Vuthela

ILEMBE LED PROGRAMME

CASE STUDY 5

Energy efficiency and energy management

Feasibility study and concept design for renewable energy at Sundumbili Water Treatment Works

April 2023

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Introduction

This case study is based on a project commissioned by the Vuthela iLembe LED Support Programme with the iLembe District Municipality.

The project consisted of two components:

Energy efficiencies and energy management at the Sundumbili Water Treatment Works (WTW)

Feasibility study and concept design for renewable energy at the Sundumbili WTW

The Vuthela Programme is funded by the Swiss State Secretariat for Economic Affairs (SECO). It aims to improve the economic future of the residents of the iLembe district through sustainable economic growth and inclusive employment opportunities.

The feasibility study was conducted by Arup, a group of consulting designers and engineers that specialises in sustainable development.

This project had two main deliverables: to assist the iLembe District Municipality to improve energy management and efficiencies, and to undertake a detailed feasibility and conceptual design for solar power generation at the Sundumbili WTW.

Efficient water services delivery is essential to sustain the health and wellbeing of communities, enable economic growth and maintain social stability in municipalities across South Africa through re-investment for infrastructure renewal and maintenance.

This case study aims to contribute towards attaining these aspirations by demonstrating how energy efficient operations and renewable energy options can make water services more sustainable by reducing costs, lowering the carbon footprint and improving energy security.

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Status of the plant

The Sundumbili WTW is a water treatment facility located on the northern bank of the lower uThukela River where it flows into the Indian Ocean.

The WTW is located within the Mandeni Local Municipality, but is owned and operated by the iLembe District Municipality. The WTW abstracts water from the uThukela River, treats the water and pumps it to remote bulk storage reservoirs. The reservoirs provide potable water to the central and northern areas of Mandeni, Sundumbili, Ndulinde and surrounding areas.

In 2011, the pumping capacity of the Sundumbili WTW was upgraded to 40 ML/day. The WTW presently provides between 25-30 ML/day of potable water, servicing about 100 000 residents in 16 wards.

The WTW's electricity is supplied by Eskom and is consumed by two main processes:

- **Raw water works** abstracts water from the UThukela River – the capacity of this section is 500 kVA and it has a notified maximum demand (NMD) of 400 kVA.
- **Internal water works** purifies the water – NMD is 1 000 kVA.

The Sundumbili WTW is a significant energy consumer and is rated at 1 400 kVA.

The Vuthela Programme conducted an energy efficiency assessment and a feasibility study to explore the use of renewable energy to meet this demand.

The study informed the design of the most feasible alternative energy source to supplement the WTW's supply from Eskom and reduce its electricity costs.

TheWTW is operating well, despite its ageing infrastructure. Plans are in place to expand the service area, making the maintenance and refurbishment of equipment necessary to ensure the WTW continues to service the surrounding areas for many years to come.

The Sundumbili WTW is the sole provider of drinking water to the surrounding community – an interruption in the power supply means that about 100 000 residents and business operators will not have access to safe water (once water from the reservoirs is utilised) until the plant resumes operations.

Efficient water services are regarded as great enablers for development and growth in municipalities. Conversely, the lack of a reliable water supply hampers development initiatives, restricting the prospects of economic growth in the district.

The plant uses electricity supplied by Eskom and is costly to operate.

Frequent power outages due to loadshedding have made it difficult to maintain a constant supply of water to residents.

There is a lack of metering to establish the load profiles of equipment at the WTW and there are no independent meters (check meters) in place to monitor the usage data provided by Eskom.

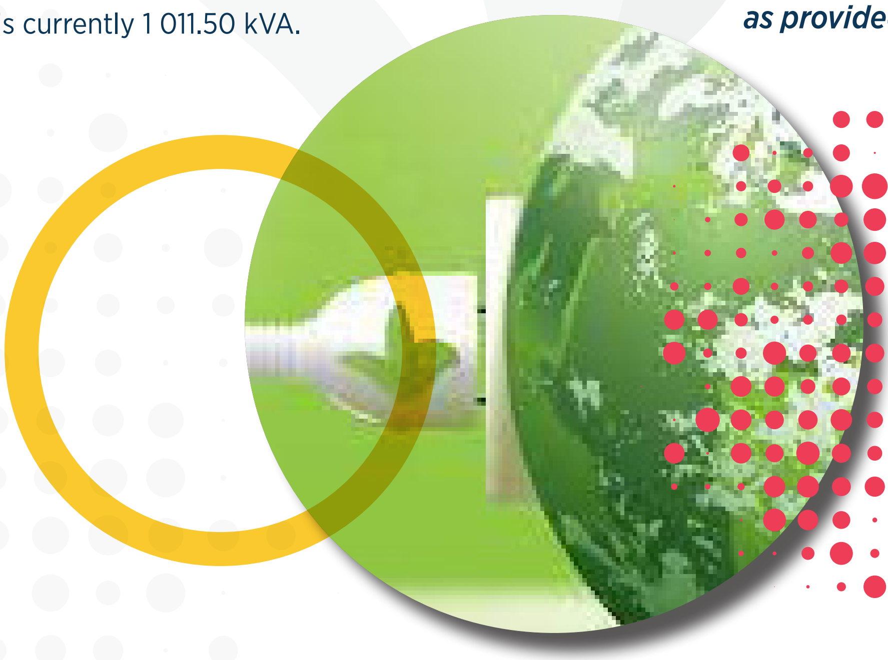
Addressing challenges

The USAID LED Programme study in 2016 on the Sundumbili WTW indicated that the NMD needed to be reviewed:

"Savings can be made on the River Pumps by reducing the NMD from 400 kVA to 200 kVA which will yield a saving of 200*(R15.48+7.85) = R5 319/month or R162 830/annum which is a no cost savings and for which the savings could be invested in an energy management and metering system. Even more beneficial is that it appears no one is aware that the bulk water has been incurring a penalty of some R100 000/month as no one has noted to increase the NMD from 500 kVA to 1 320 kVA. This penalty is reflected as the Excess Network Capacity Charge and the Utilised Capacity which is currently 1 011.50 kVA. This penalty will continue until the NMD is increased. The report further mentions the lack of metering to establish the load profiles of equipment and it seems there is no check metering in place to monitor meter data as provided by Eskom."

Arup was commissioned to undertake a feasibility study to create energy efficiencies and to explore viable options to supplement the Eskom supply with renewable energy sources that are carbon-free.

> *it seems there is no check metering in place to monitor meter data as provided by Eskom.*



Energy management

The feasibility study investigated the various options available for the WTW to utilise renewable energy, reduce carbon dioxide emissions associated with the WTW and reduce the WTW's overall energy costs.

The study aimed to ensure efficient and effective service delivery within the municipal area, to instil eco-friendly "green" values and to identify economic beneficiation opportunities.

This includes optimising existing infrastructure, creating spin-offs through innovative solutions such as renewable energy generation and improved energy management practices.

Renewable energy

Reviews of available data and site visits were conducted to inform the technical and commercial analysis of the WTW's operations:

- **Energy demand analysis** – an investigation of efficiency measures and energy savings of annual energy use at the plant, based on peak and off-peak periods.
- **Site review** – the estimated solar energy resource data specific to the site was assessed against the extent of the space available for the installation of rooftop and ground-mounted solar installations.
- **Renewable energy technologies overview** – a review of renewable energy technologies that are available locally and their integration into existing systems, highlighting opportunities and constraints in adopting the technology.
- **Technical and commercial assessment** – each technology option was assessed against criteria which included technical, operational, and financial factors (including cost-benefit-analysis), considering the resources available for the initiative.

The study of the status and performance of the Sundumbili WTW concluded that the plant can improve its energy management and efficiency by pursuing several opportunities.

Steps to reduce the plant's operational costs and ensure optimal operation in the long-term include refurbishing old electric motors and control equipment, installing digital meters to monitor the plant's consumption accurately and request for a change in billing tariff type from Eskom. An exemption from Eskom's loadshedding schedule is not possible as municipalities are advised to ensure back-up power in the event of loadshedding.

Energy efficiency

Energy efficiency: The lighting systems are already energy efficient and the plant does not have a central heating and cooling system or a building management system (BMS). No further efficiency measures can be incorporated at this stage.

Electricity meters: Installing suitable digital meters would enable plant operators to monitor and evaluate electricity consumption and compare it against billing data to improve energy management. Installation of the proposed eight electricity meters is estimated to cost between R 395,723.11 and R743,927.00 due to different supplier quotations obtained.

Notified Maximum Demand (NMD)

The plant is metered on two separate Eskom accounts as it has two separate points of supply for the internal water works and the raw water works. The internal water works' NMD was increased from 500 kVA to 1 000 kVA in 2021, but the raw water works NMD remained at 400 kVA.

The plant's electricity consumption and NMD are to be monitored going forward to avoid exceeding the thresholds.

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 the 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.

Tariff analysis: The raw water works is currently on the Nightsave Urban kVA Interval tariff. Changing the raw water works tariff to the Miniflex tariff will be more cost-effective for the plant.

Loadshedding status: A loadshedding exemption assessment was conducted for the plant as it provides a critical service.

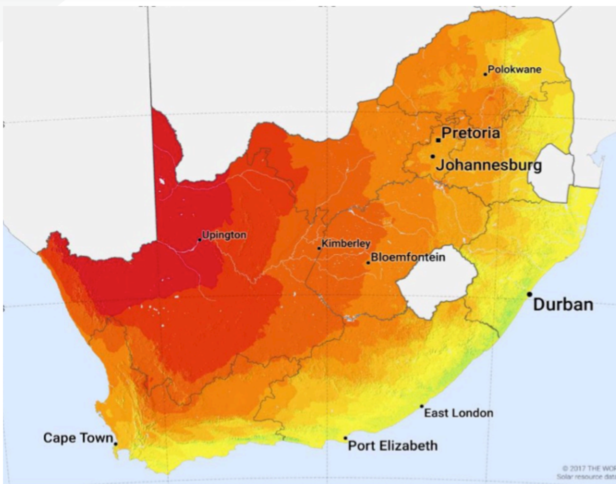
Due to the prevailing state of the national electricity supply, loadshedding provincial targets would not be met if water treatment plants are excluded from the loadshedding schedule. Based on Eskom's assessment, the Sundumbili WTW is not eligible for exemption and the iLembe District Municipality would need to establish a back-up power generation for the WTW in order to operate during loadshedding periods.

Site analysis for the renewable energy options

A Hybrid Optimisation Model for Electrical Renewables (HOMER) study was conducted to evaluate the various options available to integrate renewable energy at the plant.

The HOMER model evaluates the supply options in conjunction with the Eskom electricity tariff.

A PV solar facility was considered based on the roof and ground area available for installation and the solar resources at the site. A Photo Voltaic (PV) system typically consists of an array of solar panels, combiners that string the panels



together, regulators, inverters and banks of storage batteries.

The total solar radiation at a geographic site is referred to as global horizontal irradiance (GHI). The GHI is the sum total of direct, diffused and ground-reflected radiation at the site.

The GHI ranges from a high of around 6.62 kWh/ m^2/day in summer to a low of around 3.41 kWh/ m^2/day in winter.

The average monthly GHI at the Sundumbili WTW is suitable for the installation of a solar facility.

The GHI for the Sundumbili site is approximately 1654.8 kWh/m^2/year which is favourable considering the proximity of the plant to the coast where the GHI is usually lower.

The SolarGIS map is an industry standard and trusted source of meteorological data. It indicates the estimated solar energy resources available at any site for power generation according to the average daily and annual sum of GHI.

The meteorological data for Sundumbili indicates the average annual temperature is 21ºC

Temperatures around or below the Standard Test Conditions (STC) of 25ºC are considered favourable for solar panels as lower temperature results in lower losses in power generation.

The installation of a rooftop and ground-mounted system at the Sundumbili WTW is not expected to trigger any environmental assessments, permits or licenses, allowing the iLembe District Municipality to move swiftly toward implementation once funding is secured.

The solar power project is exempt from the NERSA licencing requirements as it is under the 100 MW limit and is exempt from a generation licence.

Solar energy

Technical and commercial assessment:

A comparison of four different solar PV configurations/ scenarios was conducted to provide relevant information to support the iLembe District Municipality's renewable energy initiatives and inform decisions regarding the implementation of the next steps.

Implementing solar power

Solar power is a mature and well understood technology that is readily available in South Africa. The plant is situated about two hours driving time from Durban and access to equipment and spare parts will not be a challenge.

Technical complexity is low and the technology is easy to install and maintain. Minimal maintenance is required, and plant operators can be trained to conduct basic plant operation and maintenance.

It is relatively easy to integrate solar power with the plant's grid electrical system.

Solar systems are modular and scalable, making it possible to install a small system if funding is constrained and gradually scale the system up.

Solar modules have a life span of about 25 years and result in minimal interruption of the water plant's daily operations.

Designing the solar power system

The plant has sufficient space to install both rooftop and ground-mounted systems, however it is not sufficient for a larger system that can allow the WTW to operate off-grid.

The rooftop system will deliver 190 kW and the ground system 219 kW. Four options with various configurations of rooftop and ground-mounted panels with various battery energy storage systems were considered. Each of the four configurations/ scenarios were analysed for their solar PV output, capital costs, operating costs, the number of years of payback and the reduction in the emission of carbon dioxide.

The most feasible solution was chosen from this analysis. A concept design was developed based on the configuration scenario considered most feasible, which is Scenario 3. **The selected scenario achieves a higher energy yield at a relatively lower cost.**

The Levelised Cost of Energy (LCOE) measures lifetime costs divided by energy production to calculate the total cost of building and operating a power plant over an assumed lifetime. The LCOE for the selected option for the Sundumbili WTW is R1.07 per kWh.

Scenario 3 recommends the use of bifacial modules which collect direct and ground-reflected radiation and were found to generate about 2% more energy at only 1% additional capital cost.

Furthermore, Scenario 3 will achieve a carbon emission reduction of about 473 tons of carbon dioxide annually.

The internal rate of return is estimated to be 9.4%, which is the highest amongst all four scenarios. A payback period of 9.4 years is estimated, which is in line with industry standards.

The selected scenario results in the highest cost savings and consists of Eskom grid energy supplemented by a ground-mounted tracking PV system with bifacial modules and a roof-mounted PV system.

Indicative layouts – Tracking ground-mounted system with bifacial modules

Indicative layouts – rooftop flush mounted installation monofacial modules

The table below provides an estimate of grid supplied energy cost savings for the chosen option.

Capex	Opex	Year 1 Annual Saving	Year 1-9 Cumulative Annual Saving	Year 1-25 Cumulative Annual Saving
R 5,259,700	R 59,598	R 541,843	R 4,779,557	R 12,685,241

Technical detail

Scenario 3 produces the highest energy yield, but is still not sufficient to charge a battery storage system. Therefore, the size of the solar PV facility is not large enough to provide reasonable autonomy from the Eskom grid for the plant.

To achieve a better autonomy a, larger portion of the solar PV facility would need to be dedicated to battery charging which would decrease the energy available for the load and decrease the amount of energy offset from the grid. But this will require more land area.

It is important to note that the solar PV facilities do not provide the plant with reliability of supply during a grid outage or loadshedding. The PV inverters are tied to the Eskom grid and operate in parallel to the grid.

The Eskom grid is required to provide a reference signal to start up the inverters and synchronise them with the grid.

The main benefit of a grid-tied solar PV facility is its simplicity and low operational and maintenance costs.

Off-grid systems require batteries to store the energy produced by the solar PV facility, which can be discharged to supply the plant's load.

An off-grid system is generally used in situations where no grid is available. The batteries would need to be sized to meet the load energy requirement. The solar PV facility would also need to be sized to sufficiently charge this battery system. Due to this battery integration, an off-grid system is much more expensive compared to an on-grid system.

The methodology of integrating the solar PV facility to the plant's existing electrical infrastructure and switchboard will need to be developed.

Earthing and lightning protection and site security should be investigated at the detailed design stage.

A typical solar PV facility consists of a solar PV module array, mounting structures, inverters and transformers (for larger systems).

The solar PV module array is the generating unit which harnesses energy from sunlight in the form of irradiation and converts it into electrical power. The power generated by the module is transmitted to inverters using direct current (DC) cabling, where it is converted from DC to alternating current (AC) by the inverters.

PV Modules

Solar PV modules commonly used in commercial facilities can be divided into three categories: Monocrystalline, Polycrystalline and Thin Film.

Crystalline modules are made from crystalline silicon material while thin film modules use less material and are made from rare metals like tellurium and cadmium. Crystalline modules can be manufactured as monofacial (absorbing light from the front only) or bifacial (absorbing from both the front and rear of the module).

The selected module technology for this feasibility study is monocrystalline technology which produces the highest energy output for the space available. Bifacial modules were selected for the ground-mounted solar tracking system.

The bifacial 400 kWp monocrystalline TSM-DE15H TallMax module by Trina Solar has a maximum efficiency of 19.7%. A procurement design may utilise newer technology, depending on when construction proceeds.

Due to constant development in technology, a higher-power module may be available during procurement.

At a nominal capacity of 349 kWp, the proposed Sundumbili solar PV facility will require 873 modules to be installed on the rooftop and on the ground. The AC capacity will be limited to 300 kWac (five 60 kW inverters).

Inverters

The main function of an inverter in a solar PV facility is to convert the DC current generated by the modules into AC current.

The Huawei SUN2000-60KTL-M0 string inverter was selected for the concept design.

The overall capacity of the proposed solar PV facility is relatively small, which favours smaller inverters as opposed to one large central inverter which would take a large section of the facility out of service during a failure or maintenance.

As the site is relatively remote, string inverters will be easier to transport and replace in the event of failure.

System conceptual design

Ground-mounted system

System Design Characteristics

Nominal DC Capacity [kWp]	219
Inverter Capacity [kWac]	60
Number of PV Modules	548
Number of Inverters	3
Modules per String	16
Row Pitch [m]	6.5

Rooftop system

System Design Characteristics

Nominal DC Capacity [kWp]	130
Inverter Capacity [kWac]	60
Number of PV Modules	325
Number of Inverters	2
Modules per String	15

kWp is the peak power of a PV system or panel.

kWac means the electric power, in kilowatts, associated with the alternating current output of the system.

PV field design

The rooftop PV systems are estimated to consist of 325 modules connected to string inverters which will be connected directly to the main LV pane located in the main WTW building.

The ground-mounted PV systems are estimated to consist of 548 modules, which will also be connected to string inverters and to an AC combiner box.

The AC combiner box will collect the AC power output from the inverters and a single AC cable will transmit the power to the main plant control room, thus integrating the two roof and ground mount systems.

Sensors

Sensors form part of the weather station and provide monitoring and performance information. The sensors can be rationalised by the contractor during detailed design.

Pyranometers are utilised to monitor irradiance at the site and validate the performance of the solar PV facility.

Ambient temperature sensors are required for the ground-mounted system and will form part of the steps to reduce the plant's operational costs and ensure optimal operation in the long term include refurbishing old electric motors and control equipment, installing digital meters to monitor the plant's consumption accurately and request for a change in billing tariff type from Eskom. An exemption from Eskom's loadshedding schedule is not possible as municipalities are advised to ensure back-up power in the event of loadshedding.

PV modules are highly sensitive to temperature and show a rapid degradation of power production with increased temperature.

Temperature data is used to validate the performance of the PV modules and monitor performance against the manufacturer's performance guarantees.

Rain has an initial negative impact on production but also provides a degree of module cleaning which has a positive effect on energy production in the short to medium term. Wind sensors are included for weather condition recording and to safely stow the trackers in the event of high wind speeds. Low wind levels have a positive impact on modules performance due to the cooling effect on the modules. In rare cases, high winds can cause damage to PV modules and sub-structures, although this can be mitigated with an adequately designed structural and clamping system.

Reference cells are single PV cells mounted in the field under the same operating conditions as the energy producing modules. The purpose of the reference cells is to assess the effect of soiling or dust build-up on the modules. The reference cells are cleaned daily and kept free of any obstructions to act as a reference for comparison. The power output of the reference cell can be used to determine if excessive dust or dirt is building up on the module.

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Finding the funding

Municipalities receive funding annually as part of the national budgetary allocation through unconditional and conditional grants.

One of the main constraints for funding municipal infrastructure projects relates to the financial health and creditworthiness of some municipalities. Potential lenders consider the creditworthiness of the municipality, and a poor credit rating will deter potential lenders.

The Public Finance Management Act (PFMA) enacted in 1999 and the Local Government: Municipal Finance Management Act (MFMA) enacted in 2003 constitute the essential framework for financial management in the public sector.

The PFMA applies to the national and provincial spheres of government, and the MFMA applies to the local sphere.

The MFMA has made the process of municipalities entering contracts for longer than three years a complex one. The MFMA currently allows municipalities to enter contracts up to 30 years via a Public-Private Partnership (PPP). This mechanism and the procurement framework can be time-consuming and expensive.

Several organisations can provide funding for solar power projects, including government, Development Finance Institutions (DFIs) and commercial organisations. The funding mechanisms can come in the form of grants, loans, municipal fiscus, PPPs, Power Purchase Agreements (PPAs) and others.

GreenCape is a non-profit organisation that has developed a database of funding sources for green energy projects.

The Municipal Infrastructure Support Agent (MISA) has several programmes to support municipalities, including the Infrastructure Delivery Management Support (IDMS) programme. The IDMS aims to deliver infrastructure projects on behalf of identified municipalities and provide infrastructure financing, procurement and contract management guidance and advice to municipalities. Infrastructure financing is a sub-programme of the IDMS, aimed at facilitating innovation and private sector financing on infrastructure and Municipal Infrastructure Grants (MIG).

Trade & Investment KwaZulu-Natal (TIKZN) and Swedfund were explored as funding opportunities. However, the mandates of these organisations do not align with the solar PV facility being investigated as part of this study. TIKZN does not fund projects, but rather acts as a facilitator of investment. Swedfund funds transaction advisory services for solar PV projects but does not provide financing to smaller plants.

The South African Local Government Association (SALGA) published a guideline for municipalities on the financing of Energy Efficiency and Renewable Energy projects in South Africa. Included in the guideline are several financing mechanisms available to municipalities.

Implementation steps

Energy efficiency

The iLembe District Municipality will need to determine whether resources are available in the budget to implement the measure to bring immediate energy efficiencies, including installing electricity meters and power factor correction devices.

If there is no budget available, a team should be assigned to explore alternate funding sources and a target date set for securing the funding.

If budget is available, the municipality should map out a programme and timeframe to implement the efficiencies recommended.

Solar energy

Should the iLembe District Municipality agree to the implementation of the solar power system option and the required funding is sourced, the next step would be to conduct a structural assessment to confirm the suitability of the WTW roof for the installation of the solar system.

This is expected to cost between R25 000 to R40 000 and will include a site visit by a professionally registered structural engineer who would sign off on the suitability of the roof.

Based on the findings of the assessment, additional costs could be incurred for repair work or additional waterproofing.

A detailed investigation and design of the solar facilities will need to be conducted before the necessary equipment is procured, based on the sizing and quantities of the detailed design.

Once construction is completed and commissioning is successful, the solar facilities could be handed over to the municipality for operation and maintenance, unless another operations and maintenance modality is pursued.

A training programme for the plant personnel will educate them about the operation and maintenance of the renewable energy system (should the iLembe District Municipality own and operate the solar facility infrastructure). It will also enable a sense of ownership and buy-in and ensure that the long-term plant operation is maintained optimally.

Options for institutional arrangement for ownership, operations and management are still to be determined. This is an opportunity to extend the participation of PPPs for the delivery of essential services.

Lessons learnt

The installation of a solar power system at the Sundumbili WTW will be a great opportunity for the iLembe District Municipality and its family of local municipalities to become familiar with solar systems.

It will also create opportunities to train people from local communities to install, operate and maintain solar systems, opening up possibilities for future work in this fast-growing field.

There is immense value in providing municipalities with information regarding the operation of renewable energy systems and the benefits that can be gained from them.

There is value in the iLembe District Municipality connecting with and gaining knowledge from the KwaDukuza Local Municipality, which is establishing an Energy Office. The eThekwini Municipality already has an Energy Office and is implementing renewable energy pilot projects, which the iLembe District Municipality can learn from.

With sufficient interaction between stakeholders and engagement with funders, this project has the potential to create an appetite for further development of solar power systems in communities and with public or private institutions throughout the iLembe district.

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