motor terminals over time, thereby limiting the inrush current and power during start-up. Soft starters can thus extend motor lifetimes particularly for motors that are stopped and started frequently [8].	    Gland packing in need of replacement



Replaced gland packing



Power factor correction panel.

Soft starter for high-lift pumps.

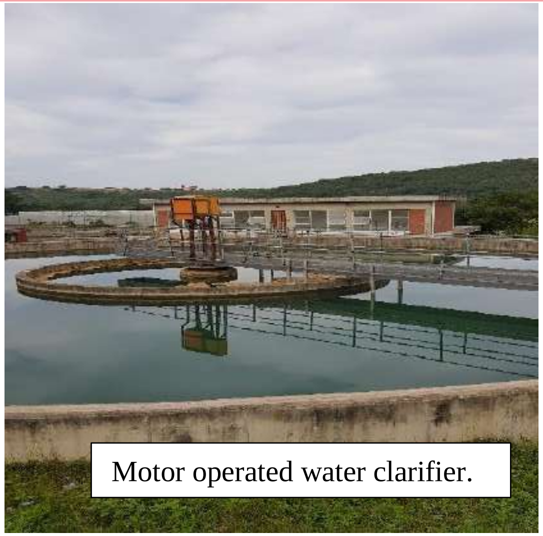
Water leakage due to gland packing needing replacement.

Blowers and Backwash Pumps	Pumps are used to clear debris from the internal water works. These pumps were in good condition and operating as usual. However, one of the backwash pumps has a leak due to needing a gland packing replacement. The panels for these pumps are in good condition.	  

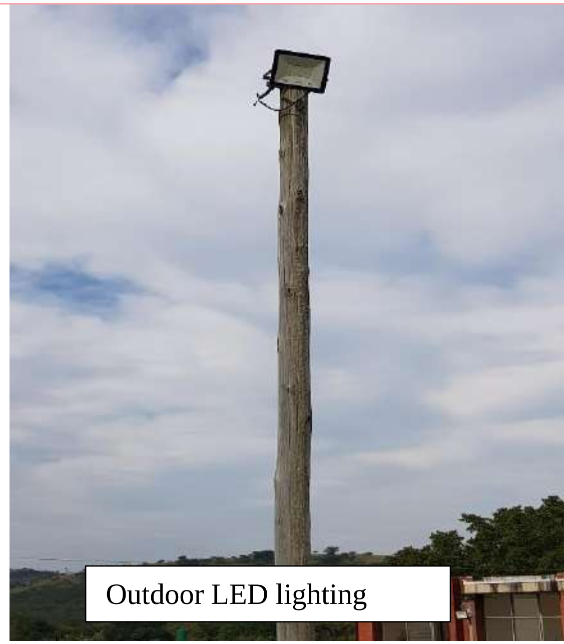
		 
Control Equipment	The control equipment in the high-lift room needs refurbishing and cleaning. Some of the panels are no longer functional. The controls on these panels can be replaced with digital meters and controls which would potentially improve energy management.	

		 
Extended Plant Section	This area contains blowers and backwash pumps rated at 30kW and 50kW, respectively. This section of the plant is fairly new and was constructed in 2011 to upgrade the plant's capacity. All electrical infrastructure is functional, and water loss was not noted in this section.	 

		 Backwash pumps.   

		 
Water Clarifier & Dosing Pumps	These motors were operational and in good condition. One of the plant's water clarifiers has been decommissioned.	 Motor operated water clarifier. 

			
Plant and Admin Building	The plant uses fluorescent lighting indoors and LED lighting outdoors. These lights are generally energy efficient with LED lighting being ~80% more efficient. The only major load consumer in the administrative building is the air-conditioner and the fridge which is generally rated energy efficient. The plants wiring is relatively in poor condition as seen on the images further below.	 Indoor fluorescent lighting	

		  Outdoor LED lighting

Eskom Transformers and Metering Cubicles	The transformers onsite are in good condition. A new 1,000kVA transformer was recently installed to replace the one that exploded and to cater for the increase in NMD. The meter cubicles were locked and there were no Eskom personnel on site to provide access.	 500kVA Transformer.  Eskom meter cabinet.  1,000kVA Transformer. 

A1.3 Eskom's Tariff Analysis

The screenshots below detail Eskom's analysis of altering the raw water works tariff from the Nightsave Urban Small tariff to the Miniflex tariff. The final comparison of costs shows that a net saving of ~R61,175 (Arup's calculated potentially savings is ~R207,091) could potentially be realised for 2022/2023 if the tariff is changed. The difference in the calculated savings is due to more variable costs considered by Arup. However, the savings determined are dependent on the plant's consumption pattern during the period as the Miniflex tariff is a TOU tariff.

Eskom *Generators tariffs are excluded* *Version 6.11 09 March 2022*

Tariff Input Sheet

Select customer classification	Large Power User	Select the appropriate customer category - Small Power User (SPU) or Large Power User (LPU)
Select supply size	>100kVA & ≤500kVA	Select the appropriate customer supply size (kVA)
Select tariff	Nightsave Small	Drop box selection driven by the supply voltage inputs
Select supply voltage	≥ 500V & < 66kV	Select the appropriate supply voltage (V)
Select transmission zone	[301 - 600km]	Select the appropriate transmission zone (km)

Please enter your consumption data in the table below

Month	Season	Peak energy kWh	Standard energy kWh	Off-peak energy kWh	Chargeable demand kVA	Utilised capacity kVA	Excess reactive energy kVArh	Total energy kWh	Year
31 Jul-22	High Demand	15 156	37 824	51 194	181	400		104 174	2023
31 Aug-22	High Demand	15 501	38 695	51 255	185	400		105 451	2023
30 Sep-22	Low Demand	17 257	41 665	56 400	209	400		115 322	2023
31 Oct-22	Low Demand	16 580	40 582	51 628	212	400		108 789	2023
30 Nov-22	Low Demand	15 968	42 180	59 832	213	400		117 980	2023
31 Dec-22	Low Demand	16 062	41 598	55 146	214	400		112 806	2023
31 Jan-23	Low Demand	16 951	42 141	62 422	215	400		121 514	2023
28 Feb-23	Low Demand	16 366	40 813	63 154	224	400		120 334	2023
31 Mar-23	Low Demand	15 751	38 907	54 247	188	400		108 904	2023
30 Apr-23	Low Demand	14 094	37 420	51 131	210	400		102 645	2023
31 May-23	Low Demand	13 172	36 809	61 711	215	400		111 692	2023
30 Jun-23	High Demand	18 178	46 686	61 154	255	400		126 018	2023
Total		191 035	485 321	679 274			-	1 355 629	

Eskom

For comparative purposes, Utilised Capacity and Chargeable Demand figures are required for all LPU tariffs.

Time of Use Comparison Data

	Nightsave Small (Urban)				
Comparison Tariffs	**2021/2022**		**2022/2023**		**% Change**
High-demand	R	693 282	R	753 009	8,62%
Low demand	R	1 417 113	R	1 539 190	8,61%
Total	**R**	**2 110 395**	**R**	**2 292 199**	**8,61%**
Average price c/kWh		**135,37**		**147,03**	**8.61%**

	Nightsave Small (Urban)				
Comparison Tariffs	**2021/2022**		**2022/2023**		**% Change**
High-demand	R	693 282	R	753 009	8,62%
Low demand	R	1 417 113	R	1 539 190	8,61%
Total	**R**	**2 110 395**	**R**	**2 292 199**	**8,61%**
Average price c/kWh		**136,56**		**148,32**	**8,61%**

	Miniflex (Urban)				
Comparison Tariffs	**2021/2022**		**2022/2023**		**% Change**
High-demand	R	685 998	R	745 075	8,61%
Low demand	R	1 368 060	R	1 485 948	8,62%
Total	**R**	**2 054 058**	**R**	**2 231 024**	**8,62%**
Average price c/kWh		**132,91**		**144,36**	**8,62%**

	Nightsave Rural (Rural)				
Comparison Tariffs	**2021/2022**		**2022/2023**		**% Change**
High-demand	R	840 216	R	912 587	8,61%
Low demand	R	1 902 913	R	2 066 751	8,61%
Total	**R**	**2 743 129**	**R**	**2 979 338**	**8,61%**
Average price c/kWh		**177,50**		**192,79**	**8,61%**

Annual Comparison	**2021/2022**		**2022/2023**		**% Change**
Nightsave Small	**R**	**2 110 395**	**R**	**2 292 199**	**8,61%**
Nightsave Small	R	2 110 395	R	2 292 199	8,61%
Miniflex	R	2 054 058	R	2 231 024	8,62%
Nightsave Rural	R	2 743 129	R	2 979 338	8,61%

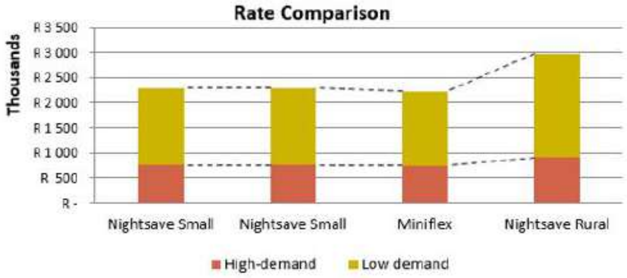


Figure 6: Eskom Tariff Analysis

A1.4 High-level Plant Single Line Diagram (SLD) provided by IDM

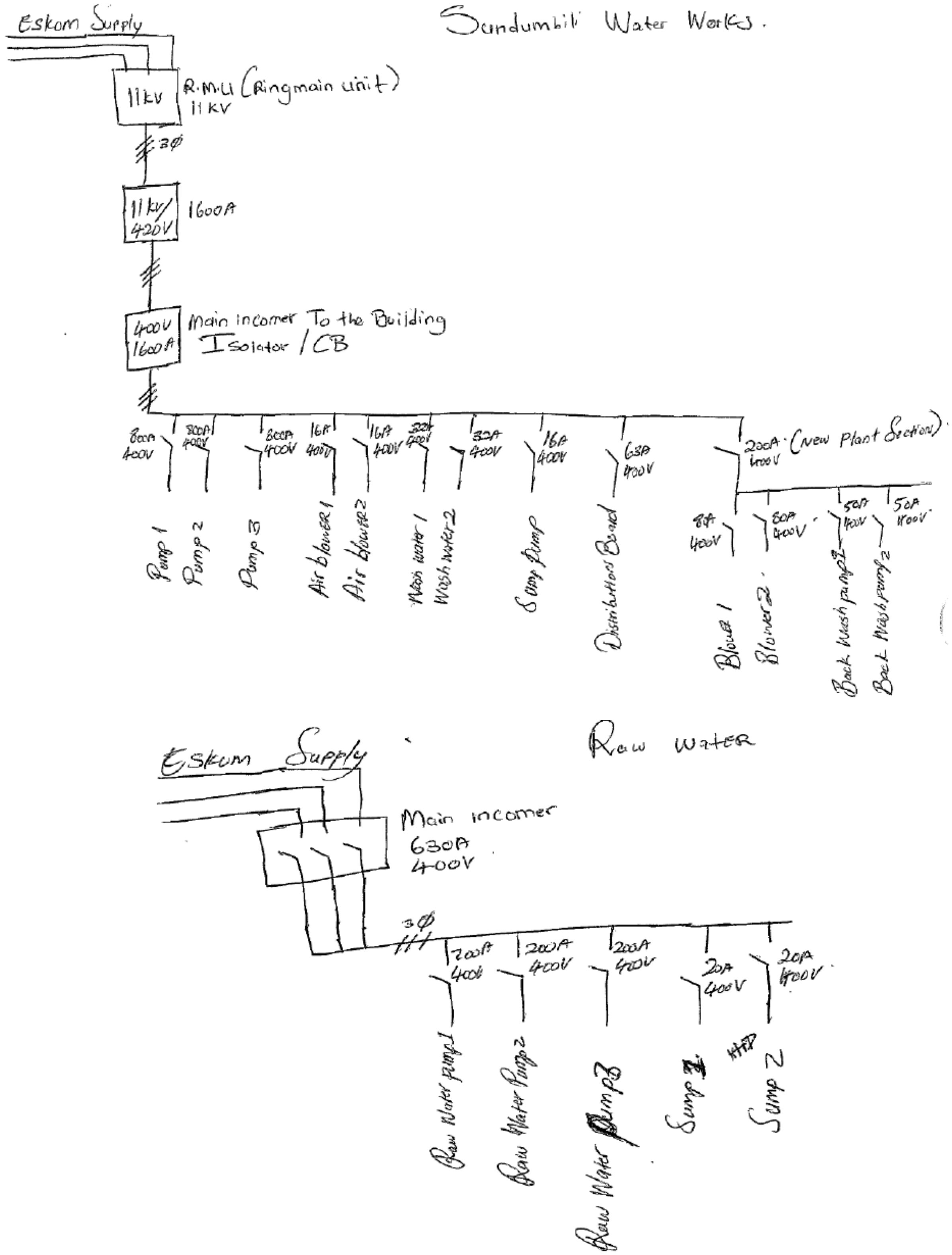


Figure 7: High-level Plant SLD

A1.5 Eskom's Defined Time-of-Use (TOU) Periods

TOU periods are time blocks based on the volume of electricity demand during high, medium, and low demand periods, which may vary depending on the tariff. TOU periods are typically peak, standard, and off-peak, and they differ during high and low demand seasons. [5] Figure 8 below shows the TOU periods for the different Eskom periods.

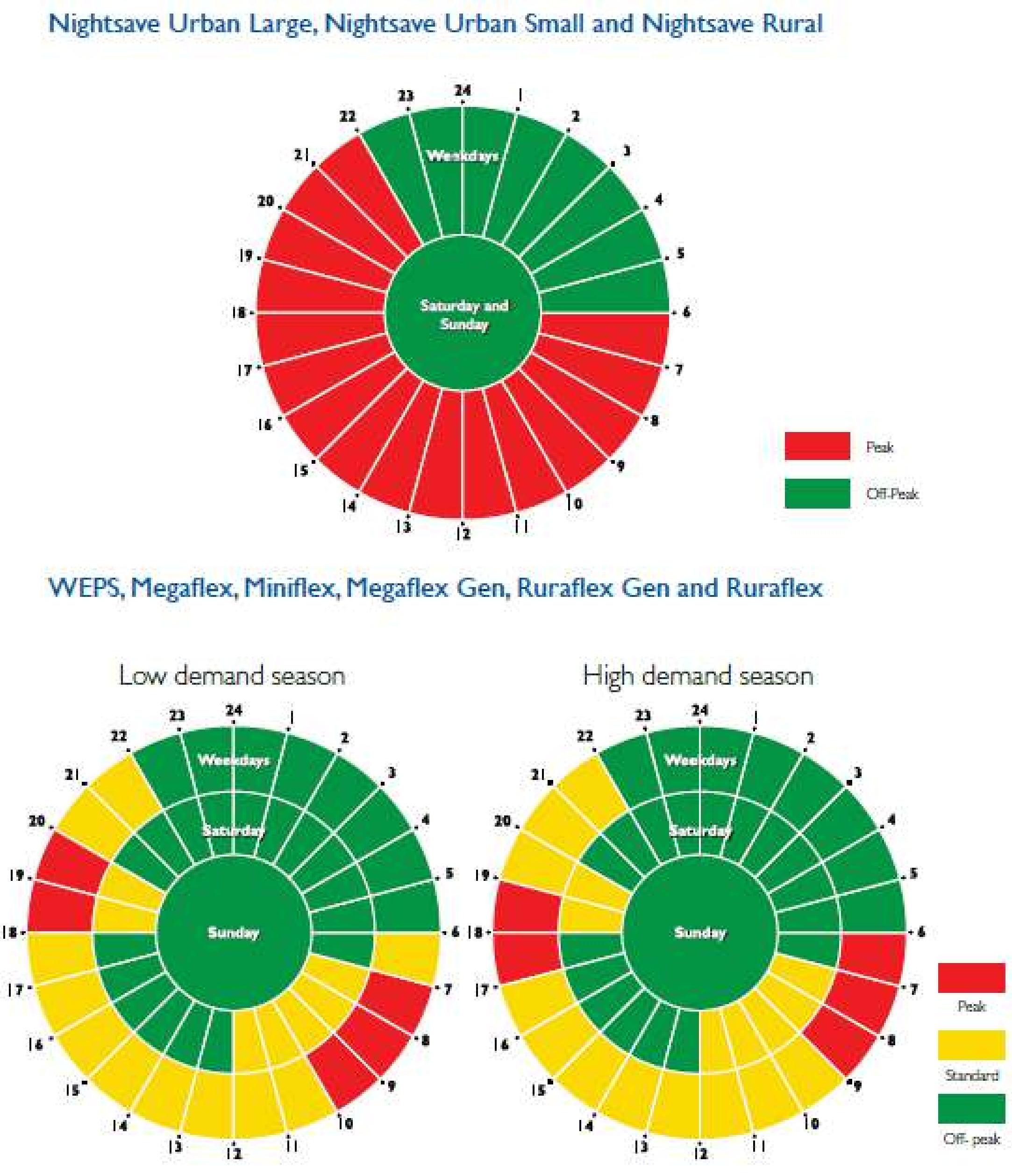


Figure 8: TOU Periods for High and Low Season [5]