CODEB Energies

PRE-FEASIBILITY STUDY FOR A 5MW SOLAR PV PROJECT

MWAMISHALI VILLAGE, MEATU DISTRICT TANZANIA

JUNE 2023

ABBREVIATIONS AND ACRONYMS

°C - Degrees Centigrade
A - Amp
AC - Alternating Current
AEDP - Alternative Energy Development Plan
AFD - Agence Francaice de Development
a-Si - Amorphous Silicon
BAPV - Building Applied Photovoltaic
BIPV - Building Integrated Photovoltaic
BOO - Build-Own-Operate
BOS - Balance of System
BoP - Balance of Plant
c-Si - Crystalline Silicon
CB - Circuit Breaker
CER - Certified Emission Reduction
CIGS/CIS - Copper Indium (Gallium)
Di-Selenide CIS - Copper Indium Selenide
CSC - Cost Settlement Center
CSP - Concentrated Solar Power
DC - Direct Current
DNI - Direct Normal Irradiation
DSCR - Debt Service Coverage Ratio
DSP - Digital Signal Processing
EHS - Environmental, Health and Safety
EIA - Environmental Impact Assessment
EnDEV - Energizing Development Program
EMI - Electromagnetic Interference
EPC - Engineering, Procurement and Construction
EWURA - Energy and Water Utilities Regulatory Authority
FAC - Final Acceptance Certificate
FiT - Feed-in Tariff
GCR - Ground Cover Ratio
GHG - Greenhouse gas
GHI - Global Horizontal Irradiation
GOP - Government of Tanzania
GSM - Global System for Mobile Communications
GOP - Government of Tanzania
GTI - Global Tilted Irradiation
HV - High Voltage
IFC - International Finance Corporation
IGBT - Insulated Gate Bipolar Transistor
IPs - Indigenous Peoples
IPP - Independent Power Producer
IRR -Internal Rate of Return
ISC - Short-Circuit Current
KWh - Kilowatt Hour
LCOE - Levelised Cost of Electricity
LD - Liquidated Damages
LPS - Lightning Protection System
LV - Low Voltage
MCB - Miniature Circuit Breakers
MPP - Maximum Power Point
MPPT - Maximum Power Point Tracking
MTTF - Mean Time to Failure
MV - Medium Voltage
MVA - Mega-volt ampere
MW - Megawatt
MWp - Megawatt Peak
NAPCC - National Action Plan on Climate Change
NPV - Net Present Value
OEM - Original Equipment Manufacturer
O&M - Operations and Maintenance
PR - Performance Ratio PV Photovoltaic
REA - Rural Energy Agency
REC - Renewable Energy Certificate
REC - Renewable Energy Credit
ROI - Return on Investment
SERC - State Electricity Regulatory Commission
SPP - Small Power Producers
SPV - Special Purpose Vehicle
STC - Standard Test Conditions
TANESCO - Tanzania Electric Supply Company
TAREA - Tanzania Renewable Energy Association
TZS - Tanzania Shilling
TCO - Total Cost of Ownership
THD - Total Harmonic Distortion
TMA - Tanzania Meteorological Agency

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I. Introduction

This pre-feasibility report provides the background of the Meatu District Solar Photovoltaic Energy Power Project that is planned to be established on land obtained in the Meatu District in the Republic of Tanzania. Tanzania’s per capita electricity consumption is very low, 104.79 kWh per year less than half of the consumption of low-income countries. That said, consumption is increasing rapidly owing mainly to accelerating productive investments and a growing population.

The PSMP (2010-35) anticipates that Tanzania’s electrification status will rise to at least 75% by 2035, whilst demand from connected customers will increase significantly as Tanzania reaches middle-income status, as stipulated in the Tanzania National Development Vision 2025. TANESCO anticipates major demand increases from several mining operations, liquefied natural gas (LNG) plants, factories and water-supply schemes. Peak demand capacity is projected to increase rapidly, from about 2300 in 2019 to about 4700 MW by 2025 and 7400 MW by 2035. Production is projected to increase ten-fold, from 4175 GWh in 2010 to 47723 GWh in 2035.

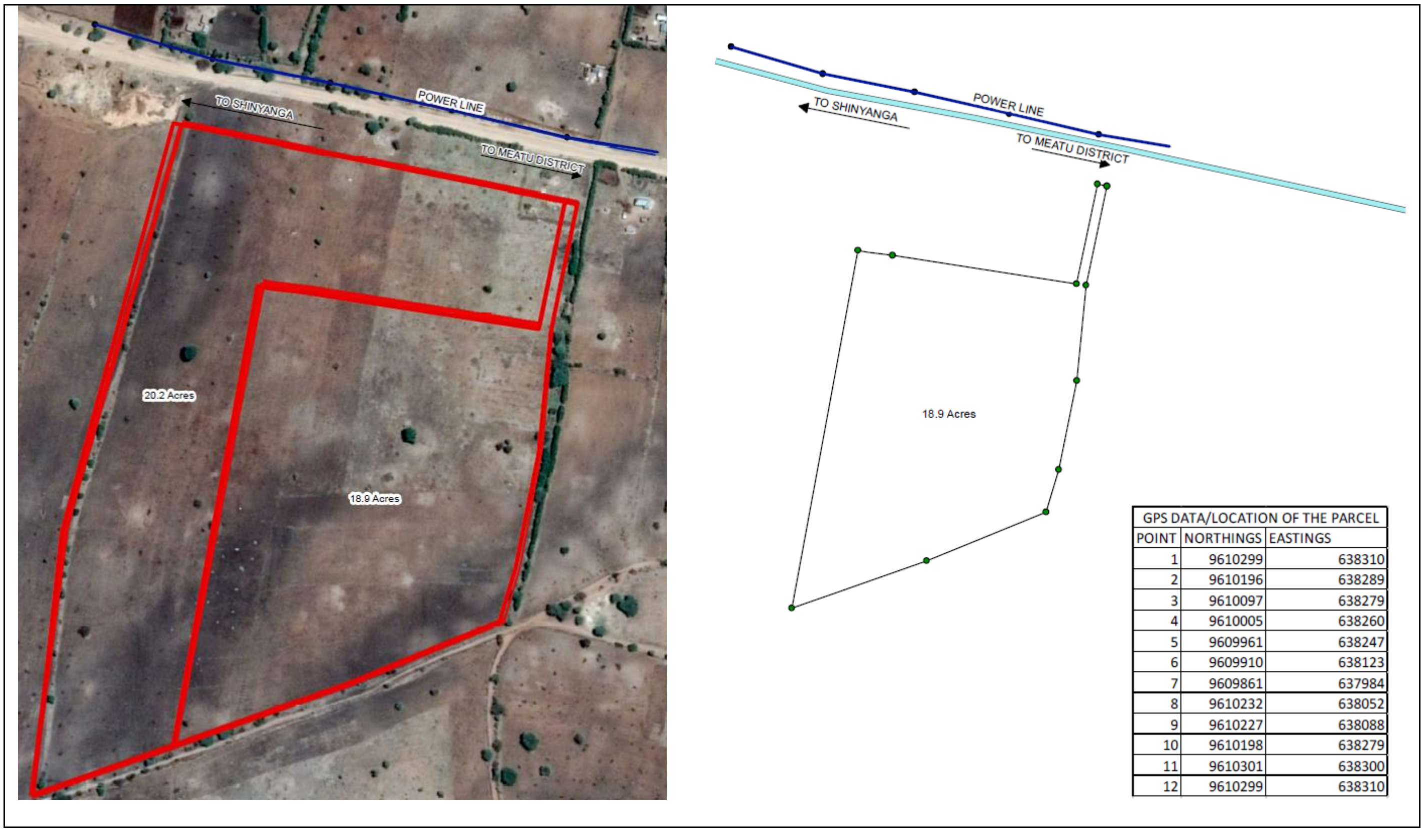
TANESCO is the Tanzania’s largest supplier of energy, delivering electricity to more than 136,000 customers in Tanzania. TANESCO is working with the Meatu government to address electricity shortage through incentives for IPP’s to BOT of comprehensive green energy, including a plan to reduce Tanzania greenhouse emissions by 2050.

II. Methodology Overview

CODEB Energies’ study methodology has been developed to integrate into the process of concept and design development, the management of safety, risk, operations, maintenance, stakeholder interfaces and budgets. CODEB Energies’ approach to the study will be to focus on achieving a practical, cost effective and low risk outcome, to meet the TANESCO scope of work and budget and to assist TANESCO in managing stakeholder expectations. CODEB Energies has reviewed different PV technologies and decided to install Monocrystalline.

III. Project Site Location

The proposed site is located at Mwamishali Village, Meatu District in Tanzania. The site is relatively flat with no obvious shading from building or the surrounding topography. The location obtained has 18.9 Acres of land and available for the PV plant.



GPS DATA/LOCATION OF THE PARCEL		
POINT	NORTHINGS	EASTINGS
1	9610299	638310
2	9610196	638289
3	9610097	638279
4	9610005	638260
5	9609961	638247
6	9609910	638123
7	9609861	637984
8	9610232	638052
9	9610227	638088
10	9610198	638279
11	9610301	638300
12	9610299	638310

IV. Capacity

CODEB Energies proposes to install a Solar PV power plant with a capacity of 5MW. The current power requirement in Simiyu region including the proposed area is around 14.5MW and it is getting power from Ibadakuli/Mabuki grid substation via 33kv Maswa or Kishapu feeder line. The voltage profile along the line at the receiving end drops around 29.6kV which is below the nominal standard voltage.

V. Strategic Area

The proposed 5MW solar PV power is located in a strategic area and will improve voltage and reduce system losses. This strategy forms part of the window of opportunity created by GoT and TANESCO for SPP for the determination of strategic areas as follows:

TANESCO policy that is applicable to Meatu, “Determination of strategic areas”

1. An area shall be deemed to be of strategic nature if it offers technical benefits to a Distribution Network Operator.
2. For an area to be of “technical benefits” an SPP developer shall be able to demonstrate that:
   a. the proposed project will improve the voltage profile towards the standard nominal voltage or to bring it within the standard tolerance levels of +/- 10% of the standard nominal voltage; or
   b. the proposed project will reduce Distribution Network Operator’s system losses by at least 10% of the existing losses.

VI. PV Technologies

A. Monocrystalline silicon

These cells are made from a cylindrical silicon ingot grown from a single crystal of silicon of high purity in the same way as a semiconductor. Sliced from single-crystal boules of grown silicon, these wafers/cells are now cut as thin as 200 microns of all panel types, monocrystalline solar panels typically have the highest efficiencies and power capacity. Research cells have reached nearly 28 percent efficiency; with commercial modules of single-crystal cells exceeding 20 percent.

Monocrystalline Panels Specifications:

- Dimensions: 1640* 992* 35 mm
- Power (Pmax): 300 W Mono module
- Working Voltage (Vmp): 30.5V
- Working Current (Imp): 9 A
- Weight: 18.5 kg

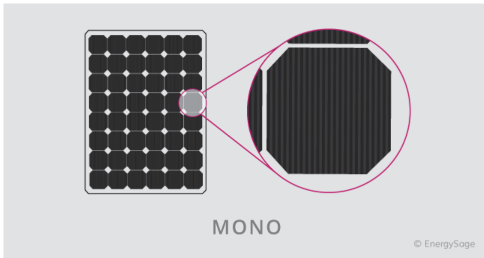


Figure 1: Monocrystalline PV Solar Panels

This is the most efficient technology to date. The PV is made from single crystals of silicon. This type of PV is the most expensive. Sliced from single-crystal boules of grown silicon, these wafers/cells are now cut as thin as 200 microns. Research cells have reached nearly 28 percent efficiency; with commercial modules of single-crystal cells exceeding 18 percent.

B. Level of maturity

PV is a relatively mature technology with many years of operating experience. Current technology has proved to be reliable and systems, particularly grid-connected systems, are generally low in maintenance. We have chosen PV for this project that comply with the standard IEC 61215 "Crystalline silicon terrestrial PV modules – Design qualification and type approval.

C. Technology analysis

For this study the following products were used in the project analysis Monocrystalline 300wp. The ground mounting will require a flat level surface and will be set into concrete. The panels will require an area that is unshaded from the sun. Any vegetation underneath the panels will need to be kept to a level below that of the panels in order to avoid shading. All the panels will be at least 1.5m from the ground. It is assumed that this is adequate to keep the panels above the flood height of the site. The panels will be mounted in rows and electrically connected with cables. The cables will need to be made safe and tamper proof.

When selecting a mount, various options were considered, taking into account dynamic tracking of the sun throughout the daylight hours. It was found that the optimal solution for flat plot with stable soil is 4 rows system, for plots with complicated relief and unstable or weak soil is 2 rows or single rows systems on one pile. These structures are optimally priced for the material consumption per unit modules and savings in bearing piles, have many positive aspects of the series, also increased distance between the tables which in turn makes it possible to use the standard mechanical engineering. With increasing design series will have adverse effect on the speed of installation and maintenance during operation as well as the height of the construction will reach critical levels. This is essentially the same design parameter as the plant with fixed panels except the panel's track the sun.

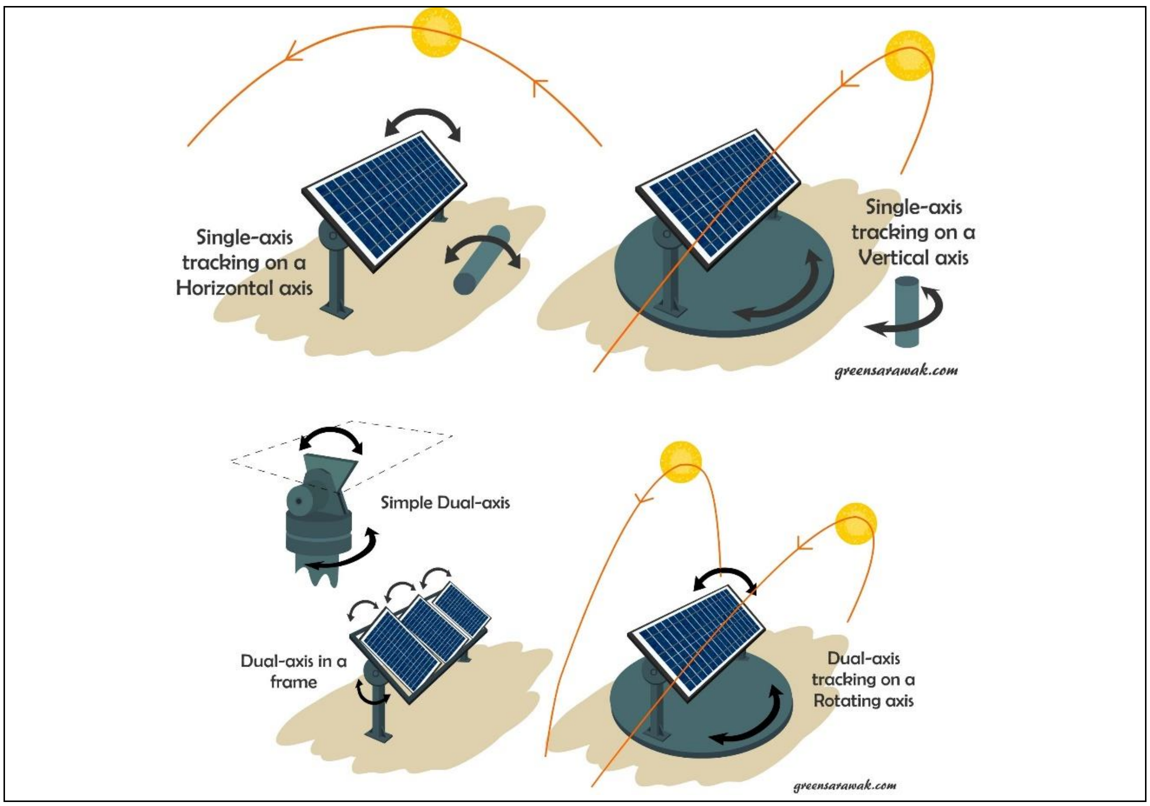


Figure 2: Single & Dual Axis Solar Trackers

The panels rotate automatically on the east-west axis in order to receive more solar radiation. The panels have a fixed tilt in the north-south axis. The CPV system is on a duel axis tracking system, which almost doubles the cost.

D. Inverters

These are required to convert the DC electricity to alternating current (AC) for connection to the utility grid. Many modules in series strings and parallel strings are connected to the inverters.

E. Module mounting (or tracking) systems

These allow PV modules to be securely attached to the ground at a fixed tilt angle, or on sun-tracking frames.

F. Step-up transformers

The output from the inverters generally requires a further step-up in voltage to reach the AC grid voltage level. The step-up transformer takes the output from the inverters to the required grid voltage (for example 25kV, 33kV, 38kV, or 110kV, depending on the grid connection point and country standards).

G. Panels, Inverters, Cables and conduits, MV cables, Solar Cables, DC cables, Data cables Specifications

VII. The Grid

Solar Panels - Mono	• Power (Pmax): 300 W Mono module • Dimensions: 1640* 992* 35 mm • Working Voltage (Vmp): 30.5V • Working Current (Imp): 9 A • Weight: 18.5 kg
PV Grid Inverter	• String PV Inverter • Efficiency: > 98% • Waterproof and Dustproof grade: IP65 • 400V 3L/N/PE or 3L/PE • Working Temp: -30oC – 60oC • LCD or Wifi+APP • 1065*567*344.

DC Cable	• 4 mm2 – Area (mm2): • 1*4mm (Red & Black) • PV 1-F- 1x4 • TUV/UL Certificates
AC Cables	• 3x 35 mm2 – Outdoor Protection Power Cable • Area(mm2) 3*35 mm2 + 1*16mm2
AC Cables	• 3x150 mm2 – Outdoor Protection Power Cables • Area (mm2): 3*150 mm2 +1*70 mm2

Figure 5: Specifications on PV Equipment

VIII. Connection Interface

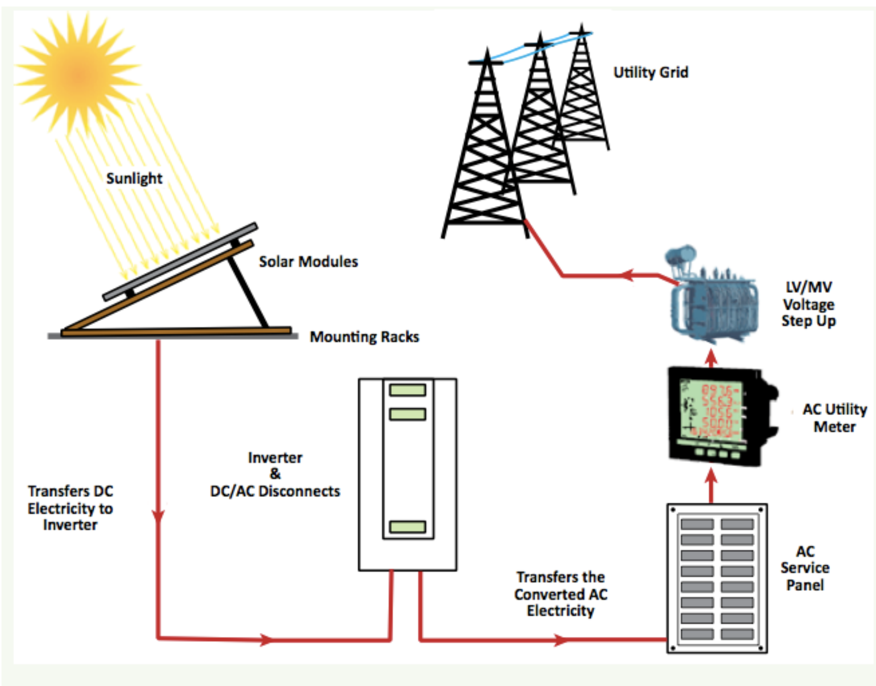


Figure 6: Illustration of typical Grid connection Interface

This is where the electricity is exported into the grid network. The substation will also have the required grid interface switchgear such as circuit breakers (CBs) and disconnects for protection and isolation of the PV power plant, as well as metering equipment. The substation and metering point are often external to the PV power plant boundary and are typically located on the network operator's property.

IX. Energy Demand and Current Cost of Energy

As of March 2020, the price of electricity is USD $ 0.10 per kWh for households and USD $0.102 for businesses which includes all components of electricity bill such as cost of power, distribution and taxes. Currently Tanzania's 2020 total power installed capacity is 1,602 MW of which 244 MW were added in past four years. Tanzania's electricity generation comes mostly from natural gas (48%), followed by hydropower (31%), HFO/Diesel (18%), solar (1%) and biofuels (1%). The number of customers connected to the main source of power also reached over 2,766 million, up from 1,473 million, or an increase of 1,293 million new connections. Power generation had also increased to 1,601.84 MW from only 1,308 MW in 2015.

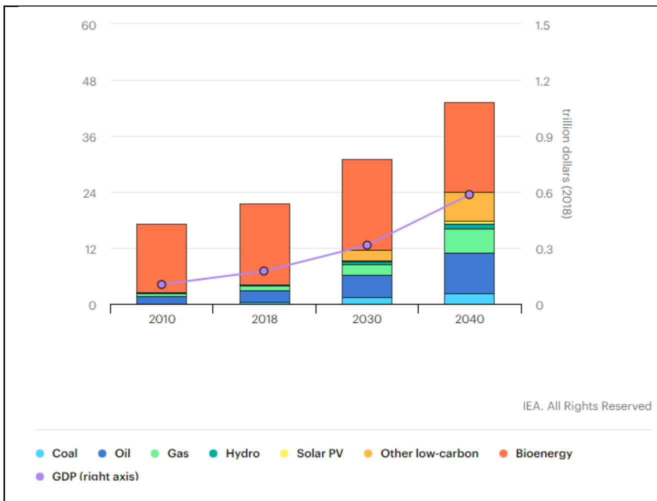


Figure 7: Tanzania primary energy demand and GDP in the Stated Policies Scenario, 2010-2040

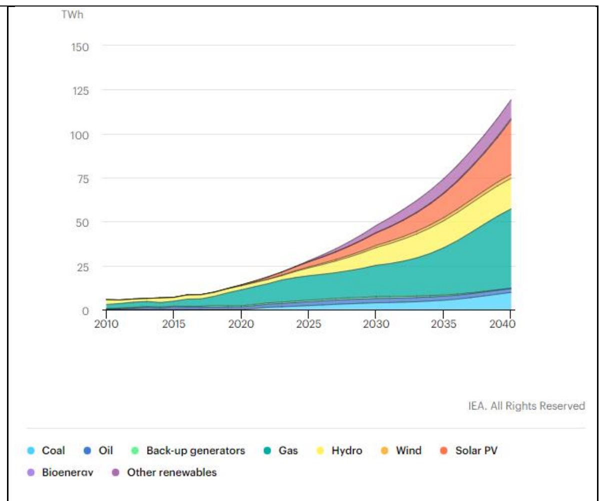


Figure 8: Tanzania energy electricity generation by technology in the Africa Case, 2010-2040

X. Site Establishment and Engineering

PV modules in large power plants are usually mounted on elevated structures to minimize the land occupancy. Due to the bigger wind aperture of those PV fields, higher loads are therefore transmitted to the foundations, resulting in a design of heavy concrete foundations.

The installation of metallic posts or screws is exceptionally fast and allows a laser cut precise installation. The ramming is performed with a special vehicle with actuators in order to press the SIGMA shaped piles into the ground. The length can be adjusted to the soil conditions' requirements.

The approach to use concrete foundations is in general not recommended if metallic ramming piles or equivalent solutions can be envisaged.

Concrete foundations generally add significantly on execution time and complexity whereas the products for metallic ramming piles can be sourced locally.

Figure 9: Project Site and PV mounting, molding and Installation

A	Construction Camp yard
B	Molding cement blocks for the PV Solar frame istallations
C	Stockyard for mounting blocks before installation into field
D	Trenching to instal mounting blocks for PV Frames
E	Installation of tracking frames and Mono Solar Panels

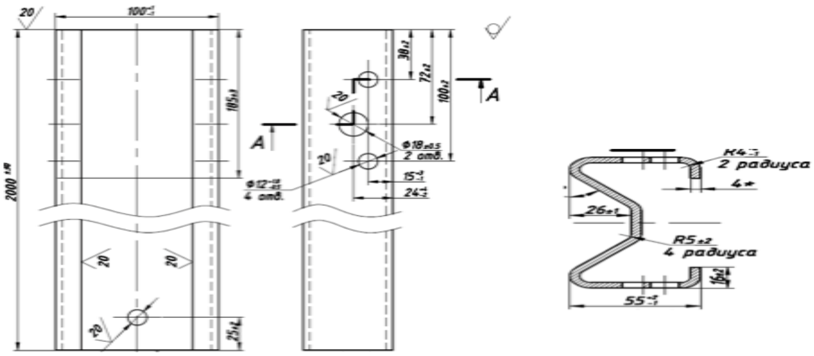


Figure 10: Brackets for the ground mounting

A. Concrete piers cast in-situ

These are most suited to small systems and have high tolerance to uneven and sloping terrain. They do not have large economies of scale.

B. Pre-cast concrete ballasts

This is a common choice for manufacturers with large economies of scale. It is suitable even at places where the ground is difficult to penetrate due to rocky outcrops or subsurface obstacles. This option has low tolerance to uneven or sloping terrain, but requires no specialist skills for installation. Consideration must be given to the risk of soil movement or erosion.

Driven piles: If a geotechnical survey proves suitable, a structural steel profile driven into the ground can result in low-cost, large-scale installations that can be quickly implemented. Special skills and pile driving machinery are required, but may not always be available.

Earth screws: Helical earth screws typically made of steel have good economics for large-scale installations and are tolerant to uneven or sloping terrain. These require specialist skills and machinery to install.

Bolted steel baseplates: In situations where the solar plant is located over suitable existing concrete ground slabs, such as disused airfield runway strips, a steel baseplate solution bolted directly to the existing ground slabs may be appropriate.

XI. Climate

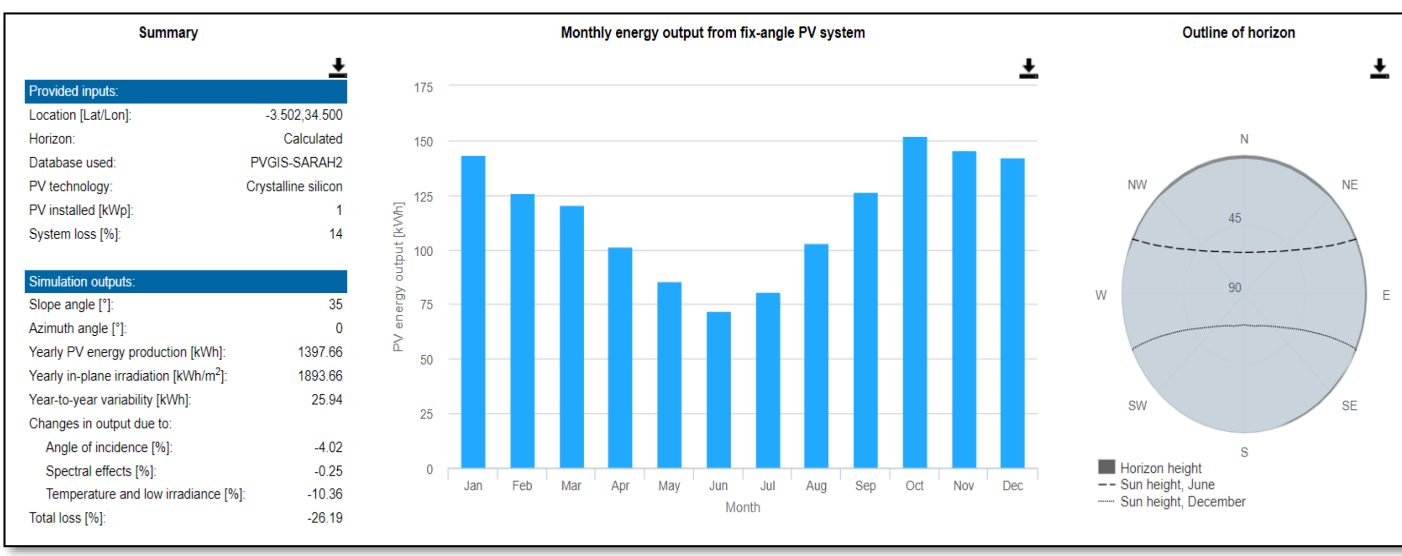
Meatu District is one of the five districts of the Simiyu Region of Tanzania. It is bordered to the north by the Itilima District, to the west by the Maswa District and Shinyanga Region to the east by the Arusha Region, to the southeast by the Manyara Region and to the south by the Singida Region. Its district capital is the town of Mwanhuzi.

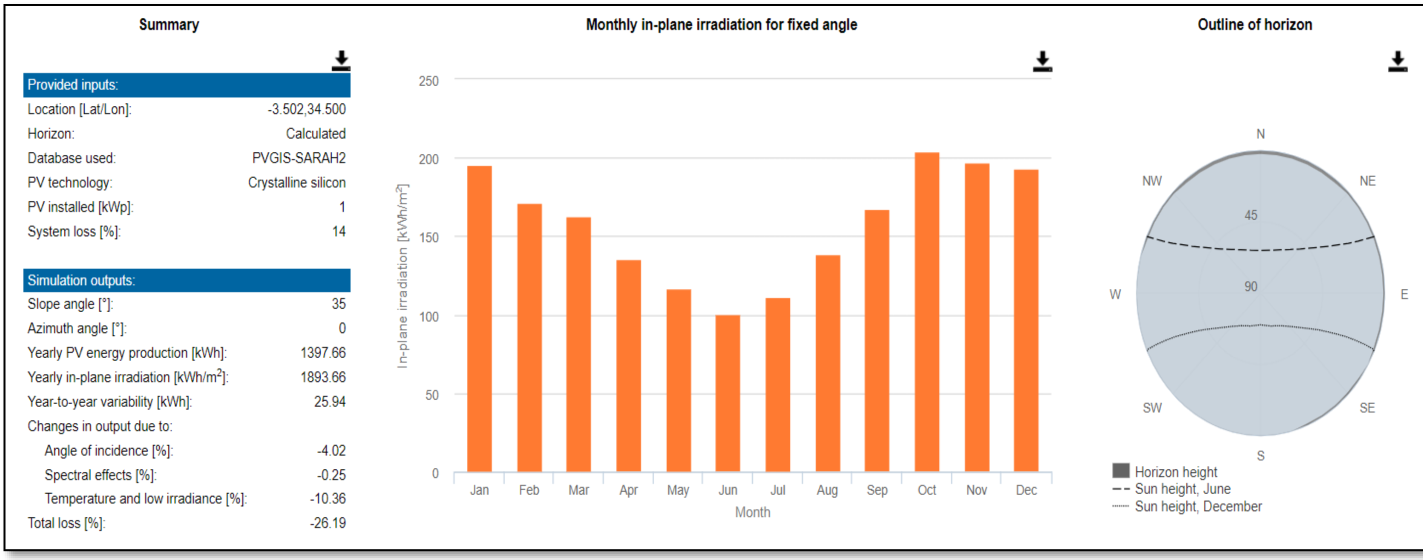
The District lies between latitude-2^{0}57and 4^{0}9 south of Equator and longitude 34^{0}8 and 34^{0}49 east of Greenwich. It is bordered with Bariadi District to the North, Ngorongoro and Karatu Districts to the East, Mbulu and Iramba Districts to the South and Maswa and Kishapu District to the west.

Meatu District can be classified as semi-arid, with a decrease in rainfall distribution from north to south. The southern half of the district receives a mean annual rainfall of 400mm, while the Northern half receives up to 900mm per year. The rainfall pattern is bimodal, with most rain in November-December and March-April.

A. Energy resource

Modeled solar statistics for the site were generated using the Direct Normal Irradiation Tanzania this gave annual average insolation on a horizontal surface of 7 kWh/m2/day, annual average diffuse radiation incident on a horizontal surface of 1.64 kWh/m2/day and annual average direct normal radiation of 6.48 kWh/m2/day.





XII. Infrastructure - Ibadakuli/Mabuki Substation

The current power requirement in Simiyu region including the proposed area is around 14.5MW and it is getting power from Ibadakuli/Mabuki grid substation via 33kv Maswa or Kishapu feeder line. The solar PV plant will be exporting 100% of the generated power to the min grid in Meatu.

The existing Ibadakuli/Mabuki grid substation is rated as 33 kV- 3 x 40 MVA.

A. Transmission and Distribution

Current transmission and distribution losses are at 16.4%. Beyond the grid, Small Power Producers (SPP) are responsible for the management of isolated micro- and mini-grids. Several development projects are in place to extend and upgrade the transmission and distribution sector to cope with expanding demand and supply, to interconnect the isolated supply network, to increase international electricity trade with neighboring countries and to improve the general reliability of the system.

XIII. Development Schedule

A development schedule for the project shows commissioning 18 months after signing of the SPPA. This includes:

XIV. Recommendations

Key recommendations for high priority work, prior to implementation are:

- Undertake a full feasibility study preceded by a short scoping study.
- The feasibility study would include engineering, project development, environmental and project planning.
- This could be a staged study that could run for 2 months, with outcomes including a clear project schedule and costs and performance estimates with a contingency of around 10%
- In parallel with this work, commercial studies should be undertaken with ongoing project viability reviews;
- The engineering study should evaluate energy storage as an option to increase output;
- This would allow advances in the other technologies to be leveraged;
- To extend power generation beyond periods of sunlight and to allow a steady supply of electricity, two approaches to solar PV plant energy storage should be considered:
- Storage of electricity at the plant and use of this electricity when direct sunlight is not available.
- This would give an extra six to eight hours operation without the Sun shining;
- This however will increase the capital cost because it requires a battery storage facility to store;

- This increases the cost of sent-out energy, but is not a technology limitation;
- The intermittent and variable nature of solar energy makes energy storage preferred, or be considered at a later stage.

XV. Conclusion

- Solar PV tracking technology offers significantly lower capital and operating costs than other PV technology;
- an alternative lower risk and much lower cost option in PV technology. The low cost makes it more attractive for African market for more affordable electricity than solar thermal;
- significant research and development of solar power generation is being funded, particularly in the USA and Europe and the last couple of years across Africa.
- there is generally wide community support for all the solar technologies; although community reaction to a large-scale solar plant in the Meatu region is untested;
- the key factors behind the relatively low cost of generation are the low capital cost of plant itself, the low proportion of infrastructure and land and the relatively low productivity. Larger plant size would significantly improve the economics by spreading the infrastructure costs over a larger productive plant, and capturing economies of scale of the production plant itself;
- Higher solar radiation levels such as at Meatu would lower electricity cost by about 17% (before rebates);
- The Sun is a reliable but intermittent and diffuse source of energy.
- There is strong daily and seasonal variation and availability may be limited or interrupted by cloud cover. This increases the cost of sent-out energy, but is not a technology limitation;
- The intermittent and variable nature of solar energy makes energy storage preferred, particularly for solar PV for peak usage
- No special skills, of a standard beyond that currently needed to operate and maintain a thermal power generation plant, would be required.
- Personnel would be required as plant operators (on shift) and for servicing and maintenance;

- a preliminary list of physical characteristics required for a site were identified. It is expected that the site would undergo a rigorous environmental and planning assessment, and an inspection and confirmation of connection points has occurred as part of the selection process;
- The solar plant could be connected to the existing Meatu Sub Station and 220 kV to increase to 400 kV transmission network, subject to the normal planning, design and approvals processes;
- the plant would require connection to the existing road, water and waste water services will need to be constructed (the waste water can be recycled and cleaned for further use;
- EIS will be required.
- CODEB ENERGIES believes that cost is the important factor for CODEB ENERGIES in the PV Solar analysis. The 216-watt tracking position system has the lowest cost in all phases, higher energy mass than the others.
- The site has high levels of solar radiation of over 8 kWh/m2, which is a strong level of solar radiation. Accordingly, the site is able to generate a return of +23% or more on capacity utilization.
- Operating cost on the plant are low on account of the feedstock materials (sunlight) being virtually free of charge.
- Capital expenditure on power transmission is not high considering near proximity of loads all within an 8 sq.km area.