Feasibility Study for the Utilization of Solar Energy for Sugarcane Irrigation Pumping by Emerging Commercial Small Cane Growers in Eswatini

Output 2: Technical feasibility assessment report and schematic designs of indicative solar irrigation systems.

Deliverables D2.1 and D2.2

Prepared by: MicroEnergy International

May 2024

Contents

List of Figures

List of Tables

1. Introduction

Due to the challenges posed by non-renewable energy sources, there is a growing interest in adopting sustainable and efficient irrigation systems to address these issues and enhance agricultural productivity. Solar-powered irrigation systems (SPIS) have emerged as a promising renewable solution, offering dual benefits: reducing dependence on fossil fuels while providing a renewable energy source.

As part of the "Enhancing Agricultural Sustainability through Solar-Powered Irrigation Systems" project conducted on behalf of the UN Climate Technology Centre and Network (CTCN), this assessment evaluates the feasibility of introducing SPIS to small-scale sugarcane growers in Eswatini. It addresses the growing demand for sustainable agricultural practices, particularly within the sugarcane sector, while considering challenges such as escalating electricity costs.

The aim is two-fold: firstly, to determine whether it would be technically feasible to install SPIS in sugarcane farms in Eswatini, based on a sample of six case study sugarcane growers, and secondly, to evaluate the impacts of the current SPIS on one farm that has already installed an SPIS and compared the proposed system with the one installed. Given Eswatini's ample sunlight and the substantial water needs of the sugarcane industry, transitioning to solar-powered irrigation offers the potential to diminish reliance on fossil fuels and ease pressure on local water resources.

The selected growers represent a diverse range of sizes, locations, and operational models within the sugarcane industry, offering a comprehensive perspective on the potential benefits and challenges of adopting solar-powered irrigation. By conducting this assessment, the aim is to provide valuable insights and recommendations to empower growers with the knowledge needed to make informed decisions regarding sustainable energy and water management practices.

2. Methodology

The assessment methodology consists of a multi-step approach designed to comprehensively evaluate the suitability and feasibility of implementing solar power irrigation systems across the six selected grower's in Eswatini. Five of them where SPIS have not yet been installed, and one with an SPIS, with the purpose of assessing the impact of the system in the farm and to compare the SPIS resulting from the technical sizing with the system that has been installed.

A thorough site analysis assessed factors such as solar irradiance, topography, water requirements, and availability. This involved field visits, and geospatial analysis using satellite imagery.

The Global Solar Atlas, an online platform developed by the World Bank Group and the Solar Energy Research Institute of Singapore (SERIS) that provides access to high-resolution solar resource data for countries worldwide, was used to obtain comprehensive information on solar radiation including direct normal irradiance (DNI), global horizontal irradiance (GHI), and diffuse horizontal irradiance (DHI).

According to data collected from the Global Atlas, Eswatini receives high levels of solar irradiance throughout the year, with an average annual solar radiation ranging from approximately 4.10 to 5.14 kWh/m²/day across different regions of the country. The geographical location of Eswatini, situated in the subtropical region of southern Africa, ensures consistent exposure to sunlight, with minimal cloud cover and atmospheric interference.

The grower data was collected through site visits, conducted between December 2023 and February 2024. The SurveyCTO software was used as a data collection tool for the farms mentioned in the report. The assessment questionnaire was divided into six different categories to get specific information about the grower's general information, production, water resources, electricity Demand, land availability, and familiarity with solar-powered irrigation systems.

The software Helioscope was used for the sizing of the Solar systems suitable for the grower's. It is a cloud-based software platform commonly used by solar energy professionals to design, analyse, and optimize solar photovoltaic (PV) systems. The primary purpose of Helioscope analysis is to determine the optimal size, configuration, and performance of solar PV systems tailored to specific project requirements. In the context of solar power irrigation, Helioscope helps in sizing the solar PV system to meet the energy demand for pumping water for irrigation purposes.

Key Features

1. Site Assessment
2. System Sizing
3. Performance Simulation
4. Optimization

Helioscope relies on various assumptions and models to simulate solar system performance, including solar radiation models, panel efficiency models, and inverter performance models. These assumptions may not always accurately represent real-world conditions, leading to discrepancies between simulated and actual performance. Helioscope-simulated results may lack comprehensive validation against real-world data for various conditions and scenarios. Implementing solar systems may be subject to local regulations, permitting requirements, building codes, zoning restrictions, and utility interconnection rules. Helioscope may not fully account for these regulatory considerations.

PV system sizing:

The sizing of the PV systems was approached through setting two distinct scenarios:

1. **Scenario 1: Simulating equivalence to yearly demand:** In this scenario, the sizing process focuses on simulating the PV system to generate power equivalent to the grower's annual electricity demand. By analysing the twelve-month electricity bills from each grower and considering factors such as seasonal variations and operational requirements, the PV system is sized to ensure sufficient energy production to meet the grower's overall electricity needs over a year.
2. **Scenario 2: Simulating equivalence to peak monthly demand:** Alternatively, this approach involves designing the solar photovoltaic (PV) system to produce electricity that meets the peak monthly energy needs of each farm or grower. This is done by examining the monthly electricity bills to determine the month with the largest energy usage and considering variations in solar radiation based on weather data.

3. Farm Assessment Results

The Farm Assessment section of this technical report provides a detailed analysis of the six selected growers, across the three target regions (KDDP, LUSIP and the Malkerns) in Eswatini, focusing on their suitability for the implementation of solar power irrigation systems.

The shortlisted growers belong to three different regions. From each region, two different growers with varying sizes were selected.

1. The Komati Downstream Development Project (KDDP) region
    a. Singeni Investments
    b. Mnyangombli Farmers Limited
2. The Lower Usuthu Smallholder Irrigation Project (LUSIP) region
    a. Asibebahle Mbabala Limited
    b. Lomdashi Investments
3. The Malkerns region
    a. Umbane Pvt. Ltd.
    b. Dalcure Agricultural Holdings Pvt. Ltd.

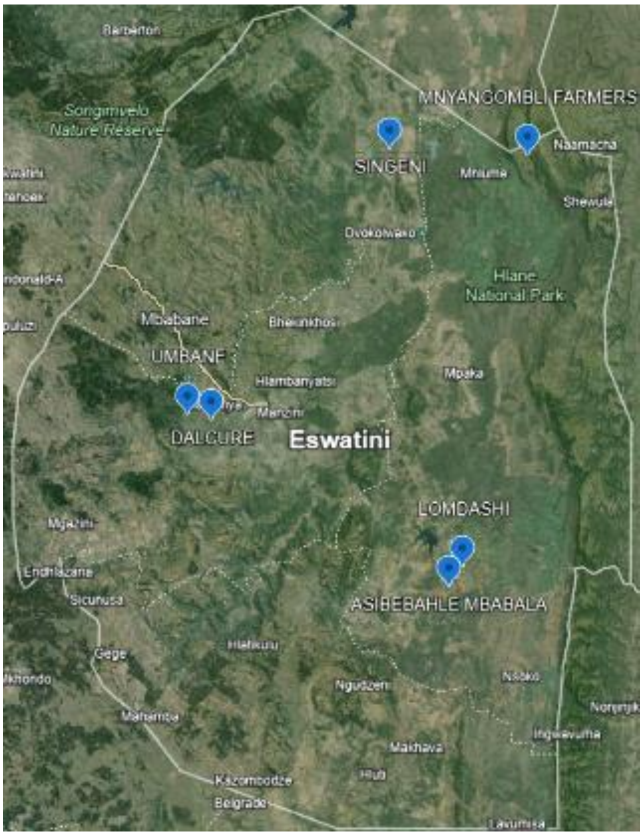


Figure 1 - Geographical Locations of growers in Eswatini.

The detailed results for each farm are presented in the following sections.

3.1 Singeni Investments

3.1.1 General Information

Table 1 - Singeni Investments grower's General Data

Name of the respondent	Muzi Dlamini
Position within the farm	Chairperson
Location of the cultivation land (using Survey CTO)	Latitude: -25.9999434 Longitude: 31.6094573
Workers employed on the farm	40
Number of women workers	29
Annual income of the farm (average last 5 years)	2,200,000 SWZ/year (114,722.52 USD/year)
Average Annual Expenditure	2,300,000 SWZ per year (119,937.18 USD per year)
Owned by	Cooperative/farming community
Total Number of pumps	2
Type of Irrigation system	Sprinkler Irrigation
Farm's Yearly Electricity Demand	165,613 kWh
Area of Land for PV system	2 ha

Figure 2 - Singeni grower's Geographical Location

The farm is collectively owned by 31 individuals, with 9 female members among them. According to the data, the farm has more expenditure than income. The total land area of the farm is 90 hectares. Sugarcane cultivation does not occupy the entire farm; however, 78 hectares of the total area are dedicated to sugarcane cultivation. The grower is currently paying back loans for development and operation purposes. The initial loan amount was 1,500,000 SWZ (80,588 USD), with 120 months remaining for loan payback.

3.1.2 Existing Infrastructure

The annual sugarcane production totals 3,500 tonnes. The largest production period spans from November to March, averaging 438 tonnes per month. Conversely, the lowest production is observed from April to July. The sugarcane farms are divided into phases, and each phase is subsequently divided into fields. In this case, there is only one phase, which in turn, has one single field. The type of irrigation used is a semi-solid sprinkler irrigation system.

Figure 3 – Singeni Farm Water Sources

Out of the entire farm area, 78 hectares are destined for sugarcane cultivation. NPK (1:0:1) and urea are fertilizers, with 250 kg of fertilizer employed per hectare (ha).

The survey results indicate that growers in Eswatini do not have access to groundwater for irrigation purposes. This finding applies uniformly across all surveyed growers in the region.

3.1.3 Irrigation Requirements

The farming operation solely relies on a single source of water for irrigation, which is the Komati River basin. The diameter of the irrigation pipes used at both the suction and delivery ends is 200 mm. The irrigation system is designed to operate 6 days a week (one full cycle) and is run for 24 hours a day during the peak period which usually occurs between November to February.

The irrigation system employs two centrifugal pumps. These pumps are typically employed in agricultural irrigation systems due to their efficiency and ability to handle large volumes of water.

Figure 4 – Pump used in Singeni Farm

The first pump has a rated power of 90 kW, while the second pump has a rated power of 55 kW. These power ratings determine each pump's pumping capacity and energy requirements within the irrigation system.

The highest irrigation demand occurs from November to February, during which the pumps are utilized continuously for 24 hours to meet the increased water requirements. Conversely, the lowest irrigation demand is observed from March to July as some fields begin to be subjected to the dry-off process before harvesting.

The farming operation experiences power outages, with a frequency of 16 times per month and an average duration of four hours. There is a single pumping station utilized in the irrigation system. The respondent (in this case the farm supervisor) stated that they have knowledge of solar-powered irrigation systems (SPIS), expressing a preference for systems capable of both on-grid and off-grid, although they favour on-grid functionality. They are interested in implementing SPIS technology. However, they are not willing to allocate funds for its purchase, nor do they intend to consider taking out a loan for SPIS.

3.2 Mnyangombili Farmers Limited

3.2.1 General Information

Table 2 - Mnyangombili Farmer's Limited General Information

Name of the respondent	Richard Velaphi Maliba
Position within the farm	Chairman
Location of the cultivation land (using Survey CTO)	Latitude: -26.0120673 Longitude: 31.9079845
Workers employed on the farm	79
Number of women workers	20
Annual income of the farm (average last 5 years)	26,000,000 SWZ/year (1,352,975 USD/year)
Average Annual Expenditure	15,000,000 SWZ per year (805,137.25 USD per year)
Owned by	Cooperative/farming community
Total Number of pumps	7
Type of Irrigation system	Sprinkle Irrigation
Farm's Yearly Electricity Demand	1,143,000 kWh
Area of Land for PV system	10 ha

Figure 5. Mnyangombili Farms' geographical location

The total area of the farmland is 400 hectares. While the total area of the farm is not entirely used for sugarcane farming, 398 hectares are dedicated to sugarcane cultivation. The farming community is not currently paying back any loans. Additionally, the grower does not possess their own SPIS systems.

3.2.2 Existing Infrastructure

The largest sugarcane production month occurs from August to December, with an average production of 8,800 tonnes per month. Conversely, the lowest sugarcane production is observed between December and March. The yearly sugarcane production totals 39,800 tonnes.

The farming operation comprises 21 cultivation plots and utilizes more than one pump for irrigation. The farming operation uses crop fertilizer, specifically Urea and NPK blends. They apply 150 units of NPK fertilizer and 100 units of Urea fertilizer.

Figure 6 - Mnyangombili Farm Water Source

3.2.3 Irrigation Requirements

The grower relies solely on a single source of water for irrigation, which is sourced from canals. The diameter of the irrigation pipe used at the suction end is 700 mm, while at the delivery end, it is 630 mm. During peak irrigation periods, 13,000 cubic meters of water are pumped per cycle, with one cycle per week being conducted. The irrigation process runs for 6 hours during each cycle. There is one water-balancing dam.

The irrigation system employs a total of 7 pumps, all of which are centrifugal pumps. Table 3 provides the power, nominal pressure, and flow rate of all the pumps.

Figure 7 - Pumps of Mnyangombili Farm

Table 3 - Pump details of Mnyangombili farm

	Pump 1	Pump 2	Pump 3	Pump 4	Pump 5	Pump 6	Pump 7
Rated power of Pump (kW)	132	185	185	185	185	132	132
Pump's Nominal Pressure (kpa)	900	950	850	650	600	-	-
Pump's Nominal Flowrate (m3/s)	0.0085	0.0065	0.0065	0.0065	0.0594	0.0065	0.0065

Figure 8 - Pumps of Mnyangombili Farm

During the highest irrigation months, which occur from November to January, the pumps are used for 24 hours per day to meet the increased water demand. Conversely, the lowest irrigation period is observed from June to July. The pumps are operated during the daytime.

The farming operation experiences power outages with a frequency of four times per month. Each power outage lasts an average of 4 hours per day. Additionally, there are two pumping stations utilized within the irrigation system. The farming operation has ten hectares of land available for solar installation. This area is affected by shading, although the specific size of the shaded region is not provided. Furthermore, there is no information regarding the distance between the pump and the solar installation area. However, the layout of the solar installation area has been provided.

Figure 9 - Mnyangombili farm Pump Station

The farm owners are aware of the SPIS. While they possess limited technical expertise, they understand the financial benefits of utilizing solar energy, particularly from training received from the Eswatini Sugar Association (ESA). They are interested in implementing SPIS technology and are willing to allocate 4,000 SWZ towards its purchase. Additionally, they are open to considering loans for financing SPIS, with plans to finance 20% of the total cost with their capital. They have identified Swazi Bank and Fincorp as specific financial institutions to potentially facilitate the loan.

3.3 Asibebahle Mbabala Limited

3.3.1 General Information

Table 4 - Asibebahle Mbabala General information

Name of the respondent	Mrs. Phumaphi Mamba (Asibebahle Mbabala)
Position within the farm	Chairlady
Location of the cultivation land (using Survey CTO)	Latitude: -26.8509153 Longitude: 31.7384192
Workers employed on the farm	20
Number of women workers	12
Annual income of the farm (average last 5 years)	3,035,254 SWZ/year (159,389.08 USD/year)
Average Annual Expenditure	1,278,594 SWZ/year (68,588.37 USD per year)
Owned by	Cooperative/farming community
Total Number of pumps	1
Type of Irrigation system	Sprinkle Irrigation
Farm's Yearly Electricity Demand	144,650 kWh
Area of Land for PV system	1 ha

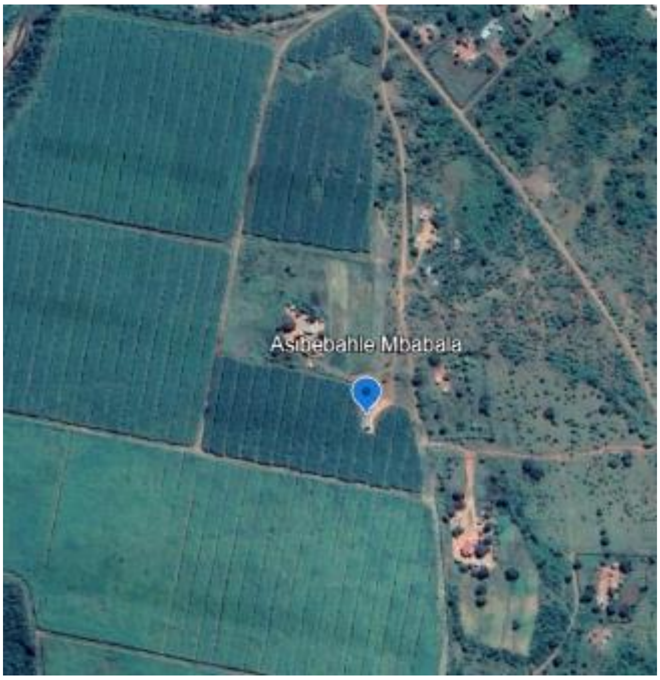


Figure 10 - Asibebahle Mbabala geographical location.

The cooperative has a total of 25 collective owners. Among these, 19 are female owners. The total area of the farmland is 47 hectares, with the entirety of this land being utilized for sugarcane farming.

This farming community is actively repaying a loan acquired to fund operational needs. The initial loan amount was 1,154,162 SWZ, although the duration for the loan payback is currently unspecified. Additionally, the farming does not possess its own SPIS.

3.3.2 Existing Infrastructure

The annual sugarcane production remains consistent at around 4,495 tonnes. The cultivation operation involves a single plot, and only one pump is utilized for irrigation. The farming operation utilizes crop fertilizer, specifically NPK blends and urea. The total amount of fertilizer used is 625 kilograms/ha.

Figure 11- Asibebahle Mbabala Water Source

3.3.3 Irrigation Requirements

The farming operation relies solely on a single water source for irrigation, which is sourced from a Mphofu storage dam. The diameter of the irrigation pipe used at the suction end is 250 mm, while at the delivery end, it is 110 mm. During the peak irrigation period (from September to March), 14,514 cubic meters of water are pumped per second. There is one irrigation cycle per week during peak irrigation, and the irrigation process runs for 168 hours.

The irrigation system utilizes a single centrifugal pump with a rated power of 75 kW, a nominal pressure of 550 kPa, and a nominal flow rate of 57 m3/s. During the highest irrigation period, the pump operates continuously for 24 hours to meet peak demand. Conversely, the lowest irrigation month, occurring during winter (April to August), also sees specific pump operation times. During peak irrigation, the pump operates for the entire day.

Figure 12 - Asibebahle Mbabala Pumping station.

The farming operation experiences power outages, with a frequency of two outages per month. Each power outage lasts for eight hours. The farming operation has one hectare of land available for solar installation, and there is no shading in the area. The distance between the solar panels and the field is 50 meters. Additionally, the layout of the solar installation area has been provided.

Figure 13 – Land available for SPIS.

The grower possesses knowledge of SPIS technology. While they understand the concept of utilizing solar energy for pumping, their technical knowledge of system components and operations is limited. However, they are interested in implementing SPIS technology. Although they are not willing to allocate personal funds for the SPIS system, they are open to considering loans for its acquisition. They would finance the entire cost of the SPIS system through the loan. Additionally, they have identified Eswatini Bank as a specific financial institution to approach for the loan.

3.4 Lomdashi Investments

3.4.1 General Information

Table 5 - Lomdashi General Information

Name of the respondent	LOMDASHI limited - Mr. Mbhekeni Ndwandwe
Position within the farm	Chairperson
Location of the cultivation land (using Survey CTO)	Latitude: -26.8124727 Longitude: 31.7684469
Workers employed on the farm	90
Number of women workers	32
Annual income of the farm (average last 5 years)	40,598,600 SWZ/year (2,117,078.95 USD/year)
Average Annual Expenditure	24,500,000 SWZ.per year (1,319,385.54 USD per year)
Owned by	Cooperative/farming community
Total Number of pumps	16
Type of Irrigation system	Sprinkle & Central Pivot Irrigation
Farm's Yearly Electricity Demand	2,340,066 kWh
Area of Land for PV system	10 ha

Figure 14 - Lomdashi Geographical Location

The cooperative comprises a total of 453 collective owners, including 182 female owners. However, the respondent, Mr Mbhekeni Ndwandwe, is not the owner of the farm. The total area of the farm is 623 hectares, and the entire area is utilized for sugarcane farming. The farming community is paying back a loan, obtained for capital purposes, with an initial amount of 7,400,000 SWZ and 24 months are remaining for the loan payback. However, the grower do not have their own SPIS.

3.4.2 Existing Infrastructure

Annually, 56,000 tonnes of sugarcane are yielded per month. Conversely, the lowest production months are experienced from April to July. The farming operation maintains a single cultivation plot. Additionally, they utilize crop fertilizer, specifically NPK and urea granules, with a total of 150 kg per ha of urea and 475 kg per ha of NPK being applied.

Figure 15 - Lomdashi water source.

3.4.3 Irrigation Requirements

The farming operation relies solely on a single source of water for irrigation, which is sourced from canals. They use an 800 mm diameter pipe at the suction end and a 110 mm diameter pipe at the delivery end for irrigation. During peak irrigation periods, they pump 1,297,445 cubic meters of water per second. There is one irrigation cycle per week during peak irrigation, and the irrigation process runs for 96 hours. A water-balancing dam has been installed on the farm. However, the storage capacity of the dam was not provided. The diameter of the pipe used to pump water from the balancing dam to the field is 800 mm, and the distance between the balancing dam and the field is 10 meters.

The irrigation system employs a total of 16 centrifugal pumps, with the grower utilizing two pumping sites. These sites facilitate lift pumping from the canal to the balancing dam, as well as infield pumping to operate the sprinkles in the field. Although the rated power and nominal flow rate of the pumps were not specified, each pump maintains a normal pressure of 600Pa.

Figure 16 – Pumps of Lomdashi Farms

During the highest irrigation months, spanning from September to January. The pumps are used for 24 hrs 6 days a week during the peak irrigation months. During the off-peak period, the pumps are operated for 12 hrs. The lowest irrigation months are from March to July. The farming operation experiences power outages, occurring 5 times per month, with each outage lasting an average of two hours. Additionally, there are two pumping stations on the farm.

Figure 17 - Lomdashi Farm Pump Station

The farming operation has 10 hectares of land available for solar installation, with no shading in the area. The distance between the solar panels and the field is 50 meters. However, there is no layout provided for the solar installation area. The respondent stated that the growers are knowledgeable about SPIS. They believe that if installed correctly and according to specifications, SPIS can effectively reduce energy costs for the grower. However, they note that batteries, which are necessary for storing solar energy, can be expensive, necessitating better scheduling practices.

Although they are interested in SPIS technology, they are not willing to allocate personal funds for its acquisition. However, they are open to considering loans to finance the SPIS. They would not contribute any personal financing percentage towards the SPIS system. Moreover, they have identified NED Bank as a specific financial institution from which they would seek a loan for the SPIS.

3.5 Umbane Pvt Ltd

3.5.1 General Information

Table 6 - Umbane General Information

Name of the respondent	Umbane Limited - Mr. Jeremiah Manana
Position within the farm	Chairperson
Location of the cultivation land (using Survey CTO)	Latitude: -26.5157664 Longitude: 31.1711472
Workers employed on the farm	42 workers; 23 permanent, 19 seasonal
Number of women workers	10
Annual income of the farm (average last 5 years)	14,419,014 SWZ per year (751,255.14 USD per year)
Average Annual Expenditure	13,346,268 SWZ.per year (718,729 USD per year)
Owned by	Cooperative/farming community
Total Number of pumps	2
Type of Irrigation system	Sprinkle Irrigation
Farm's Yearly Electricity Demand	181,831 kWh
Area of Land for PV system	3 ha

Figure 18 - Umbane Farm Geographical Location

There are 155 collective owners within the cooperative, including 60 female owners. The total area of the farmland is 264 hectares, and the entire area is utilized for sugarcane farming. The farming community is not currently paying back any loans, and the farm does not have a SPIS.

3.5.2 Existing Infrastructures

The largest sugarcane production months are from October to February, with an average production of 7,500 tonnes per month. Conversely, the lowest sugarcane production occurs from April to August. Annually, the sugarcane production amounts to 20,000 tonnes. The farming operation maintains a single cultivation plot and utilizes only one pump. Additionally, they use crop fertilizer, including NPK blends and urea, using 200 Kg per ha of urea and 270 Kg per ha of NPK.

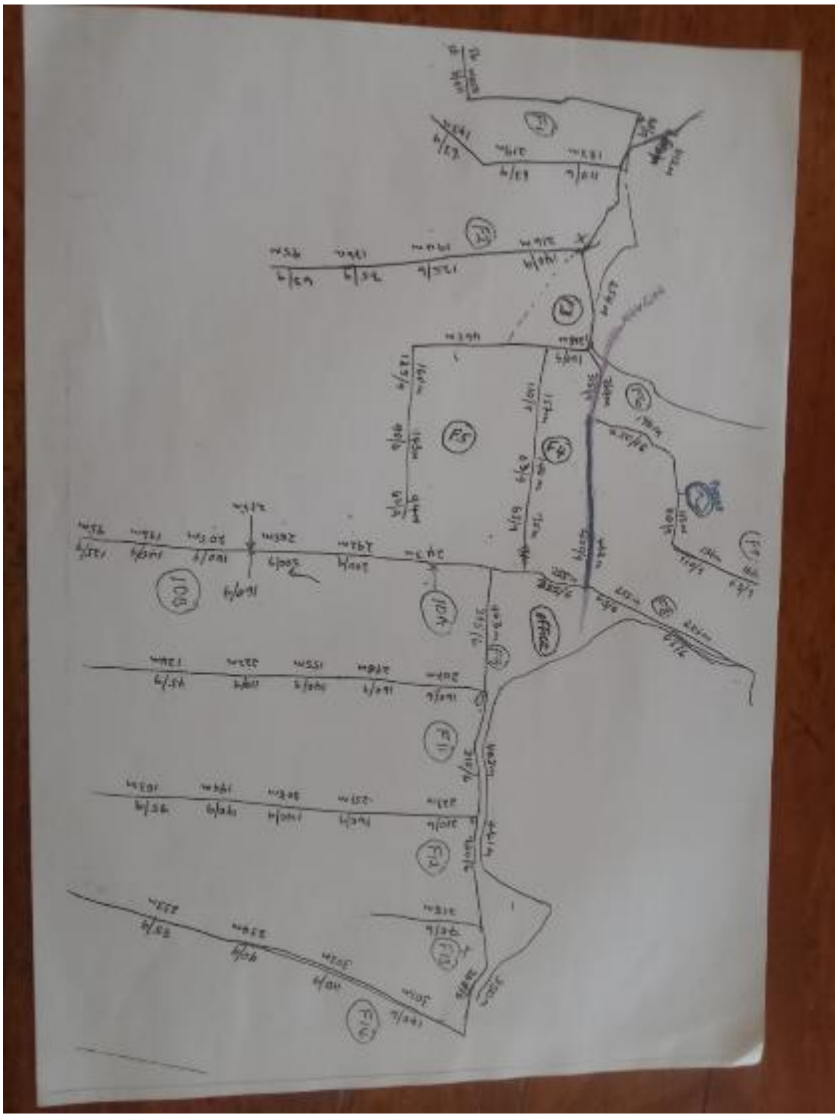


Figure 19 - Umbane Farm Layout

3.5.3 Irrigation Requirements

The farming operation solely relies on a single water source for irrigation, which is obtained from the Malkerns canal. They utilize a 500 mm diameter pipe at the suction end and a 450mm diameter pipe at the delivery end for irrigation purposes. The amount of water pumped during peak irrigation was not provided. However, there is one irrigation cycle per week during peak irrigation, and the irrigation process runs for nine hours. Additionally, there is no water-balancing dam.

Two centrifugal pumps are used for irrigation. The first pump has a rated power of 110 kW and a nominal pressure of 730 Pa, while the nominal flow rate was not provided. Similarly, the second pump also features a rated power of 110 kW and a nominal pressure of 730 Pa, with the nominal flow rate not provided. During the highest irrigation months, spanning from October to December, the pump is operated for 18 hours per day to meet the peak irrigation demand. Conversely, the lowest irrigation months are from March to June.

The pumps are operated at specific times, with 24-hour operation during peak irrigation periods, which covers the entire day. Further details regarding the power required for irrigation and the electricity bill are discussed further in the report. The farm has experienced power outages, occurring four times per month, with each outage lasting for 8 hours. Additionally, there is one pumping station on the farm.

Figure 20 - Umbane Land Area for SPIS

The area available for solar installation on the farm is three hectares, with no shading present in the area. The distance between the solar panels and the field is 50 meters. Additionally, a layout of the solar installation area is available. The representative of the farm possesses knowledge of SPIS. They believe that solar panels can be utilized to convert sunlight into energy to power water pumps. Furthermore, they express interest in implementing SPIS technology. However, they are not willing to allocate any funds for the acquisition of SPIS. Despite this, they are open to considering a loan to finance the SPIS, to finance 10% of the total cost. Moreover, they have identified FNB as a specific financial institution from which they would seek a loan for the SPIS.

3.6 Dalcrue Agricultural Holdings Pvt Ltd

3.6.1 General Information

Table 7 - Dalcrue General Information

Name of the respondent	Dalcrue Agricultural Holdings
Position within the farm	Manager - Mr. Sibusiso Mahlalela
Location of the cultivation land (using Survey CTO)	Latitude: -26.5263119 Longitude: 31.2222721
Workers employed on the farm	120
Number of women workers	80
Annual income of the farm (average last 5 years)	22,000,000 SWZ per year (1,157,167 USD per year)
Average Annual Expenditure	12,000,000 SWZ per year (644,011.94 USD per year)
Owned by	Single Farmer
Total Number of pumps	10
Type of Irrigation system	Sprinkle Irrigation
Farm's Yearly Electricity Demand	173,043 kWh
Area of Land for PV system	2 ha

Figure 21 - Dalcrue Geographical Location

This farm has a total area of farmland spanning 300 hectares, all dedicated to sugarcane farming. Additionally, images and layout plans have been provided. The grower is currently paying back a loan obtained for solar purposes, with an initial amount of 6,000,000 SWZ (318,960 USD), and 36 months remaining for loan repayment. Furthermore, a SPIS has already been installed on the farm.

3.6.2 Existing Infrastructures

The largest sugarcane production occurs from November to January, with an output of 3,750 tonnes during this period. Conversely, the lowest production months are from March to August. The yearly sugarcane production totals 30,000 tonnes. The farm utilizes three cultivation plots and employs more than one pump. There are a total of 13 fields included in the phase. For irrigation, the farm utilises a sprinkler system. The maximum flow rate of water in the system is 33 cubic meters per hour (m^3/hr), while the maximum operating water pressure for the irrigation system is 600 kilopascals (kpa). The farm utilizes crop fertilizer, specifically NPK granular type, with a total amount of 400 kilograms.

Figure 22- Dalcrue existing SPI System

The farm exclusively relies on a single source of water for irrigation, sourced from the Malkerns canal. The irrigation system employs a pipe with a diameter of 400 millimetres at the suction end and 50 millimetres at the delivery end. During peak irrigation, the system pumps 43,200 cubic meters per second (m^3/s). The irrigation process runs continuously for 24 hours, with one cycle per week during peak irrigation. The farm has a water-balancing dam with a storage capacity of 1,000 litres It is located 10 meters from the field.

The farm is divided into four distinct sites, each featuring its own SPIS system with a unique size. Across all four sites, the total combined capacity of the SPIS systems is 450 kW. The information available pertains specifically to one of these sites, where a 60kW SPIS was installed on May 7th, 2021. This particular system generates approximately 64,800 kWh of power per month. However, despite its output, the power generated by this SPIS falls short of meeting the farm's electricity demand. Financing for this SPIS was obtained through Standard Bank, with a loan term of 60 months.

Figure 23 - Dalcrue Existing SPIS

The security and theft of the SPIS pose a problem, as indicated by incidents of theft of panels. To mitigate this issue, the farm has implemented measures such as providing lighting and manned security. The entire system had a cost of 60,000,000 SWZ (3,221,361.30 USD). Growers have received training to operate the system effectively. Maintenance and operation costs of the SPIS are within budget constraints. The estimated yearly maintenance cost of the system is 552,000 SWZ (29,630.86). The SPIS irrigates an area of 300 hectares of land.

The farm still uses electricity from the grid. They would recommend the solar system to other growers. However, they have experienced several problems with the SPIS, including damage from hailstorms, the need to maintain a clean area around the panels, vandalism, theft, and the inability to export excess energy to the grid or receive compensation for it.

The system service provider offers an installation warranty, which has been transferred to the owner's name, valid for 180 months. The service provider is The Renewable Resource Company (TRRC). The farm is aware of the expected lifetime of the system, which is 25 years. However, the supplier will not collect the system at the end of its productive life, and the farm has not been informed of any alternatives for the disposal of the SPIS system.

3.6.3 Irrigation Requirements

The farm uses ten centrifugal pumps for irrigation. Each pump has a rated power of 75 kW and operates at a nominal pressure of 600 kPa. The nominal flow rate of each pump is 1 litre per second. Throughout the year, the pumps are operational 24 hours a day during the peak irrigation months from October to January. During the off-peak hours, the system runs for 12 hrs.

Similarly, during the lowest irrigation months, from February to August, the pumps remain operational for the entire day. There are no experienced power outages. The farm has a total of three pumping stations. Details regarding the power required for irrigation and electricity bills are further discussed in the report. The farm has not experienced any power outages. There are three pumping stations on the farm. The area available for solar installation is two hectares, and there is no shading in the area.

4. Technical sizing of the SPIS systems

Solar power irrigation systems (SPIS) leverage renewable energy sources to pump water, offering growers a reliable and cost-effective means of crop irrigation.

The tool used for the technical sizing of the systems was Helioscope. Helioscope is a software tool used in the design and analysis of solar energy systems. It enables users to accurately assess the feasibility and optimize the design of solar photovoltaic (PV) installations for various applications, including solar power irrigation systems. Table 8 provides the values assumed for the technical sizing of the solar systems.

4.1 Assumptions

Table 8 - SPIS sizing assumptions

Main Sizing Criteria	
Sizing Power Factor	15%
Solar Yield Eswatini (Check Simulations)	1,484 kWh/kWp/year
Area per kWp	6.29 sqm

The main sizing criteria for the solar power system include a sizing power factor of 15%, a solar yield specific to Eswatini (as determined by simulations) of 1,484 kWh/kWp/year and an area requirement of 6.29 square meters (sqm) per kWp. These criteria are essential for determining the appropriate size of the solar installation based on factors such as available space, expected energy output, and efficiency considerations.

In terms of the placing and orientation of the SPIS, the following parameters were assumed:

- **Racking & Orientation:** The racking configuration is set to "East-West," indicating that the solar panels are installed in an east-west orientation, allowing for optimal sunlight exposure throughout the day.
- **Tilt:** The tilt angle is set at 15°, which is the angle at which the solar panels are tilted relative to the horizontal plane.
- **Azimuth:** The azimuth angle is set at 0°, indicating that the solar panels are facing due south.
- **Interrow Spacing:** The interrow spacing, or the distance between rows of solar panels, is set at 2.4 meters.
- **Frame Size:** The frame size is specified as "4*1," indicating that each frame supports four solar panels arranged in a single row.

These parameters are standardized across all farms to ensure consistency in the solar panel installation process and optimize energy production efficiency.

Table 9 - Standard parameters for SPIS sizing

Racking	Orientation	Tilt	Azimuth	Interrow Spacing	Frame Size
East-West	Landscape (Horizontal)	28°	0°	2.4m	4*1

4.2 Outputs

This section outlines the outcomes of the PV system sizing conducted utilizing the Helioscope software. These are divided into system specifications and component requirements.

System specifications:

- **Total system Capacity:** The maximum power output that the entire solar power system can generate.
- **Inverter Capacity:** the minimum amount of DC power that the inverters installed in the system can convert to AC power.
- **Estimated Annual Energy Production:** The anticipated amount of electricity that the system can generate over one year.
- **Performance Ratio:** A measure of the efficiency of the system, representing the ratio of actual energy output to the theoretically possible energy output.
- **kWh/kWp:** The specific energy yield of the system, indicating the amount of energy generated per unit of installed capacity. This metric helps assess the energy generation efficiency of the system relative to its installed capacity.

Component requirements:

- **Module:** These are the individual solar panels that convert sunlight into electricity through the photovoltaic effect,
- **Inverters:** Inverters are electronic devices that convert DC into AC.
- **AC Home Runs:** AC home runs refer to the electrical wiring that carries the AC electricity from the inverter to the main electrical panels.
- **Strings:** These refer to groups of solar panels that are connected in series to form a single electrical circuit.
- **Frames:** Represents the total number of support structures or frames used to mount the solar panels.
- **Power:** indicates the total power generation capacity of the solar installation, typically measured in KW/MW

4.3 Sizing Results

4.3.1 Singeni Investment

Demand for pumping.

Number of Pumps	Power for single pump (kW)	Pump total (kW)	Suggested PV (kWp)
Pump Size 1 (x1)	90	90	111.59
Total		90	111.59

The table above shows pump location identified for the Singeni farms requires a total pump size of 90 kW, which corresponds to a suggested photovoltaic (PV) system size of 112 kWp. This sizing ensures that the solar power system can adequately meet the energy demands of the pumps at the specified location.

Table 10 – Energy consumption and expected PV output per scenario.

Month	Total electricity demand (kWh)	Expected PV output – Scenario 1 (kWh)	Expected PV output – Scenario 2 (kWh)
January	1,097	17,879.56	50,094.90
February	4,147	15,316.48	43,456.80
March	20,421	15,386.19	44,377.60
April	36,077	12,715.70	36,331.30
May	1,228	11,365.42	32,550.70
June	1,228	10,052.73	29,101.60
July	12,301	10,882.11	31,518.40
August	8,019	12,419.69	35,281.30
September	15,213	13,552.76	38,564.80
October	19,669	14,818.16	42,209.10
November	28,713	15,530.62	42,786.10
December	17,500	17,427.69	48,071.90
Total	**165,613**	**167,347.16**	**474,344.50**

Table 10 above indicates the monthly demand and Expected PV output of Singeni Farms in both scenarios. The highest electricity demand occurs in April, with a total demand of 36,077 kWh, while the lowest demand is in January, with only 1,097 kWh needed. On average, the demand for electricity across all months is approximately 13,801 kWh.

In scenario 1, the sizing of the PV system is implied to satisfy the total yearly demand thus, the expected PV output from the solar panels varies throughout the year, with the highest output expected in January at 17,879.56 kWh and the lowest in June at 10,052.73 kWh. The total expected PV output for the entire year is 167,347.16 kWh, slightly exceeding the total demand for electricity over the year of 165,613 kWh.

In scenario 2, the PV system is designed to meet or exceed the highest monthly consumption. In April, the expected PV output is 36,331.30 kWh, indicating that the system can generate more electricity than the total demand for that month, as indicated by the peak in the Figure *24*. The PV system is projected to produce a total output of 474,344.50 kWh. This surplus output ensures the system's capacity to meet peak energy requirements and potentially contribute excess energy back to the grid, highlighting the efficiency and reliability of the solar power system design.

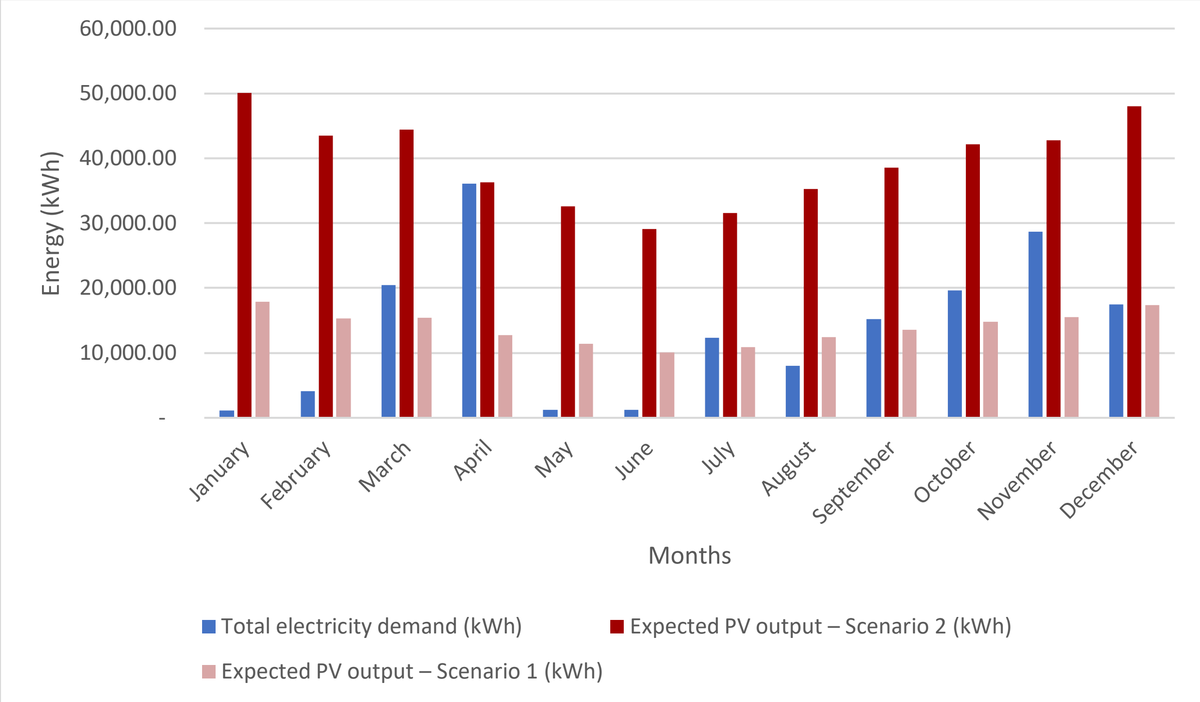


Figure 24 – Comparison of energy demand and PV output across scenarios.

4.3.1.1 Technical sizing according to the yearly demand (Scenario 1)

Table 11 - Singeni Scenario 1 SPIS system specification

System sizing				
Module capacity	Inverter capacity	Estimated annual energy production	Performance ratio	kWh/kWp
118 kW	96.2 kW	167.0 MWh	80.1 %	1,415.00
Component requirements				
Module	Inverters	Strings		
342	4	38 (1,068 m)		
Field segments				
Frames	Racking	Tilt		
43	East-West	28°		

4.3.1.2 Technical sizing according to the highest monthly demand (Scenario 2)

Table 12 - Singeni Scenario 2 SPIS system specification

System sizing				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kW p
334.0 kW	288.7 kW	474.3 MWh	80.4 %	1,420.0
Component requirements				
Module	Inverters	Strings		
968	12	60 (2,745.5 m)		

Field segments		
Frames	Racking	Tilt
121	East-West	28°

4.3.2 Mnyangombili Farmers Limited

Demand for pumping.

Number of Pumps	Power for single pump (kW)	Pump Total (kW)	Suggested PV (kWp)
Pump Size 1 (x3)	135	405	465.75
Pump Size 2 (x1)	90	90	103.5
Pump Size 3 (x4)	185	740	851
Total		1,235	1,420.25

The pumping system in Mnyangombili has a total of eight pumps, for a total power requirement of 1,235 kW, and a photovoltaic (PV) system with a total capacity of 1,420.25 kW.

Table 13 – Energy consumption and expected PV output per scenario.

Month	Total electricity demand (kWh)	Expected PV output – Scenario 1 (kWh)	Expected PV output – Scenario 2 (kWh)
January	128,000	129,399.40	242,071.30
February	1,000	110,635.10	208,620.70
March	43,000	111,096.50	210,354.90
April	116,000	92,279.80	175,440.10
May	80,000	82,686.20	157,590.30
June	73,000	73,079.80	139,620.20
July	40,000	79,184.10	151,131.00
August	105,000	90,499.50	171,638.90
September	158,000	98,277.90	186,813.10
October	118,000	106,938.90	202,017.60
November	156,000	111,878.10	210,174.80
December	125,000	126,178.00	235,173.40
Total	**1,143,000**	**1,212,133.3**	**2,290,646.30**

Table *13* above shows that the energy demand varies across the months, reaching its peak in January at 129,399.40 kWh and its lowest point in June at 73,079.80 kWh. However, the PV system is designed to meet the annual demand, resulting in a total annual energy demand of 1,143,000 kWh. Surpassing this demand, the expected PV output in Scenario 1 stands at 1,212,133.3 kWh, indicating that the system can generate more energy than required to fulfil the annual electricity needs.

In turn, the PV system in Scenario 2 is designed to satisfy the highest monthly consumption, resulting in a total expected PV output of 2,290,646.30 kWh for the year.

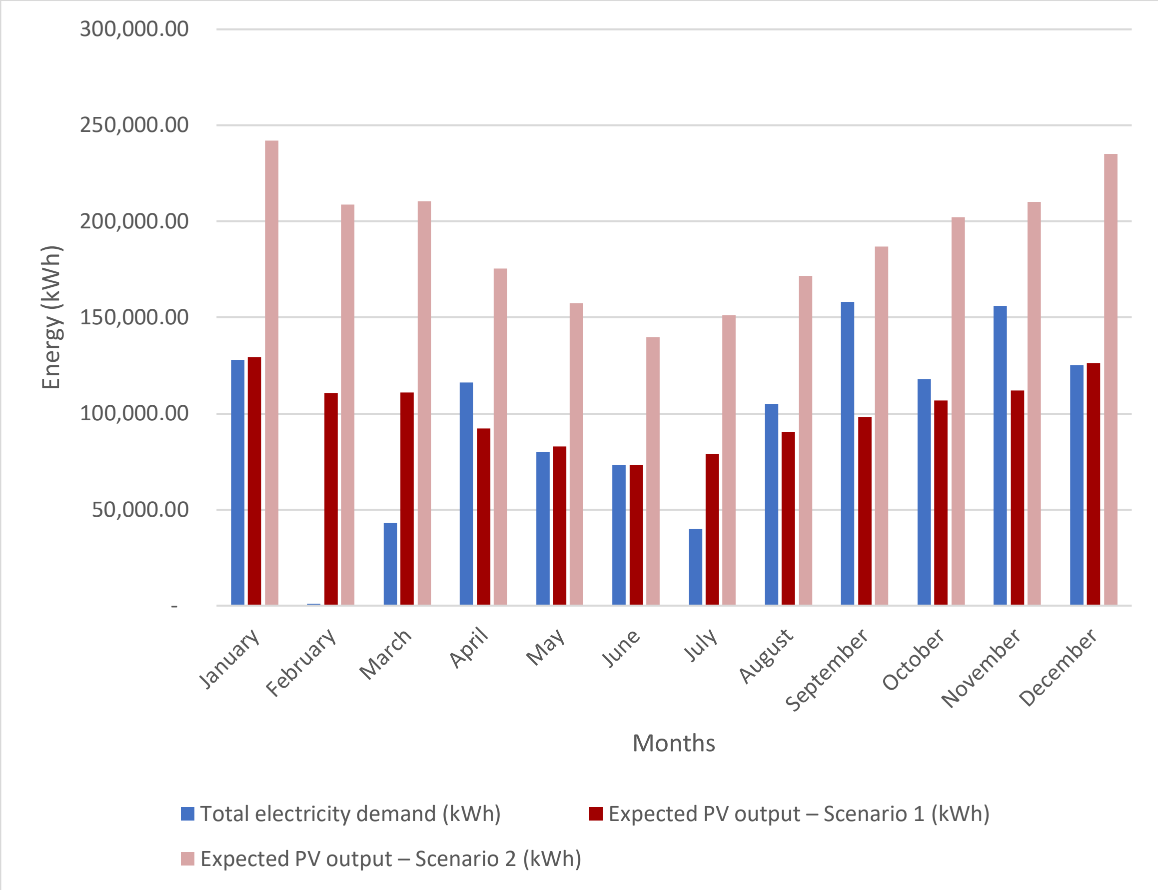


Figure 25 - Comparison of energy demand and PV output across scenarios.

4.3.2.1 Technical sizing according to the yearly demand (Scenario 1)

Table 14 - Mnyangombili Scenario -1 SPIS system specification

System sizing				
Module capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
880 kW	721.8 kW	1,212 MWh	77.8%	1,376.7
Component requirements				
Module	Inverters	Strings		
2,552	30	160 (10,480.0 m)		
Field segments				
Frames	Racking	Tilt		
319	East-West	28°		

4.3.2.2 Technical sizing according to the highest monthly demand. (Scenario 2)

Table 15 - Mnyangombili Scenario -2 SPIS system specification

System sizing				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
1.53 MW	721.8 kW	2,291 MWh	81.5%	1,500.8
Component requirements				
Module	Inverters	Strings		
4,424	48	420 (12,592.1 m)		
Field Segments				
Frames	Racking	Tilt		
553	East-West	28°		

4.3.3 Asibebahle Mbabala Limited

Demand for pumping.

Number of Pumps	Power for a single Pump (kW)	Pump Total (kW)	Suggested PV (kWp)
Pump Size 1 (x1)	55	55	98.06
Total		55	98.06

In the specified pump location of Asibebahle Mbabala, there is one single pump, with a total power of 50 kW, the suggested PV capacity is 98.061 kW.

Table 16 - Energy consumption and PV output per scenario

Month	Total electricity demand (kWh)	Expected PV output – Scenario 1 (kWh)	Expected PV output – Scenario 2 (kWh)
January	9,665.00	15,362.80	28,982.00
February	4,293.00	13,281.80	25,027.30
March	25,376.00	13,446.90	25,373.00
April	18,148.00	11,131.90	21,045.10
May	777.00	9,986.80	18,854.00
June	5,419.00	8,847.80	16,663.10
July	11,671.00	9,478.10	17,858.40
August	15,961.00	10,727.50	20,238.70
September	19,317.00	11,889.20	22,458.10
October	9,263.00	12,703.20	24,000.80
November	15,833.00	13,739.90	25,920.30
December	8,927.00	15,112.70	28,482.20
Total	**144,650.00**	**146,164.65**	**274,903.00**

The data from the energy bills shows that monthly demands vary throughout the year. May has the lowest demand (777 kWh), while March has the highest demand (25,376 kWh). However, the PV system in Scenario 1 is designed to meet the annual demand, as shown by the Expected PV Output exceeding the 146,164.6565-kWh total energy demand for the year.

The system in Scenario 2 provides a PV output for March of 25,373 kWh, matching the highest monthly demand and effectively matching the peak energy demand, ensuring sufficient power generation to meet the highest consumption periods, and leading to a yearly output of 274,903.00 kWh.

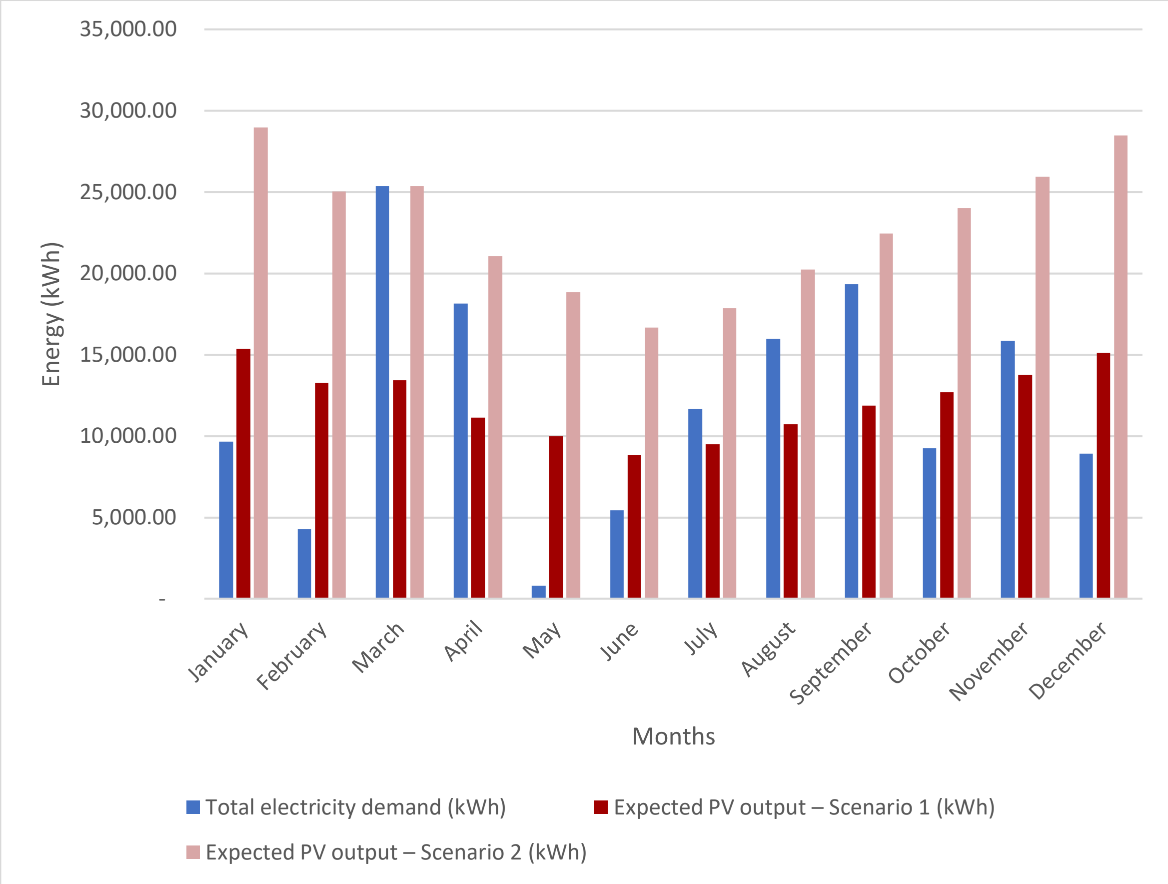


Figure 26 - Comparison of energy demand and PV output across scenarios.

4.3.3.1 Technical sizing according to the yearly demand (Scenario 1)

Table 17. Asibebahle Mbabala Scenario 1 SPIS system specification

System sizing				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
96.6 kW	96.2 kW	156.1 MWh	81.2%	1,616.10

Components requirements		
Module	Inverters	Strings
280	4	16 (331.3m)
Field Segments		
Frames	Racking	Tilt
70	East-West	28°

4.3.3.2 Technical sizing according to the highest monthly demand (Scenario 2)

Table 18 - Asibebahle Mbabala Scenario 2 SPIS system specification

System Specification				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
198.7 kW	168.4 kW	274.9 MWh	79.7%	1383.4

Components (Counts)		
Module	Inverters	Strings
576	7	35 (1280.9 m)

Field Segments		
Frames	Racking	Tilt
72	East-West	28°

4.3.4 Lomdashi Investments

Demand for pumping.

Number of Pumps	Power for single Pump (kW)	Pump Total (kW)	Suggested PV (kWp)
Pump Size 1 (x2)	110.00	220.00	315.07
Pump Size 2 (x4)	132.00	528.00	756.18
Pump Size 3 (x5)	37.00	185.00	264.95
Pump Size 4 (x2)	55.00	110.00	157.54
Pump Size 5 (x1)	75.00	75.00	107.41
Pump Size 6 (x1)	11.00	11.00	15.75
Pump Size 7 (x1)	7.50	7.50	10.74
Total		**1,136.50**	**1,627.65**

The table above provides details about the pumping requirements at Lomdashi and the corresponding suggested photovoltaic (PV) systems. In total, the 16 pumps at Lomdashi have a cumulative power requirement of 1,136.5kW, with a suggested PV system capacity of 1,627.65kWp.

Table 19 - Energy consumption and expected PV output per scenario.

Month	Total electricity demand (kWh)	Expected PV output – Scenario 1 (kWh)	Expected PV output – Scenario 2 (kWh)
January	160,933	262,886.80	404,380.30
February	89,128	228,196.20	349,587.20
March	300,470	232,140.90	353,802.20
April	174,951	191,601.00	293,444.10
May	188,025	172,461.20	263,478.60
June	231,277	152,978.40	231,972.40
July	158,038	164,192.90	250,259.10
August	242,423	183,152.10	281,619.50
September	272,140	205,290.70	314,332.20
October	158,611	220,497.10	337,882.50
November	166,994	233,301.90	356,451.20
December	197,076	257,325.80	395,035.70
Total	**2,340,066**	**2,504,025.00**	**3,832,245.00**

Table 19 above presents the monthly energy demand and expected PV output for the Lomdashi Farm. The highest total electricity demand is observed in March, reaching 300,470 kWh, while the lowest demand occurs in February, totalling 89,128 kWh. On average, the total electricity demand across the months amounts to approximately 195,005.5 kWh.

In Scenario 1, the expected PV output exhibits the highest value in March, with 232,140.90 kWh, and the lowest in June, at 152,978.40 kWh. On average, the expected PV output is approximately 208,668.75 kWh, for a total yearly output of 2,504,025.00.

The PV system of Scenario 2 is specifically made to meet the highest monthly demand, delivering a PV output of 353,802.20 kWh in March.

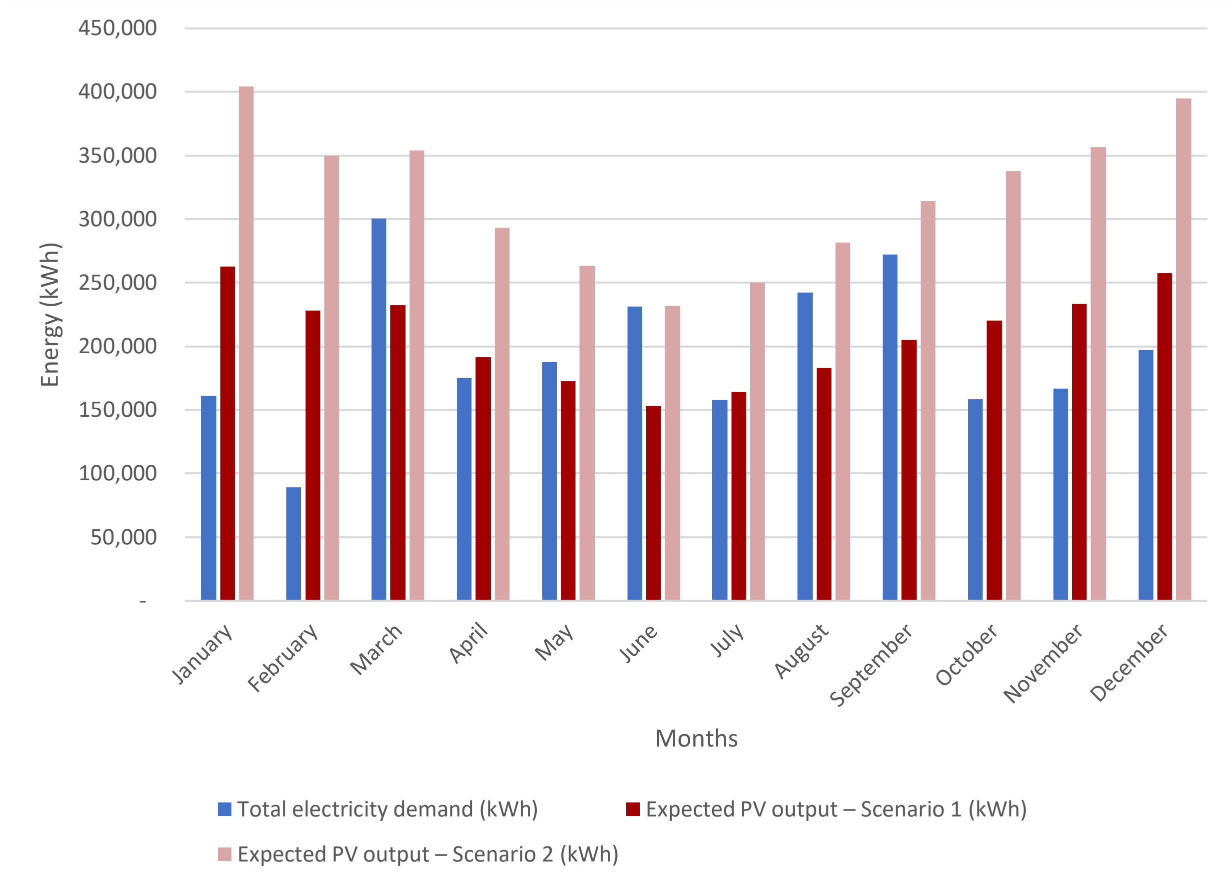


Figure 27- Comparison of energy demand and PV output across scenarios.

Figure 27 above illustrates the relationship between the highest month of energy demand and the corresponding expected PV output. It demonstrates that the PV system's projected output exceeds the peak energy demand.

4.3.4.1 Technical sizing according to the yearly demand (Scenario 1)

Table 20. Lomdashi Mbabala Scenario 1 SPIS system specification

System sizing				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
1.53 MW	1.23 MW	2.194 GWh	79.60%	1,437.7
Component requirements				
Module	Inverters	Strings		
4,424	51	255 (7,073.6m)		
Field Segments				
Frames	Racking	Tilt		
553	East-West	28°		

4.3.4.2 Technical sizing according to the highest monthly demand (Scenario 2)

Table 21 - Lomdashi Mbabala Scenario 2 SPIS system specification

<table>
<tr><th colspan="6">System Specification</th></tr>
<tr><td>Module Capacity</td><td>Inverter Capacity</td><td colspan="2">Estimated annual energy production</td><td>Performance Ratio</td><td>kWh/kWp</td></tr>
<tr><td>1.53 MW</td><td>1.23 MW</td><td colspan="2">2.194 GWh</td><td>79.60%</td><td>1,437.7</td></tr>
<tr><th colspan="6">Components (Counts)</th></tr>
<tr><td colspan="2">Module</td><td colspan="2">Inverters</td><td colspan="2">Strings</td></tr>
<tr><td colspan="2">4,424</td><td colspan="2">51</td><td colspan="2">255 (7,073.6m)</td></tr>
<tr><th colspan="6">Field Segments</th></tr>
<tr><td colspan="2">Frames</td><td colspan="2">Racking</td><td colspan="2">Tilt</td></tr>
<tr><td colspan="2">553</td><td colspan="2">East-West</td><td colspan="2">28°</td></tr>
</table>

4.3.5 Umbane Pvt. Ltd.

Demand for pumping.

Number of Pumps	Power for single Pump (kW)	Pump total (kW)	Suggested PV (kWp)
Pump Size 1 (x1)	320	320	368
Total		320	368

The table above presents data for the pump location at Umbane, this farm has one single pump, with a power output of 320 kW. The suggested PV system size to meet the energy demands of this pump is 368 kWp.

Table 22 - Energy consumption and expected PV output per scenario.

Month	Total electricity demand (kWh)	Expected PV output – Scenario 1 (kWh)	Expected PV output – Scenario 2 (kWh)
January	10,692	18,911.80	55,024.50
February	21,633	17,141.70	49,719.30
March	11,135	17,332.00	50,676.50
April	20,473	14,235.20	41,766.40
May	10,219	13,506.10	39,424.10
June	34,124	12,030.50	34,990.60
July	14,331	12,986.30	37,800.80
August	17,048	14,775.20	43,308.60
September	16,720	16,250.10	47,646.60
October	4,667	16,406.90	47,892.60
November	11,862	17,148.60	49,870.90
December	8,927	18,676.90	54,422.50
Total	**181,831**	**189,401.30**	**552,543.40**

The Umbane farm has an annual demand of 181,831 kWh and an expected PV output of 189,401.30 kWh in Scenario 1. With 34,124 kWh, June has the highest energy demand, while October has the lowest, at 4,667 kWh. On the other hand, January is expected to have the largest PV output (18,911.80 kWh), while June is the lowest (12,030.50 kWh). In general, the PV system is made to fulfil the entire year's energy requirements, guaranteeing adequate coverage all through the year at an overall output of 189,401.30 kWh.

Scenario 2, designed to match the maximum electricity demand, has an expected PV output of 552,543.40 kWh, with the largest electricity output from the system in January, with 55,024.50 kWh, and the lowest in June, with 34,990.60 kWh.

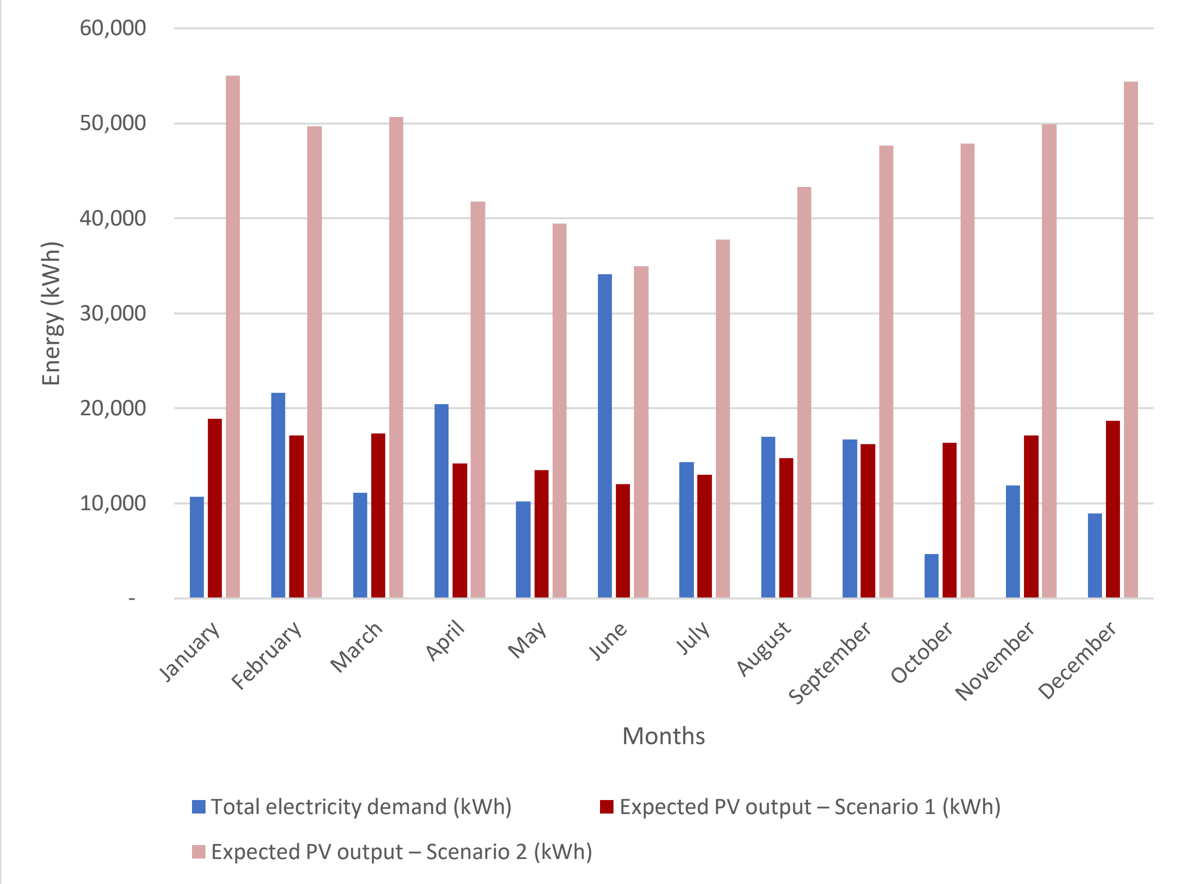


Figure 28 - Comparison of energy demand and PV output across scenarios.

However, the PV system is built to accommodate the maximum monthly demand, guaranteeing adequate coverage during times of peak consumption—December in this case. The graph provides a clear comparison between the energy demand and the anticipated PV generation for each month.

4.3.5.1 Technical sizing according to the yearly demand (Scenario 1)

Table 23. Umbane Scenario 1 SPIS system specification

System sizing				
Total System Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
143.5 kW	120.3 kW	189.4 MWh	78.6%	1,319.70
Components requirements				
Module		Inverters	Strings	
416		5	25 (853.3 m)	
Field Segments				
Frames		Racking	Tilt	
52		East-West	28°	

4.3.5.2 Technical sizing according to the highest monthly demand (Scenario 2)

Table 24 - Umbane Scenario 2 SPIS system specification

<table>
<tr><th colspan="6">System sizing</th></tr>
<tr><td>Total System Capacity</td><td>Inverter Capacity</td><td colspan="2">Estimated annual energy production</td><td>Performance Ratio</td><td>kWh/kWp</td></tr>
<tr><td>411.2 kW</td><td>336.8 kW</td><td colspan="2">552.5 MWh</td><td>80.1%</td><td>1,343.6</td></tr>
<tr><th colspan="6">Components (Counts)</th></tr>
<tr><td colspan="2">Module</td><td colspan="2">Inverters</td><td colspan="2">Strings</td></tr>
<tr><td colspan="2">1,192</td><td colspan="2">14</td><td colspan="2">70 (2,572.9 m)</td></tr>
<tr><th colspan="6">Field Segments</th></tr>
<tr><td colspan="2">Frames</td><td colspan="2">Racking</td><td colspan="2">Tilt</td></tr>
<tr><td colspan="2">149</td><td colspan="2">East-West</td><td colspan="2">28°</td></tr>
</table>

4.3.6 Dalcrue Agricultural Holdings Pvt. Ltd.

Number of Pumps	Power for single Pump (kW)	Pump Total (kW)	Suggested PV (kWp)
Pump size 1 (x1)	280	280	322
Total		280	322

In Dalcrue, the total power requirement to operate the single pump used at the farm is 280 kWh. For the suggested PV system to meet this demand, a capacity of 322 kWh is recommended.

Table 25 – Energy consumption and expected PV output per scenario.

z	Total electricity demand (kWh)	Expected PV output – Scenario 1 (kWh)	Expected PV output – Scenario 2 (kWh)
January	82,372.09	39,047.70	90,987.40
February	Not available	35,334.9	82,286.40
March	84,213.00	35,935.80	83,861.10
April	Not available	29,592.30	69,105.00
May	33,078.00	28,040.70	65,288.20
June	59,823.00	24,918.00	57,935.20
July	37,313.00	26,903.10	62,584.80
August	Not available	30,731.20	71,688.00
September	56,621.00	33,785.00	78,818.00
October	Not available	33,996.40	79,245.00
November	Not available	35,385.00	82,479.50
December	38,563.18	38,598.00	90,040.20
Total	**391,983.27**	**392,268.10**	**914,318.80**

The highest total electricity demand was recorded in March, reaching 84,213 kWh, lowest demand was observed in May, 33,078.00 kWh. In April and August, the farm experiences low or no irrigation, which likely contributes to the absence of electricity demand data for that month. In February, October, and November, although the irrigation process took place, the provided data was unreadable, preventing us from obtaining the corresponding electricity demand information.

Under Scenario 1, the highest PV output is in January, with an expected output of 39,047.70 kWh, while the lowest output is in June, with 24,918 kWh. Under Scenario 2, the highest output occurs in January as well, reaching 90,987 kWh, while the lowest output is in June, at 57,935.20 kWh. Scenario 1 is simulated to fulfil the farm's yearly demand. Under Scenario 1, the total expected PV output for the year Is 392,268.10 kWh. For scenario 2, the highest monthly demand occurs in March, with a total electricity demand of 84,213.00 kWh. The simulated PV output under Scenario 2 for March is 83,861.10 kWh.

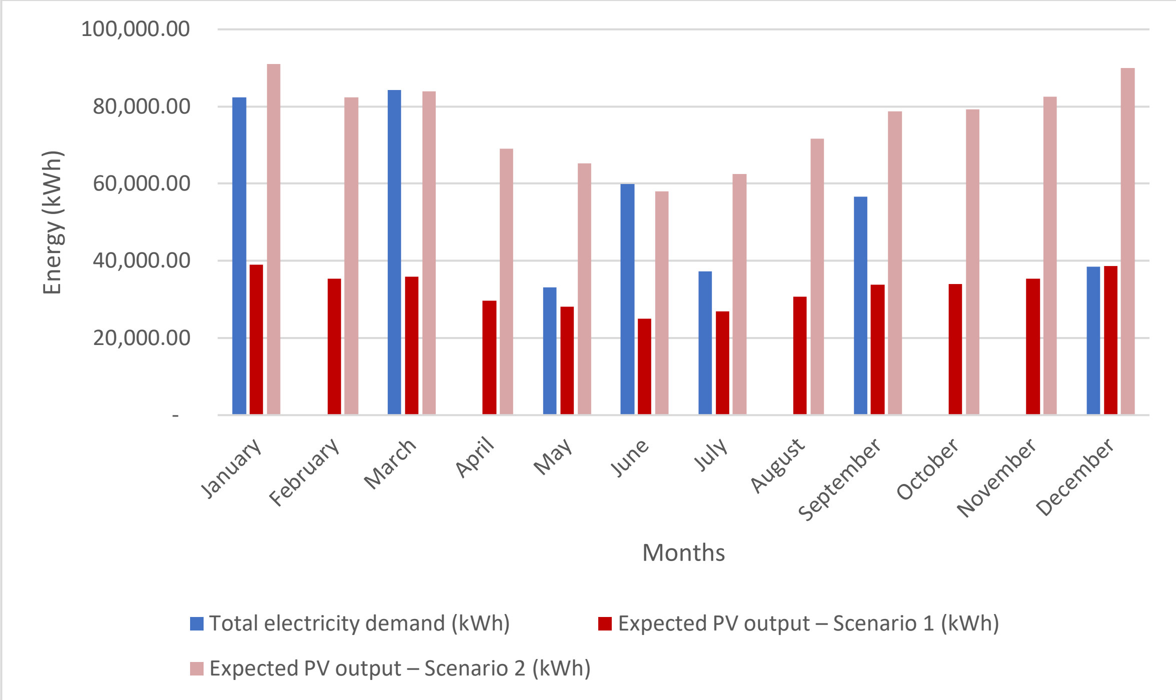


Figure 29 - Comparison of energy demand and PV output across scenarios.

Figure 29 illustrates the monthly comparison between the total electricity demand and the expected PV output for the given period.

4.3.6.1 Technical sizing according to the yearly demand (Scenario 1)

Table 26. Dalcrue Scenario 1 SPIS system specification

System Specification				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
298.8 kW	240.6 kW	392.3 MWh	80.6%	1,353.6
Components (Counts)				
Module	Inverters	Strings		
840	10	50 (1627.9 m)		
Field Segments				
Frames	Racking	Tilt		
105	East-West	28°		

4.3.6.2 Technical sizing according to the highest monthly demand (Scenario 2)

Table 27 -. Dalcrue Scenario 2 SPIS system specification

System Specification				
Module Capacity	Inverter Capacity	Estimated annual energy production	Performance Ratio	kWh/kWp
681.7 kW	553.4 kW	914.3 MWh	79.9%	1,341.2
Components (Counts)				
Module	Inverters	Strings		
1,976	115	23 (4958.8 m)		
Field Segments				
Frames	Racking	Tilt		
247	East-West	28°		

4.3.6.3 Comparison between the existing and recommended system size.

The existing SPIS system installed on 300 ha of land has a capacity of 450 kW. Despite this, it is observed that the annual consumption of electricity by the grower amounts to 391,983.27 kWh. This indicates that the system is adequately sized to fulfil the grower's electricity needs and is even producing an excess amount of electricity to meet the demand.

The helioscope design for scenario 1 suggests a system with a minimum capacity of 298.8 kW would be required to adequately fulfil the grower’s energy requirements. This recommended system size is calculated based on an estimated annual energy production of 392.3 MWh, which exceeds the grower's actual electricity consumption. The difference in sizing between the existing SPIS system and the helioscope design recommendation can be attributed to several factors. One factor is the incomplete data collection, which may have led to an underestimation of the actual electricity demand, resulting in a smaller system size. Additionally, other factors such as budget constraints and efficiency improvements in the helioscope design could contribute to the variance.

4.4 Comparison between farms

4.4.1. Area requirement for PV system

Table 28 – Area requirements and PV sizing estimates for each farm in both scenarios.

Name	Area available for PV (ha)	Area Required (Scenario 1) (ha)	Area Required (Scenario 2) (ha)	Approximate PV size (Scenario 1) (kW)	Approximate PV size (Scenario 2) (kW)
Singeni Investment	2	0.13	0.34	118.00	334.00
Mnyangombili Farmers Ltd	10	0.94	1.26	880.00	1,530.00
Asibebahle Mbabala Ltd.	1	0.122	0.19	96.60	198.70
Lomdashi Investment	10	1.26	1.60	1,510.00	2,950.00
Umbane Pvt. Ltd.	3	0.12	0.35	134.50	411.20
Dalcrue Agricultural Holdings Pvt. Ltd.	2	0.248	0.542	289.8	681.7

Table 28 provides a comparison of six farms regarding the area reported as available to install a PV system; the area required for installing solar panels under both scenarios and the approximate PV size needed for each scenario.

Lomdashi has the largest area requirements and PV sizing in both scenarios. In Scenario 1, Lomdashi requires 1.26 hectares with a PV sizing of 1,510 kW. In Scenario 2, Lomdashi requires 1.6 hectares with a PV sizing of 2,950 kW. Conversely, Asibebahle Mbabala has the smallest area required and PV sizing in both scenarios, needing only 0.122 hectares of land with an approximate PV sizing of 96.6 kW in Scenario 1 and 0.19 hectares with a PV sizing of 198.7 kW.

4.4.2 Potential for feeding-in electricity to the grid.

Table 29 - Potential Feed-into Grid for both scenarios

Grower	Total Annual Energy Demand (kWh)	Scenario 1		Scenario 2	
		Expected PV output (kWh/year)	Potential Feed-into grid (kWh/year)	Expected PV output (kWh/year)	Potential Feed-into grid (kWh/year)
Singeni Investment	165,613.00	167,347.00	1,734.00	474,344.00	308,731.00
Mnyangombili Farmers Ltd.	1,143,000.00	1,212,133.30	69,133.00	2,290,646.30	1,147,646.00
Asibebahle Mbabala Ltd.	144,650.00	146,164.65	1,515.00	274,903.00	130,253.00
Lomdashi Investment	2,340,066.00	2,504,025.00	163,959.00	3,832,245.00	1,492,179.00
Umbane Pvt. Ltd.	181,831.00	189,401.00	7,570.00	552,543.40	370,712.00
Dalcrue Agricultural Holdings Pvt. Ltd.	391,983.27	392,268.10	285.00	914,319.00	522,336.00

The table displays the total annual energy demand, expected PV output, and potential feed-into grid for six growers under Scenario 1 and Scenario 2. In Scenario 1, the highest potential feed-into grid is observed for Lomdashi Investment, with 163,959 kWh, while the lowest is for Dalcrue Agricultural Holdings Pvt. Ltd., with 285 kWh. Under Scenario 2, the largest potential feed-into grid is for Lomdashi

Investment, with 1,492,179.00 kWh. The lowest potential feed-into grid for Scenario 2 is for Asibebahle Mbabala Ltd., with 130,253 kWh.

Given the presence of a net metering system, surplus electricity generated by the farms can be fed back into the grid, allowing the farms to receive credits for the excess electricity supplied. However, without specific feed-in tariffs from the government, the financial implications of this surplus generation cannot be accurately determined.

5. Conclusions

- Detailed assessments of electricity demand, expected PV output, and system sizing criteria reveal that solar power systems can effectively meet or exceed the energy needs of these farms.
- Each farm presents unique characteristics and requirements, such as varying electricity demand and available land area, but the data suggests that solar power systems offer viable solutions for reducing reliance on conventional grid electricity and mitigating operational costs.
- While the highest month of the year may experience peak energy demand, sizing the PV systems based on the yearly energy demand ensures a balanced and reliable energy supply across all seasons.
- Designing the system according to scenario 2, as per the simulation data would require more components compared to scenario 1. This would lead to an increase in investment costs for the grower.
- Oversizing PV systems in some cases provides opportunities for future growth, energy security, and potential revenue generation through surplus electricity production, and accounts for potential implementation of feed-in tariff frameworks in the future.
- Under the current regulation in Eswatini, oversizing a SPIS allows farms to export excess electricity to the grid, but without receiving monetary compensation. Instead, farms are compensated for the power they consume from the grid. Therefore, consideration of the system sizing is crucial to avoid investing in excess capacity with financial benefits.
- Consideration should be given to the minimum allowed system size as per local regulations, ensuring compliance with legal requirements for solar power installations.
- Specific components such as inverters, panels, and wiring should be carefully selected to meet both regulatory standards and the unique needs of each farm, optimizing system efficiency and longevity.
- It is essential to acknowledge that these conclusions are derived from simulation results, implying a degree of uncertainty and the possibility of variations in real-world scenarios. Therefore, while the feasibility analysis provides valuable insights, actual implementation may require further on-site assessments and adjustments to optimize system performance.

Annexes

Annex I - Survey questionnaire

Introduction – "The objective of this questionnaire is to assess the technical and economic feasibility of integrating solar photovoltaics into irrigation systems in Eswatini, aiming to gather insights from farms to establish the potential for broader adoption that is both profitable and beneficial to farmers"
Section A. Introduction
A.1. Date of data collection (*required)*
A.2. Name of the respondent *(required)* Name and surname
A.3.What is your position within the farm?
A.4. Where is the farm located? (required) Street, n°, town Data collector, please record the location of the farm using the Survey CTO data collection app GPS coordinates can only be collected when on site.
A.5. How many workers are employed on the farm? *(required)*
A.6. How many of these workers are women? *(required)*
A.7. What is the annual income of the farm? (SZL/year) (*required)*
A.8. Is the farm solely owned by one individual? (required) 1. Yes 2. No
If A8 is No A.8.1. Is the farm owned by a cooperative/farming community? 1. Yes 2. No
If A8.1 is yes A.8.2. If it's owned by a cooperative or community, could you provide the name of the owner(s)?
If A8.1 is yes A.8.3. How many people collectively own the farm?
If A8.1 is yes A.8.4. If it's a cooperative, how many female members are part of the cooperative?
A.9 Are you the owner of the farm or part of the cooperative/farming community? (required) 1. Yes 2. No
If A9 is no A.9.1 What is the name of the farm owner?
A.10 What is the total land area of the farm? *(in ha) (required)*
A.11. Is the entire farm used for sugarcane cultivation? (required) 1. Yes 2. No
If A.11. is No A.11.1. what is the total area of the farm dedicated to sugarcane cultivation? *(in ha)*
A.12. Could you describe the layout of the farm and the irrigation system used specifically for sugarcane cultivation? Data collector, Ask the representative to provide you with a schematic representation of the farm layout, if they don't have one, ask them to draw one for you and **take a picture of it with your device.**

A.13. Are you/the farming community paying back a loan currently? 1. Yes 2. No
If A.13. is Yes A.13.1 What was the loan for?
If A.13. is Yes A.13.2 What was the initial loan amount? (in SZL)
If A.13. is Yes A.13.3 How many months do you still need to pay back the loan?
A.14. Do you have a SPIS (Solar Powered Irrigation System) already installed? 1. Yes 2. No
B. Assessment of farm and cane growing cultivation practices
B.1 Do you harvest sugarcane more than once a year? *(required)* 1.Yes 2. No
If B.1 is Yes B.1.1. During which month of the year do you collect the second harvest? *Month*
B.2. During which month of the year do you collect the first harvest? *(required)* *Month*
B.3. During which month is sugarcane production the largest? *Month*
B.3.1 How much sugarcane do you produce during that month? *MT*
B.4. During which month is sugarcane production the lowest? *Month*
B.5 What is the yearly sugarcane production at the farm? *(required)* *MT/year*
B.6. How many cultivation plots or subfields are there in the farm? *(required)*
B.6.1. What is the area of the cultivation plots/ subfields? (If there are more than one, please list the sizes of all the agricultural plots and sub-fields) *(required)* *in Ha*
B.7. Are several pumps used for separate plots/subfields? (required) 1. Yes 2. No
B.7.1. For each plot/subfield, what kind of irrigation system is used? (Mention it if various plots employ different irrigation methods.) *(required)* 1. Drip 2. Sprinklers 3. Center pivot 4. Others (please mention) *Data collector, this question needs to be asked according to the number of plots provided by the respondent*
B.7.2 What is the water's flow rate? (Mention it if a different plot employs a different flow rate.) *(required)* m^3/hr. Data collector, this question needs to be asked according to the number of plots provided by the respondent
B.7.3 What is the irrigation system's operating water pressure? (Mention various water pressures for various plots/subfields) *(required)* Pa Data collector, this question needs to be asked according to the number of plots provided by the respondent

B.8. Do the crops receive any fertilizer? (required) 1. Yes 2. No
If B.8 is Yes B.8.1. What type of fertilizer do you use?
If B.8 is Yes B.8.2. How much fertilizer do you use per month? *Kg/Month*
C. Assessment of water resources
C.1. Do you source the water from a single water source? *(required)* 1.Yes 2. No
If C.1. is Yes C.1.1. Where do you source the water for irrigation? 1. Well 2. Dams 3. Lake 4. Canal 5. Others (please mention)
If C.1. is No C.1.2. How many sources of water do you use?
If C.1. is No C.1.3. Select the sources of water used for irrigation *(Multiple Choice)* 1. Well 2. Dams 3. Lake 4. Canal 5. Others (please mention)
If C.1. is No C.1.4. Please mention your primary and secondary source of water.
C.2. What is the Diameter of pipe used for irrigation purposes? *(required)* *cm*
C.3. How far is the water source located from the field? (required) M Data collector, this question needs to be asked according to the number of plots provided by the respondent
C.4. How much water is pumped during a single irrigation cycle? *(required)* *m^3/cycle*
C.5. How many irrigation cycles are completed per week? *(required)* *cycle/week*
C.6. How long does the irrigation process run per cycle? *(required)* hrs./cycle
C.7. Do you have a water storage tank installed? (required) 1. Yes 2. No
If C.7. is yes C.7.1 What size is the storage tank? *liters*
If C.7. is yes C.7.2 What is the Diameter of the pipe used? *cm*
If C.7. is yes C.7.3 What is the Distance between the storage tank and the plot/field? *m* Data collector, this question needs to be asked according to the number of plots provided by the respondent

If C7. is yes

C.7.4. What is the distance between the water Source and Storage Tank?

m

Data collector, this question needs to be asked according to the number of plots provided by the respondent

C.8. Do you have access to Groundwater? (required)

1. Yes 2. No

If C.8. is yes

C.8.1. How deep is the available groundwater?

m

Section D: Assessment of electricity demand

D.1. How many pumps are used in total for the irrigation system? *(required)*

D.1.1. What kind of pump is currently being used in the irrigation system?? *(required)*

1. Positive displacement pump 2. Centrifugal Pump

Data collector, this question needs to be asked according to the number of plots provided by the respondent

D.1.2. What is the rated power of the pump? *(required)*

KW

Data collector, this question needs to be asked according to the number of plots provided by the respondent

D.1.3. What is the pump's nominal pressure? *(required)*

pa

Data collector, this question needs to be asked according to the number of plots provided by the respondent

D.1.4. What is the water pump's nominal flow rate?

m^3/s

Data collector, this question needs to be asked according to the number of plots provided by the respondent

D.2. In which month is the demand for the irrigation system the highest? *(required)*

Month

D.3. In the month with the highest irrigation demand, how many hours per day are the pumps used? *(required)*

Hrs.

D.4. In which month is the demand for the irrigation system the lowest? *(required)*

Month

D.5. Are the pumps operating at a specific time frame? (required)

1. Yes 2. No

If D.5 is yes

D.5.1. During which time frame are the pumps operating?

1. Morning 2. Afternoon 3. Evening

4. The entire day

D.6. How much total power is necessary to operate the current irrigation system? *(required)*

kWh/month

D.7. How much do you pay for power each month? *(required)*

SWZ

D.8. Have you experienced any power outages? (required)

1. Yes 2. No

If D.8. is yes

D.8.1 How many hours does a power outage typically last? *(required)*

If D.8. is yes D.8.2 How many times per month do you experience power outages? *(required)*
Section E. Land Availability for installation of PV Generators
E1. What is the size of the area available for installing solar systems? *(required)* *ha*
E2. Is there shading in the indicated area? (required) 1. Yes 2. No
If E2 is yes E2.1 What is the size of the area excluding the shading region? *(required)* *ha*
E.3. How far will the cultivation area(s) be from the specified area? *(required)* *(m)* Data collector, this question needs to be asked according to the number of plots provided by the respondent
E.4.What is the layout of the land for installing PV systems? (required) Data collector, **please take a picture with your device** of the plot of land where the PV system can be installed
Section F. Impact assessment
If A.13 is Yes The following set of questions will be asked only in the farm where the solar irrigation system has already been installed and the purpose of these questions is to evaluate the experience of the farm with the SPIS
F.1. What is the SPIS's power generation capacity? *(required)* *kWp*
F.2. Does your SPIS have a battery installed? 1.Yes 2. No
If F.2. is yes F.2.1 What is the size of the battery system? *(required)* *kWh*
F.2.2 Did the supplier inform you of the replacement period of the battery? 1. Yes 2. No
If F2.2 is yes F.2.3 What is the time period for replacing the battery? years
If F2.2 is yes F.2.4 Who will collect the battery that is no longer in the working condition?
F.3. What is the date of installation of the system? *(required)*
F.4. Does the power generated by SPIS meet your electricity needs? *(required)* 1. Yes 2. No
F.5. How much power is generated by the system? *kWh/day*
F.6. How was the system funded? *(required)* 1. Grant 2. Financial Institution 3. Own funds 4. Others (please specify)
If F.6. is 2

F.6.1. Who financed your loan? *(required)*
If F.6. is 2 F.6.2. How much did you pay upfront as an initial payment? *(required)*
If F.6. is 2 F.6.3. How much do you pay on a monthly basis for your loan? *(required)*
If F.6. is 2 F.6.4. What is the total duration of your loan? *(required)*
If F.6. is 2 F.6.5. What is the interest rate on your loan? *(required)*
F.7. What was the cost of the entire system? *(required)* *SWZ*
F.8.Were you trained to use the system? (required) 1. Yes 2. No
If F8 is yes F.8.1. Which institution/authority trained you to use the system? *(required)*
If F8 is yes F.8.2. How many hours did the training take? *(required)* *h*
F.9. Are the maintenance and operation costs of the system within budget? *(required)* 1. Yes 2. No
F.10. What is the maintenance cost of the system? *(required)* *SWZ/Month*
F.11. How much area of land is being irrigated using SPIS? *(required)* *ha*
F.12. What is the distance between Solar panels and the Cultivation field? *(required)* *m* Data collector, this question needs to be asked according to the number of plots provided by the respondent
F.13. What is the distance between solar panels and the water sources? *(required)* *m* Data collector, this question needs to be asked according to the number of plots provided by the respondent
F.14. Do you still use electricity from the grid? (required) 1. Yes 2. No
F.15. Would you recommend the solar system to other farmers? (required) 1. Yes 2. No
F.16. Have you experienced any problems with the SPIS (required) 1. Yes 2. No
If F16 is yes F.16.1 Please specify the issue/problem you faced
F.17. Did the system servicing provider offer a system warranty? (required) 1. Yes 2. No
If F17 is yes F.17.1 What is the Time period of the warranty? *(required)* *months*

F.17.2. Please provide the name and contact information for your system service provider? *(required)* *Email and Phone. No*
F.18. Did the supplier inform you of the lifetime of the system components? 1. Yes 2. No
If F18 is yes F.18.1 What is the expected lifetime of the system? *(required)* years
F.19. Will the supplier collect the equipment at the end of its productive life? 1. Yes 2. No
F.20 Where you informed of any alternatives to dispose of the SPIS components? 1. Yes 2. No
If F20 is yes F.20.1 What were the method of disposal?
Thank you for responding to this survey.

Annex II - Technical sizing outputs

According to the Annual Demand

1. Singeni

HelioScope — Annual Production Report produced by Shrirang Garje

Annual demand Singeni Farm, -25.9999434, 31.6094573

Report

Project Name	Singeni Farm
Project Address	-25.9999434, 31.6094573
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	Annual demand
Module DC Nameplate	118.0 kW
Inverter AC Nameplate	96.2 kW Load Ratio: 1.23
Annual Production	167.0 MWh
Performance Ratio	80.1%
kWh/kWp	1,415.0
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	[illegible]

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	4 (96.2 kW)
Strings	10 AWG (Copper)	38 (1,068.0 m)
Module	Canadian Solar, CS6U 345M (345W)	342 (118.0 kW)

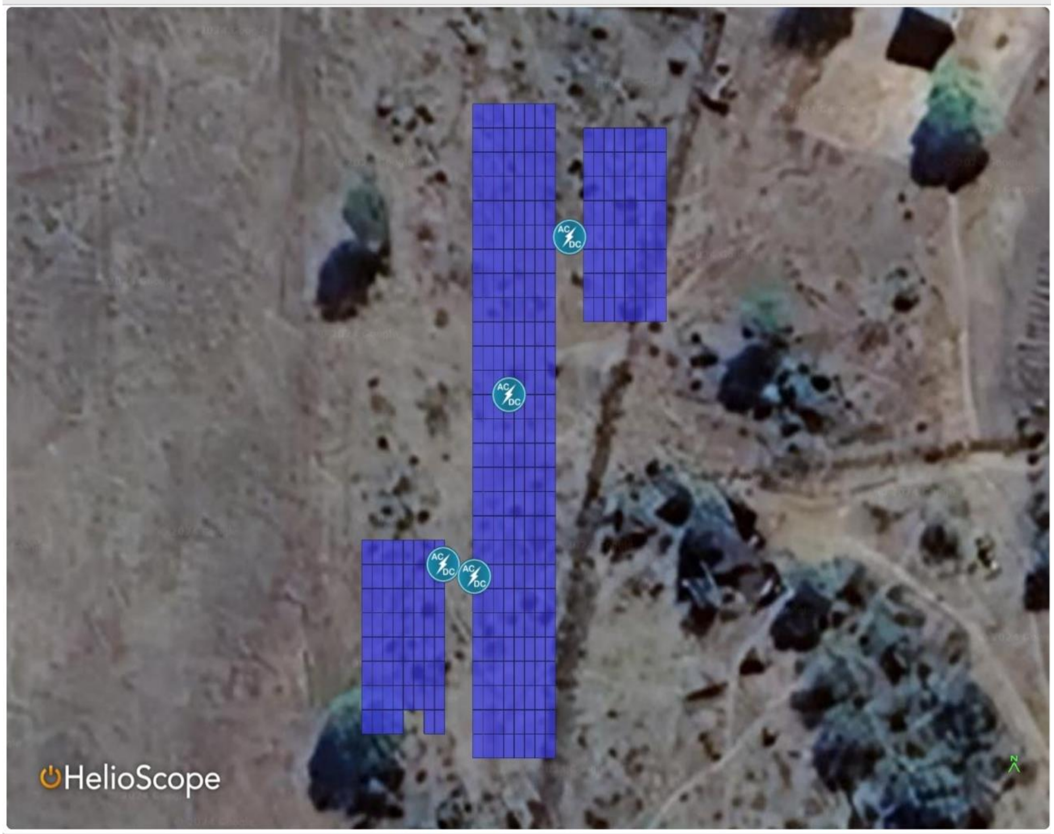
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	9-9	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	2.4 m	4x1	43	342	118.0 kW

Detailed Layout



2. Mnyangombili Farmers Limited

HelioScope Annual Production Report produced by Shrirang Garje

According to Annual demand Mnyangombili Farmers Limited, -26.0120673 31.9079845

Report

Project Name	Mnyangombili Farmers Limited
Project Address	-26.0120673 31.9079845
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	According to Annual demand
Module DC Nameplate	880.4 kW
Inverter AC Nameplate	721.8 kW Load Ratio: 1.22
Annual Production	1.212 GWh
Performance Ratio	77.8%
kWh/kWp	1,376.7
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	ca5f553451-8eeb45b495-9e424b3c9d-808ca3f286

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	30 (721.8 kW)
Strings	10 AWG (Copper)	150 (10,480.0 m)
Module	Canadian Solar, CS6U 345M (345W)	2,552 (880.4 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	0.0 m	4x1	319	2,552	880.4 kW

Detailed Layout

3. Asibebahle Mbabala

HelioScope — Annual Production Report produced by Shrirang Garje

Annual Scenario Asibebahle Mbabala, -26.8509153, 31.7384192

Report

Project Name	Asibebahle Mbabala
Project Address	-26.8509153, 31.7384192
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	Annual Scenario
Module DC Nameplate	104.9 kW
Inverter AC Nameplate	96.2 kW Load Ratio: 1.09
Annual Production	145.7 MWh
Performance Ratio	80.0%
kWh/kWp	1,389.3
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	d0c16790f1-dac7c3e857-2c3158a897-425e0017ce

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	4 (96.2 kW)
Strings	10 AWG (Copper)	16 (373.4 m)
Module	Canadian Solar, CS6U 345M (345W)	304 (104.9 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	1.5 m	4x1	38	304	104.9 kW

Detailed Layout

4. Lomdashi

HelioScope — Annual Production Report produced by Shrirang Garje

Annual Scenario Lomdashi, -26.8124727 31.7684469

Report

Project Name	Lomdashi
Project Address	-26.8124727 31.7684469
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	Annual Scenario
Module DC Nameplate	1.82 MW
Inverter AC Nameplate	1.47 MW Load Ratio: 1.24
Annual Production	2.504 GWh
Performance Ratio	78.9%
kWh/kWp	1,372.5
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	d0c16790f1-dac7c3e857-2c3158aa97-425e0017ce

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	61 (1.47 MW)
Strings	10 AWG (Copper)	306 (14,892.0 m)
Module	Canadian Solar, CS6U 345W (345W)	5,288 (1.82 MW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	20°	0°	1.5 m	4x1	661	5,288	1.82 MW

Detailed Layout

5. Umbane

HelioScope Annual Production Report produced by Shrirang Garje

Annual Scenario Umbane, -26.5157664 31.1711472

Report

Project Name	Umbane
Project Address	-26.5157664 31.1711472
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	Annual Scenario
Module DC Nameplate	143.5 kW
Inverter AC Nameplate	120.3 kW Load Ratio: 1.19
Annual Production	189.4 MWh
Performance Ratio	78.6%
kWh/kWp	1,319.7
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	ca3f533451-8eeb45b493-9e424b3c9d-808ca3f286

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	5 (120.3 kW)
Strings	10 AWG (Copper)	25 (853.3 m)
Module	Canadian Solar, CS6U 345W (345W)	416 (143.5 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	1.0 m	4x1	52	416	143.5 kW

Detailed Layout

6. Dalcrue

HelioScope — Annual Production Report produced by Shrirang Garje

Annual Scenario Dalcrue, -26.5263119, 31.2222721

Report

Project Name	Dalcrue
Project Address	-26.5263119, 31.2222721
Prepared By	Saraswati Huggi saraswathihuggi18@gmail.com

System Metrics

Design	Annual Scenario
Module DC Nameplate	289.8 kW
Inverter AC Nameplate	240.6 kW Load Ratio: 1.20
Annual Production	392.3 MWh
Performance Ratio	80.6%
kWh/kWp	1,353.6
Weather Dataset	TMY, 10km Grid, Meteonorm 7 (meteonorm)
Simulator Version	4b98f34a9d-780c506817-5efa0f6ca5-6ac8134b53

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	10 (240.6 kW)
Strings	10 AWG (Copper)	50 (5,340.9 ft)
Module	Canadian Solar, CS6U-345M (345W)	840 (289.8 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	8.0 ft	4x1	105	840	289.8 kW

Detailed Layout

According to the Monthly scenarios

1. **Singeni Farm**

HelioScope

Annual Production Report produced by Shrirang Garje

According to monthly demand Singeni Farm, -25.9999434, 31.6094573

Report

Project Name	Singeni Farm
Project Address	-25.9999434, 31.6094573
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	According to monthly demand
Module DC Nameplate	334.0 kW
Inverter AC Nameplate	288.7 kW Load Ratio: 1.16
Annual Production	474.3 MWh
Performance Ratio	80.4%
kWh/kWp	1,4[illegible]
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	ca5f553431-8eeb45b495-9e424b3c9d-8c8ca3f286

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL US (SMA)	12 (288.7 kW)
Strings	10 AWG (Copper)	60 (2,746.5 m)
Module	Canadian Solar, CS6U 345M (345W)	958 (334.0 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	25°	0°	2.4 m	4x1	121	958	334.0 kW

Detailed Layout

2. Mnyangombili Farmers Limited

HelioScope

Annual Production Report produced by Shrirang Garje

According to monthly demand Mnyangombili Farmers Limited, -26.0120673 31.9079845

Report

Project Name	Mnyangombili Farmers Limited
Project Address	-26.0120673 31.9079845
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	According to monthly demand
Module DC Nameplate	1.53 MW
Inverter AC Nameplate	1.15 MW Load Ratio: 1.32
Annual Production	2.291 GWh
Performance Ratio	81.5%
kWh/kWp	1,500.8
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	d10fb4e340-bbae3cc8c0-71cb177a1a-a36c51459 2

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	48 (1.15 MW)
Strings	10 AWG (Copper)	240 (12,582.1 m)
Module	Canadian Solar, CS6U 345W (345W)	4,424 (1.53 MW)

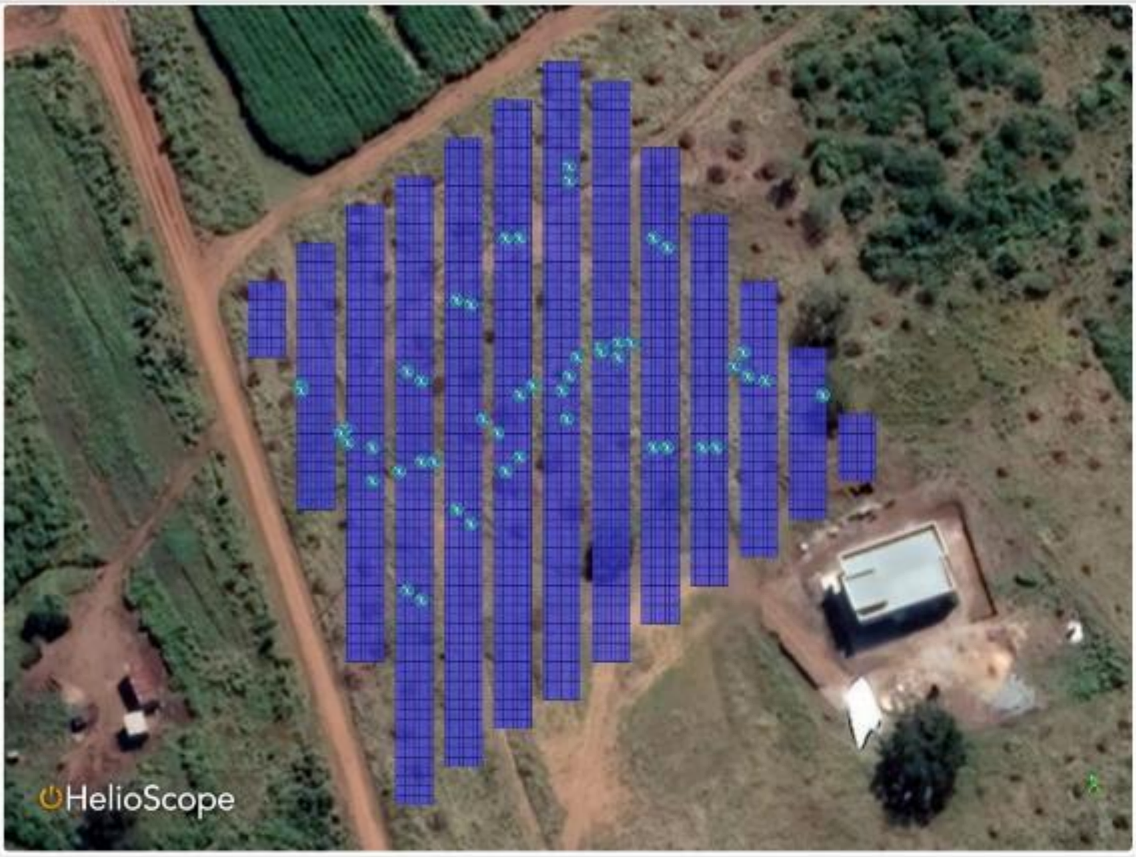
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	15°	0°	2.4 m	4x1	553	4,424	1.53 MW

Detailed Layout



3. Asibebahle Mbabala

HelioScope Annual Production Report produced by Shrirang Garje

According to monthly demand Asibebahle Mbabala, -26.8509153, 31.7384192

Report

Project Name	Asibebahle Mbabala
Project Address	-26.8509153, 31.7384192
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	According to monthly demand
Module DC Nameplate	198.7 kW
Inverter AC Nameplate	168.4 kW Load Ratio: 1.18
Annual Production	274.9 MWh
Performance Ratio	75.7%
kWh/kWp	1,38[illegible]
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	ca5f553431-8eeb45b495-9e424b3c9d-8c8ca3286

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	7 (168.4 kW)
Strings	10 AWG (Copper)	35 (1,280.9 m)
Module	Canadian Solar, CS6U-345M (345W)	576 (198.7 kW)

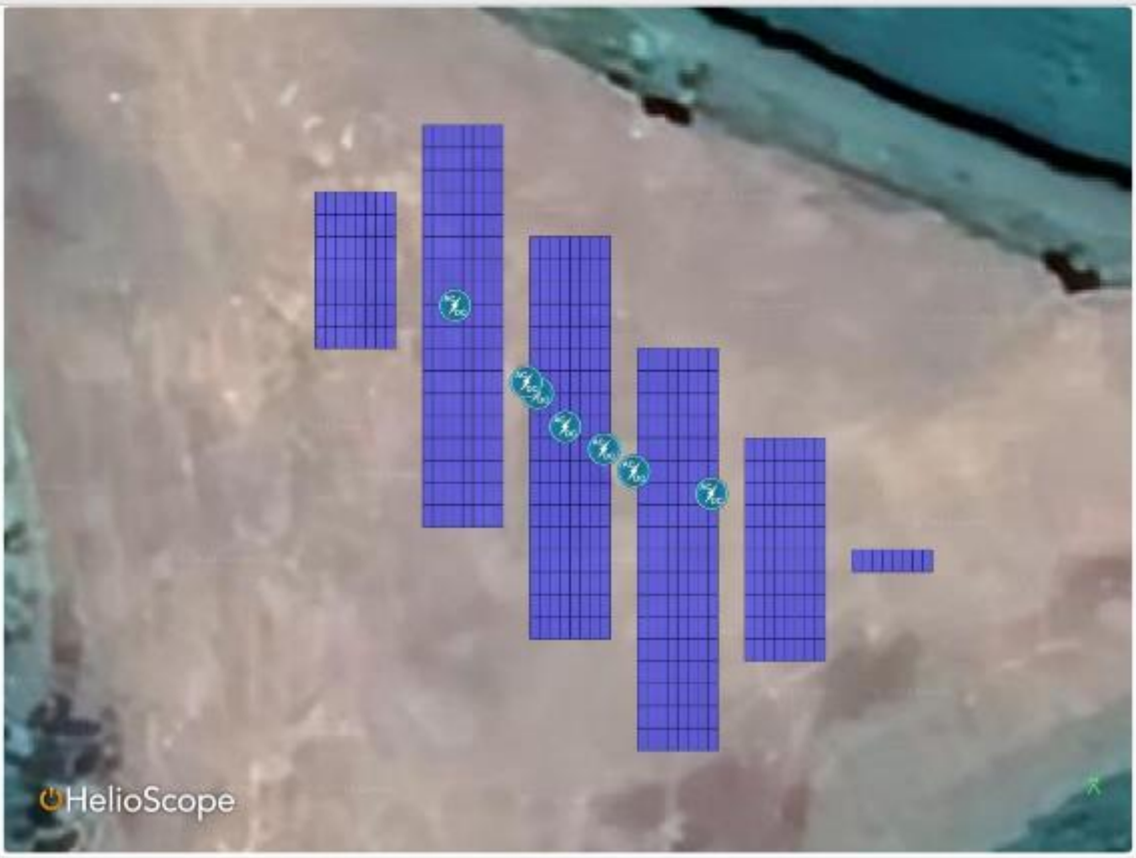
Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	2.4 m	4x1	72	576	198.7 kW

Detailed Layout



4. Lomdashi

HelioScope Annual Production Report produced by Shrirang Garje

According to monthly demand Lomdashi, -26.8124727 31.7684469

Report

Project Name	Lomdashi
Project Address	-26.8124727 31.7684469
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	According to monthly demand
Module DC Nameplate	2.85 MW
Inverter AC Nameplate	2.29 MW Load Ratio: 1.25
Annual Production	3.832 GWh
Performance Ratio	77.3%
kWh/kWp	1,344.1
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	d0c16790f1-dac7c3e897-2c3158a297-429e0017ce

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL US (SMA)	95 (2.29 MW)
Strings	10 AWG (Copper)	475 (21,594.5 m)
Module	Canadian Solar, CS6U 345M (345W)	8,254 (2.85 MW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	0.0 m	4x1	1,033	8,254	2.85 MW

Detailed Layout

5. Umbane

HelioScope Annual Production Report produced by Shrirang Garje

According to monthly demand Umbane, -26.5157664 31.1711472

Report

Project Name	Umbane
Project Address	-26.5157664 31.1711472
Prepared By	Shrirang Garje shrirang.garje.me@gmail.com

System Metrics

Design	According to monthly demand
Module DC Nameplate	411.2 kW
Inverter AC Nameplate	336.8 kW Load Ratio: 1.22
Annual Production	552.5 MWh
Performance Ratio	80.1%
kWh/kWp	1,343.6
Weather Dataset	TMY, 10km Grid, meteonorm (meteonorm)
Simulator Version	ca3f553431-8edb45b495-9e424b3c9d-808ca3f286

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL US (SMA)	14 (336.8 kW)
Strings	10 AWG (Copper)	70 (2,572.9 m)
Module	Canadian Solar, CS6U-345M (345W)	1,192 (411.2 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	0°	2.4 m	4x1	149	1,192	411.2 kW

Detailed Layout

6. Dalcrue

HelioScope Annual Production Report produced by Shrirang Garje

Monthly Scenario Dalcrue, -26.5263119, 31.2222721

Report

Project Name	Dalcrue
Project Address	-26.5263119, 31.2222721
Prepared By	Saraswati Hugg saraswatihugg18@gmail.com

System Metrics

Design	Monthly Scenario
Module DC Nameplate	581.7 kW
Inverter AC Nameplate	553.4 kW Load Ratio: 1.23
Annual Production	914.3 MWh
Performance Ratio	79.9%
kWh/kWp	1,[illegible]
Weather Dataset	TMY, 10km Grid, Meteonorm 7 (meteonorm)
Simulator Version	4b98f34a8d-78c0606817-5efef89ca5-5ac813db53

Project Location

Components

Component	Name	Count
Inverters	Sunny Tripower 24000TL-US (SMA)	23 (553.4 kW)
Strings	10 AWG (Copper)	115 (16,269.2 ft)
Module	Canadian Solar, CS6U 345M (345W)	1,976 (581.7 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	4-19	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	East-West	Landscape (Horizontal)	28°	9°	8.0 ft	4x1	247	1,976	581.7 kW

Detailed Layout