KZN Operating Unit

Network Engineering & Asset Design

Mashaqiya Solar Project Nkandla

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1.Executive Summary

Mashaqiya Village is a remote village about 20km South of Melmoth Town

(31°17′23.81″, -28°43′15.86″).

Purpose is to Supply electricity to a residential Customers

There are a total of 60 household including 1 primary school (Maqhashiya Primary School)

The community has been identified for potential electrification, using PV Solar Home Systems.

2.Project Information

Location: Northern KwaZulu-Natal (20kM south of Melmoth Town) (31°17′23.81″, -28°43′15.86″).

Scope of Work:

The proposed system simulated for each household is a 5.4kWp PV generator connected to 1x 5kW Hybrid Inverter with a total of 2-MPPT’s and a 5.3kWh battery storage system. The Contractor shall supply the complete Modbus register map and communication protocol documentation for the inverter system.

This is composed of the following equipment:

System Type: Off-Grid PV System
PV Array: 9 × 600 W Modules
Inverter: 5 kW Hybrid Inverter (2 MPPT)
Battery: 5.3 kWh Lithium Battery (48 V)
String Configuration: 1 String of 9 Modules

The PV plant will be installed on a carport structure, with the 5kW Hybrid inverter and 5.3kWh battery bank being placed in an enclosure. Power will then be reticulated to the end-user’s household of about 60 households per Carport Structure.

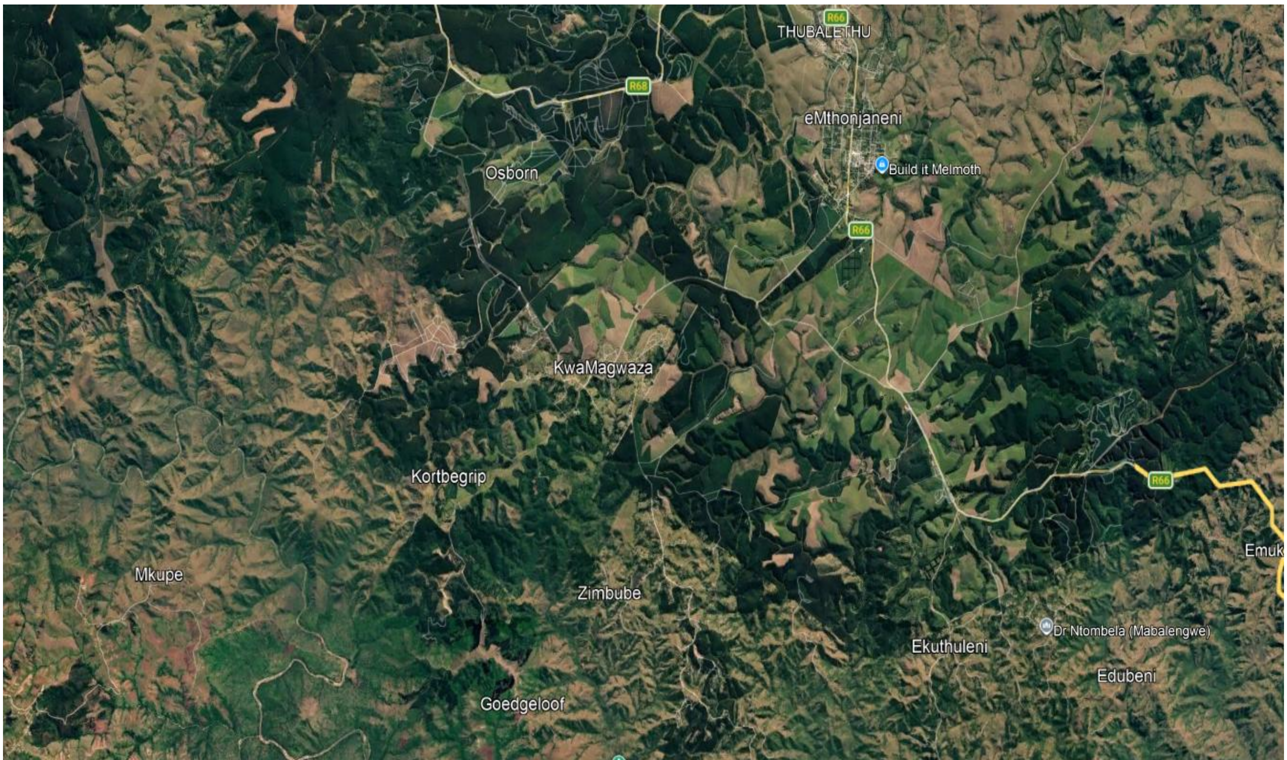
Customer load management.

a) The conditions stated in 240-170000943, Microgrids Planning Standard, must be observed when implementing the load management in Home Solar Systems.

b) The smart meters shall be configured to provide load management according to the Table 1 below.

Table 1: Load management schedule Summer		**Winter**	**Stage**		**House limit [A]**
Start time		**End time**	**Start time**		**End time**
09:00	18:00	10:00	17:00	1	10
18:00	22:00	17:00	21:00	2	1
22:00	05:00	21:00	05:00	3	0.5
05:00	09:00	05:00	10:00	2	1

Geographical Location



NETWORK OVERVIEW

Raw Energy

$$E = P \times PSH$$
$$E = 5.4 \times 5.5$$
$$= 29.7kWh/day$$

System Losses

Loss	%
Temperature	8
Dust	3
Cable	2
Inverter	5
Mismatch	2

Total Loss:

$$20\%$$

Net production:

$$29.7 \times 0.8$$

$$= 23.76 kWh/day$$

Expected Daily Yield

≈ 24 kWh/day

4.PV System Design

Design Inputs

Calculations for ensuring electrical compatibility between the inverters and the modules

Solar Module Data (Typical 600 W Module)

- Pmax = 600 W
- Voc = 52.4 V
- Vmp = 43.76 V
- Isc = 14.48 A
- Imp = 13.71 A
- Temperature Coefficient Voc = -0.250 %/°C
- Temperature Coefficient Isc = +0.045 %/°C
- Temperature Coefficient Pmax = -0.290 %/°C

Ambient Temperature:

- Minimum = 5°C
- Maximum = 50°C

STC Temperature = 25°C

Total PV Capacity

$$P_{array} = 9 \times 600$$

$$P_{array} = 5400W$$
$$P_{array} = 5.4kWp$$

Operating Voltage

$$V_{mp,string} = 9 \times 43.76$$
$$V_{mp,string} = 394V$$

Open Circuit Voltage

$$V_{oc,string} = 9 \times 52.4$$
$$V_{oc,string} = 471.6V$$

Temperature Corrected Voc

Lowest site temperature = 5°C

Temperature difference:

$$\Delta T = 25 - 5 = 20°C$$

Temperature Coefficient Voc = -0.250 %/°C

Voltage increase:

$$0.250\% \times 20$$
$$= 5.\%$$

General Formula

$$V_{corrected} = V_{STC} \times [1 + (\beta \times \Delta T)]$$

Where:

- $V_{corrected}$= Corrected voltage at site temperature
- V_{STC}= Module voltage at STC
- β= Temperature coefficient of voltage (%/°C)
- ΔT= Temperature difference from STC

Corrected Voc:

$$471.6 \times (1.05)$$
$$= 495.V$$

Max. number of modules per string = Max. PV input voltage / Voc@Tmin
= 495 / 9 =55
= 500 / 55
= 9 Modules

Result

Corrected Voc = **495 V**

This remains below a typical inverter maximum PV input of 500 V, but with only 5 V margin.

A 550 V or 600 V PV input inverter is preferred.

Practical Inverter Design Check

For your system:

Item	Value
Corrected Voc	495 V
Typical Inverter Max PV	500 V
Safety Margin	5 V

This is very close to inverter limit.

Recommended:

- Use inverter with:
  - Preferably 600 V PV input
  - MPPT Operating Voltage Range 40-560V
  - Start-up Voltage 50V
  - Nominal Input Voltage 360V
  - Maximum Input Current per MPPT
  - Number of Strings Per MPPT 1
  - Nominal output Power 5000W
  - Nominal Output Voltage 230/240V

Current Temperature Correction (Isc)

Current increases slightly as temperature increases.

$$I_T = I_{SC} \times \left[1 + \left(\frac{\alpha}{100}\right)(T_{actual} - 25)\right]$$

Where:

Symbol	Meaning
I_T	Corrected Current
I_{SC}	Current at STC

Symbol	Meaning
α	Current Temp Coefficient (%/°C)

Current coefficient:

$$+0.045\%/°C$$

Module Isc:

$$14.48A$$

Temperature:

$$50°C$$

Temperature rise:

$$50 - 25 = 25°C$$

Current Increase:

$$0.045 \times 25$$
$$= 1.125\%$$

Corrected Isc

$$14.48 \times (1 + 0.01125)$$
$$= 14.64A$$

PV String Current

String current:

$$I_{mp} = 13.71A$$

Design current:

$$1.25 \times 13.71$$
$$= 17.14A$$

Temperature-corrected maximum power (Pmax)

$$P_{max,T} = P_{max,STC}[1 + \gamma(T_c - T_{STC})]$$

Where:

- $P_{max,T}$= Corrected module power at operating temperature (W)
- $P_{max,STC}$= Rated module power at STC (W)
- γ= Power temperature coefficient (%/°C or decimal/°C)
- T_c= Cell temperature (°C)
- T_{STC}= Standard Test Condition temperature = 25°C

If the power coefficient is given as:

$$\gamma = -0.290\%/°C$$

Convert to decimal:

$$\gamma = -0.0029/°C$$

Then:

$$P_{max,T} = P_{max,STC}[1 - 0.0029(T_c - 25)]$$

- $P_{max,STC} = 600W$
- $\gamma = -0.290\%/°C$
- Cell temperature = 50°C

Temperature difference:

$$\Delta T = 50 - 25 = 25°C$$

Corrected power:

$$P_{max,T} = 600[1 - (0.0029 \times 25)]$$
$$= 600(0.9275)$$
$$= 556.5W$$

Array Power Correction (9 × 600 W Modules)

STC Array Power:

$$P_{array} = 9 \times 600$$
$$= 5400W$$

At 50°C cell temperature:

$$P_{array,T} = 5400[1 - (0.0029 \times 25)]$$
$$= 5400 \times 0.9275$$
$$= 5008.5W$$
$$P_{array,T} \approx 5kW$$

Design Rules

Parameter	Temperature Effect
Voc	Increases in cold weather
Vmp	Increases in cold weather
Isc / Imp	Increases in hot weather
Power Output	Decreases in high temperatures

5.Inverter Design

Practical Inverter Design Check

Item	Value
Corrected Voc	495 V
Typical Inverter Max PV	500 V
Safety Margin	5 V

This is very close to inverter limit.

Recommended:

- Use inverter with:
    - 550 V MPPT minimum
    - Preferably 600 V PV input

The DC/AC ratio is calculated as:

DC/AC Ratio = Total PV Array Power (kW) ÷ Inverter AC Power (kW)

For a **5 kW off-grid inverter**:

Option 1: 9 × 600 W PV modules

- Total DC power = 9 × 600 W = **5,400 W = 5.4 kW**
- Inverter AC power = **5.0 kW**

DC/AC Ratio = 5.4 ÷ 5.0 = 1.08

Result: DC/AC Ratio = 1.08:1

9 × 600 W (1.08): Conservative design with minimal inverter clipping.

Inverter Compliance
Hybrid Operation & Multi-Source Integration

The proposed inverter is hybrid (bi-directional) type, capable of accepting power from PV panels, batteries, standby generators, and the grid, while optimally managing energy to ensure reliable AC supply to connected loads.

6.Battrey Storage Design (Off Grid/Hybrid)

Battery Capacity: $\mathbf{5.3}\boldsymbol{kWh}$

Battery Voltage: $\mathbf{48}\boldsymbol{V}$

Battery Ah:

$$Ah = \frac{5300}{48} = 110Ah$$

Battery rating:

48 V, 110 Ah $\mathbf{LiFePO_4}$

Usable energy (90% DoD):

$$5.3 \times 0.9$$
$$= 4.77kWh$$

Battery Compliance:

Daily Cycling
The proposed battery system is designed for daily charge and discharge cycles under normal weather conditions, ensuring consistent operational performance.

7.Protection System Design and Cable Sizing

DC Protection

PV Side

- 20 A DC String Fuse
- 600-1000 V DC Isolator
- Type 2 DC SPD 600-1000V DC
- $4mm^2$ Solar Cable

Battery Side

Battery current: $I = \frac{5000}{48} = 104A$

Design Current: $104 \times 1.25 = 130A$

Protection:

- 160 A DC Fuse
- 35 mm^2 Battery Cable

- 160 A DC Battery Isolator

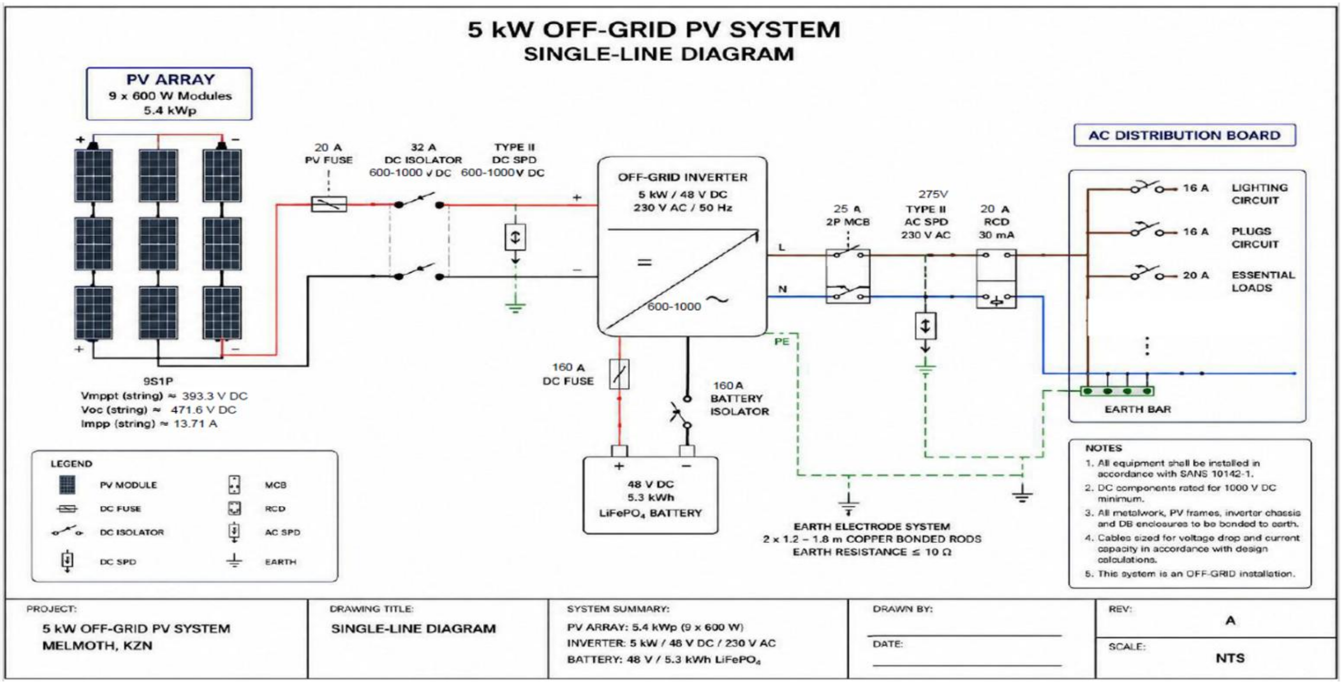
<u>AC Side Protection</u>

Maximum AC Current: $I = \frac{5000}{230} = 21.7A$

Protection:

- 20 A AC RCD
- 25 A AC MCB
- Type 2 AC SPD 275V
- 2.5 mm² Copper Cable

8.Single-Line Diagram (SLD)



9. Solar Resource Assessment

9.1 Assessment Methodology

A site-specific solar resource assessment was undertaken using PVGIS and the SARAH3 database. The assessment used the centroid of the surveyed household locations to avoid reliance on generic regional irradiance assumptions. The objective was to confirm solar resource adequacy, identify critical design months and support SHS performance validation using site-specific data.

Two PVGIS tools were used for different design questions. PVcalc was used to evaluate PV-only energy production, while SHScalc was used to evaluate complete off-grid SHS performance including load demand, battery behaviour and surplus energy not captured.

9.2 Assessment Inputs

Parameter	Value
Location basis	Household centroid
Coordinates	-28.718, 31.286
Solar database	PVGIS-SARAH3
Study period in DRT validation	2005–2023
Orientation	North-facing
Horizon	Calculated
DRT benchmark tilt	30 degrees
Post-DRT investigated tilt	20 degrees

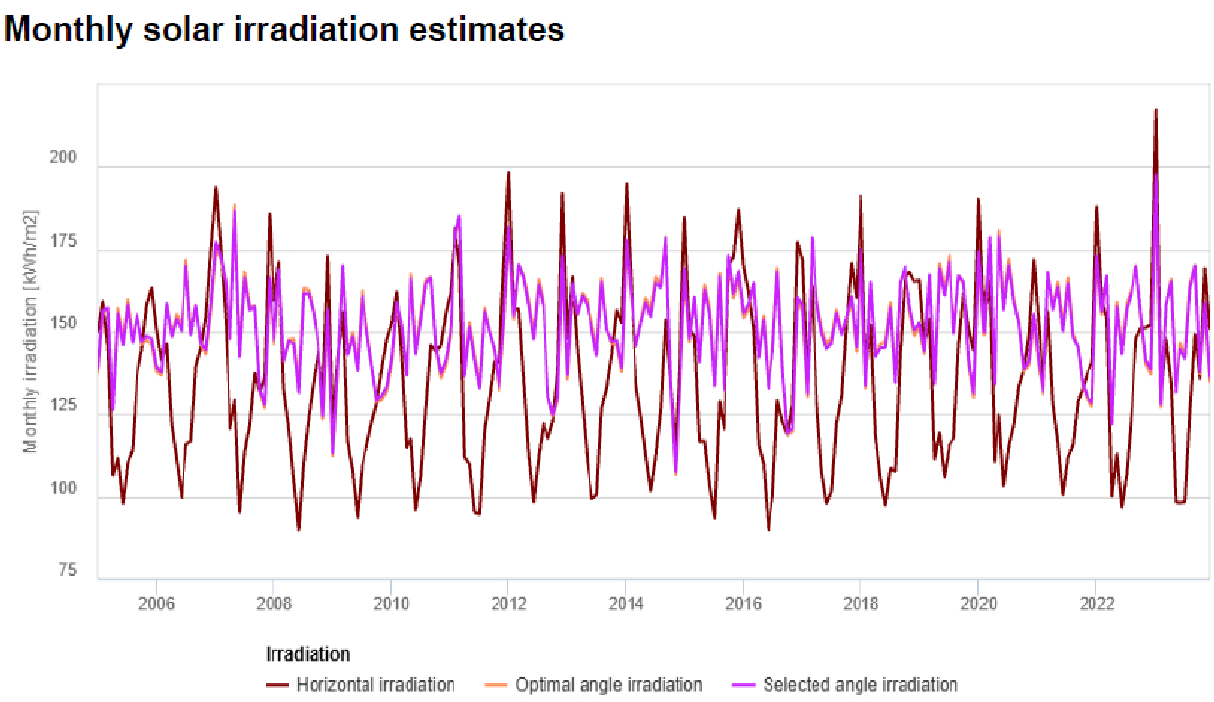


Figure 9-1: Monthly solar irradiation / PVGIS site-specific solar resource profile

9.3 Solar Resource Findings

- The site-specific PVGIS assessment confirms adequate solar resource for SHS deployment.
- The assessment does not indicate a marginal solar resource location.
- June and July are identified as the critical design months due to reduced winter solar resource.
- The design focus is therefore not only annual energy yield but winter reliability and battery behaviour.

9.4 Critical Winter Months

Monthly energy production analysis identified June and July as the governing winter design months. These months represent the period of greatest stress for the SHS because reduced solar resource increases reliance on battery storage and increases the probability of customer supply limitations under high demand.

9.5 PVcalc and SHScalc Interpretation

PVGIS Tool	Purpose	Design Interpretation
PVcalc	PV-only generation assessment	Used to compare PV energy production and tilt-angle effects without battery/load influence

SHScalc	Off-grid SHS performance assessment	Used to evaluate customer energy supply, battery full/empty days and energy not captured

This distinction is important because PV-only generation and complete SHS performance answer different engineering questions. In the final design context, SHScalc performance indicators are used to assess customer supply reliability, while PVcalc results support interpretation of PV generation behaviour.

9.6 Solar Resource Assessment Conclusion

The Mashaqiya site has adequate solar resource for off-grid SHS electrification. June and July govern the reliability assessment and shall remain the critical design months for system performance validation. Site-specific modelling using PVGIS provides the technical basis for the system performance assessment documented in Section 10.

10. System Performance Analysis

10.1 Assessment Configuration

System performance analysis was undertaken to validate the DRT-approved standard SHS configuration against representative and high-demand household demand cases. The assessment evaluated battery full days, battery empty days, energy supplied to load and winter performance.

Component	Approved / Assessed Rating
PV array	5.4 kWp
PV modules	9 × 600 W modules
Hybrid inverter	5 kW
Battery storage	5.3 kWh lithium battery
Sensitivity storage case	10.6 kWh
System type	Stand-alone off-grid SHS

10.2 Representative Household Performance

Parameter	Value
Daily load	5.0 kWh/day
PV array	5.4 kWp
Battery	5.3 kWh
Inverter	5 kW

Performance Metric	Result
Battery full days	75.36%
Battery empty days	17.65%
Key conclusion	Approved SHS configuration adequately supports representative household demand

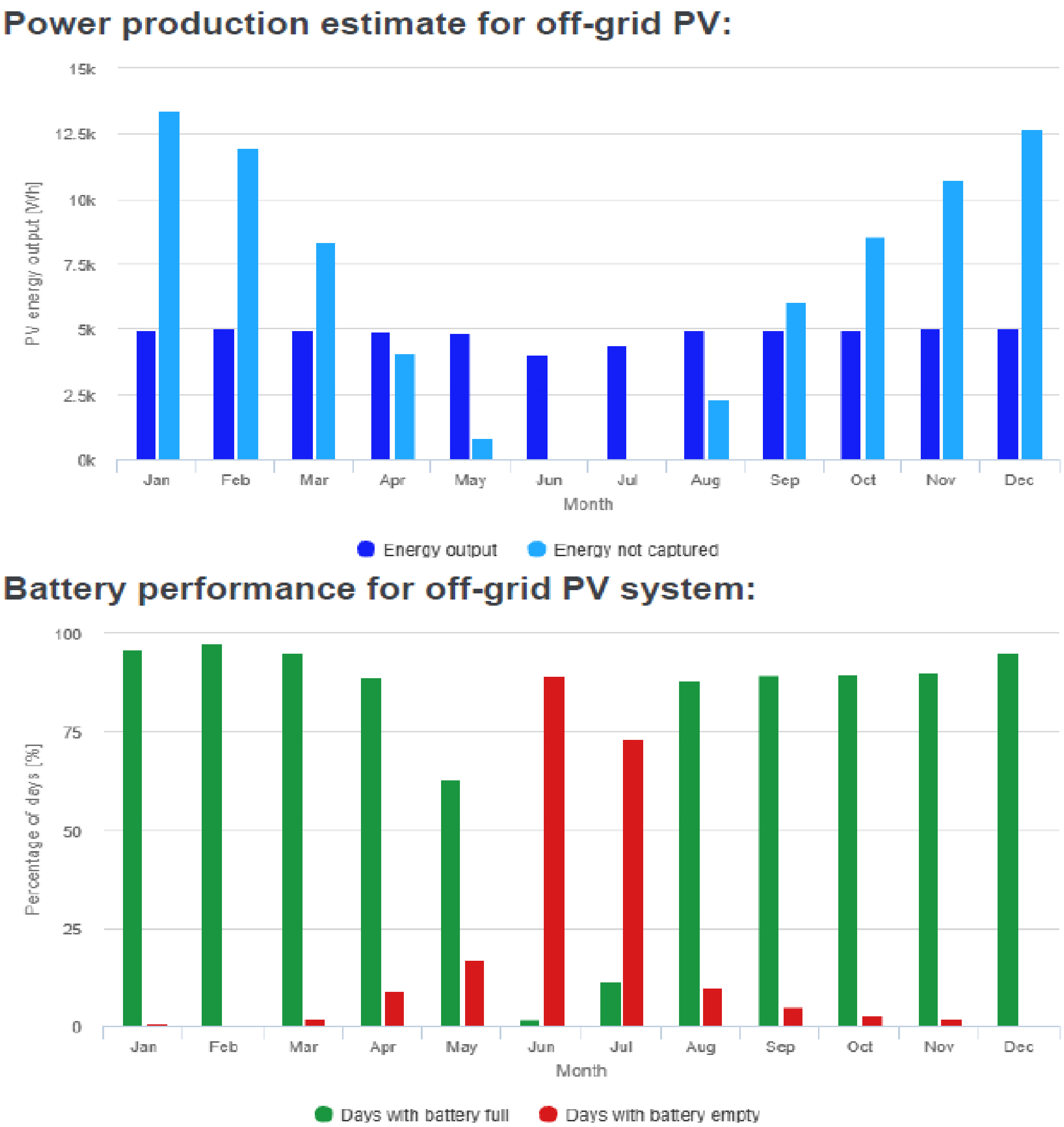


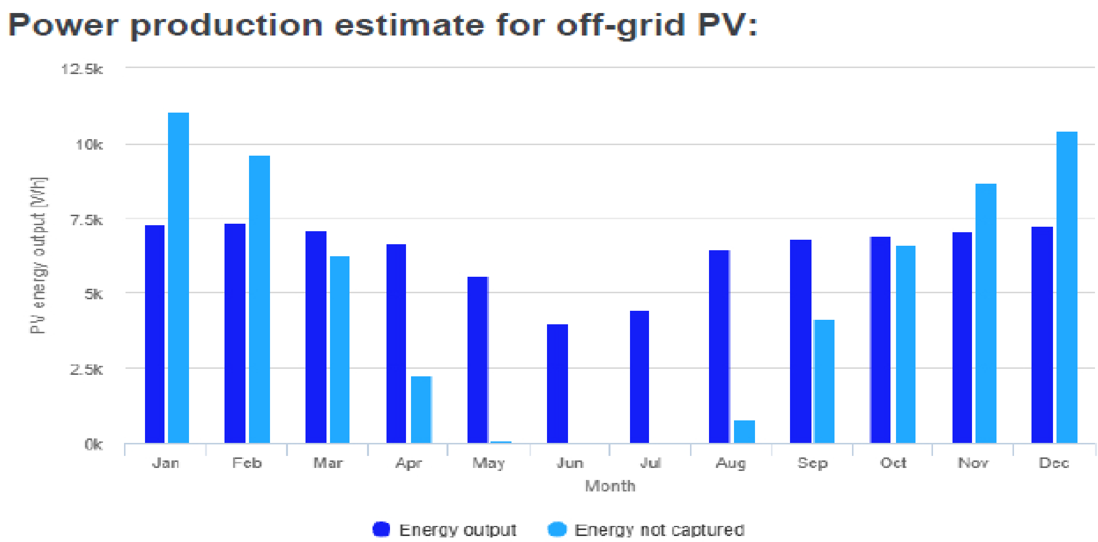
Figure 10-2: Representative household PVGIS performance result

The representative household case confirms that the standard SHS configuration is technically suitable for the majority of surveyed households. The system performs satisfactorily over the annual period, with winter performance reduction occurring during June and July as expected from the solar resource assessment.

10.3 High-Demand Household Assessment

Parameter	Value
Daily load	7.665 kWh/day
PV array	5.4 kWp
Battery	5.3 kWh
Inverter	5 kW

Performance Metric	Result
Battery empty days	89.85%
Key conclusion	Storage capacity is the primary reliability constraint for the high-demand case



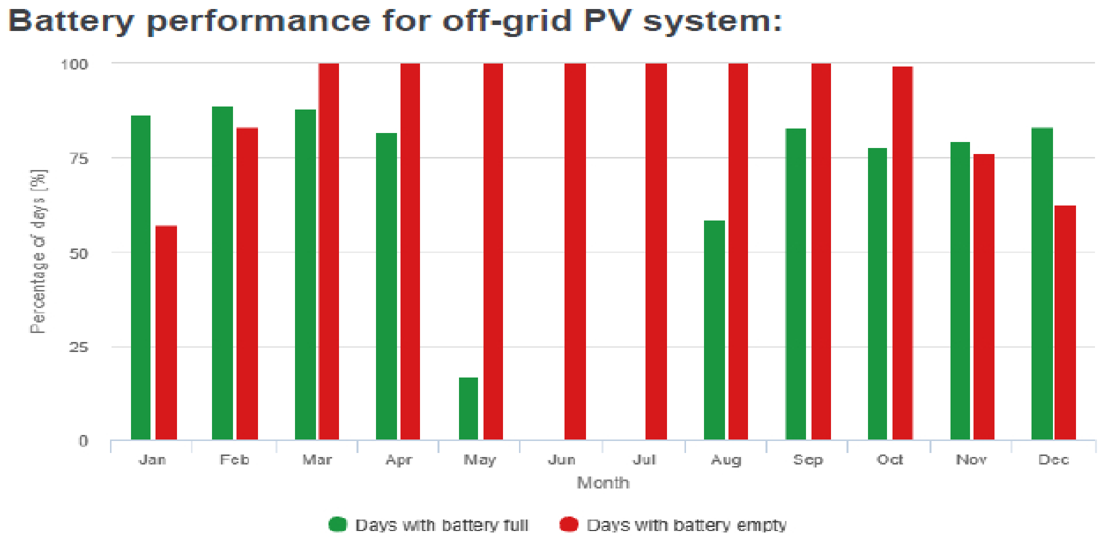


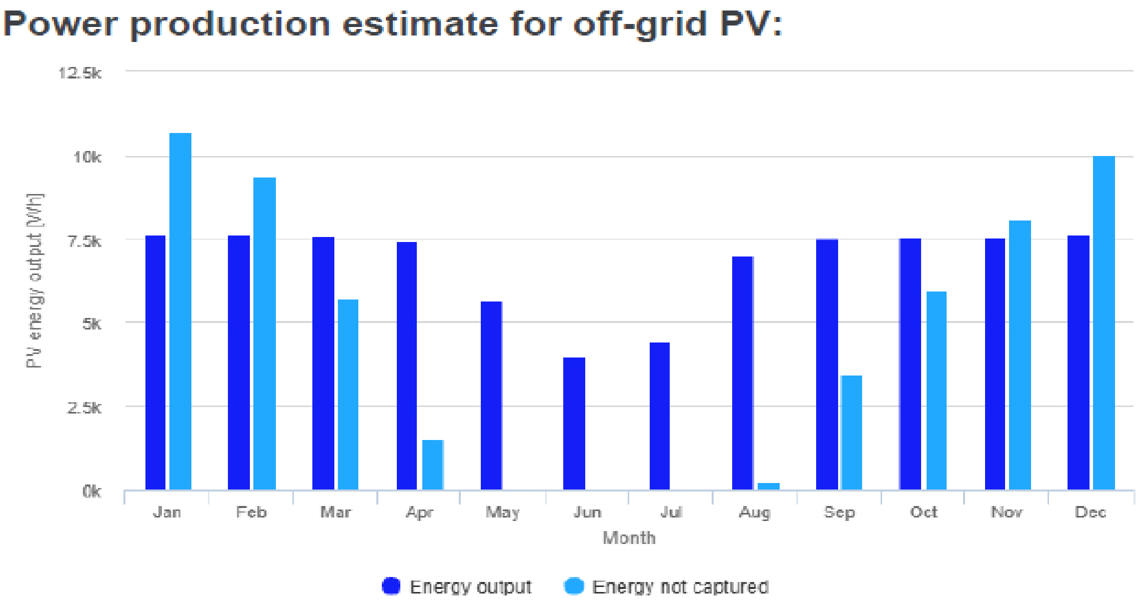
Figure 10-3: High-demand household PVGIS performance result

The high-demand case demonstrates that the standard SHS package is not intended to be globally sized around the highest surveyed load. The result confirms that high-demand households should be treated as exceptions requiring targeted mitigation.

10.4 Battery Sensitivity Assessment

A battery sensitivity study was undertaken to determine whether high-demand performance limitations were primarily caused by PV generation or storage capacity. The battery capacity was increased from 5.3 kWh to 10.6 kWh while retaining the 5.4 kWp PV array.

Metric	5.3 kWh Battery	10.6 kWh Battery
Battery empty days	89.85%	32.53%
Interpretation	High depletion	Reliability materially improved



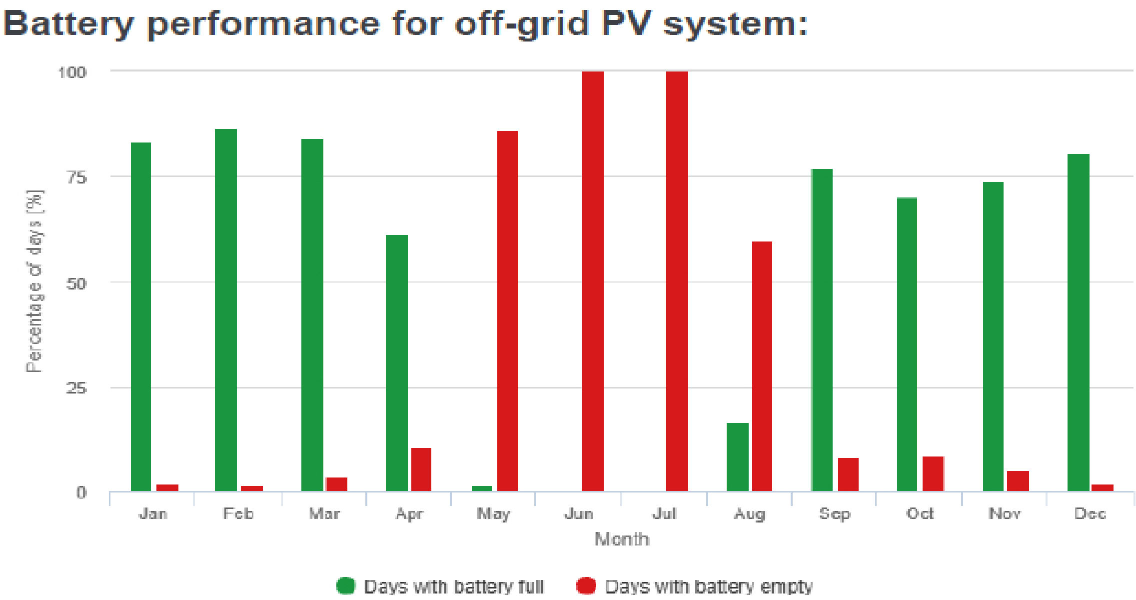


Figure 10-4: Battery storage sensitivity result

The sensitivity assessment confirms that additional storage materially improves reliability for high-demand households. This supports the final design position that battery storage is the dominant limitation for exceptional high-load customers and should be addressed through targeted mitigation rather than redesigning the complete project around the highest demand case.

10.5 Reduced Tilt-Angle Assessment

Following DRT approval, a reduced tilt-angle investigation was undertaken in response to management and constructability considerations. A 20 degree module tilt angle was assessed using PVGIS for representative and high-demand scenarios. The objective was to determine whether lowering the tilt angle would materially affect electrical performance while potentially improving structural height, wind loading and constructability.

Assessment Item	Value / Finding
Original benchmark tilt	30 degrees
Alternative assessed tilt	20 degrees
PVGIS database	SARAH3
Coordinates	-28.718, 31.286
Representative household battery full days at 20 degrees	92.66%
Representative household battery empty days at 20 degrees	4.24%
High-demand one-battery result	Storage constrained; battery empty days 89.11%
High-demand two-battery result	Improved reliability; battery empty days 17.38%

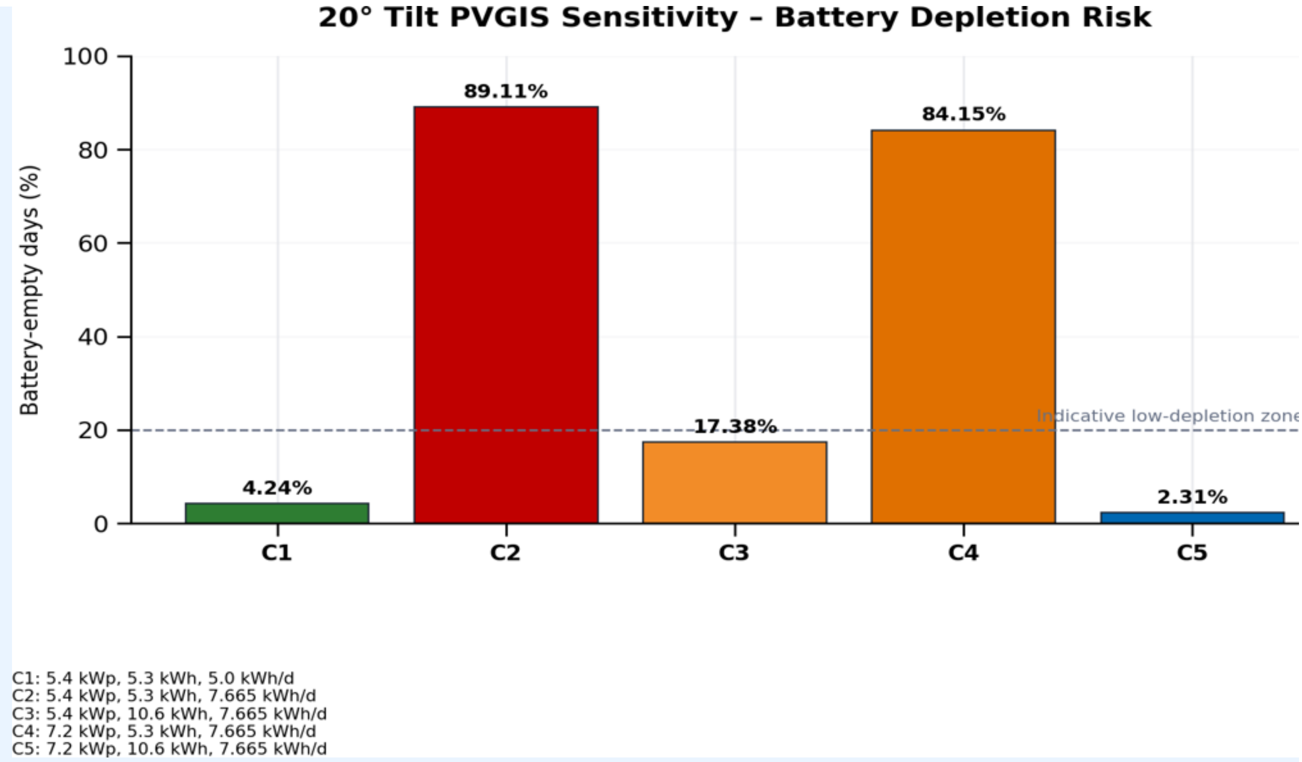


Figure 10-5: 20 degree tilt-angle battery depletion risk

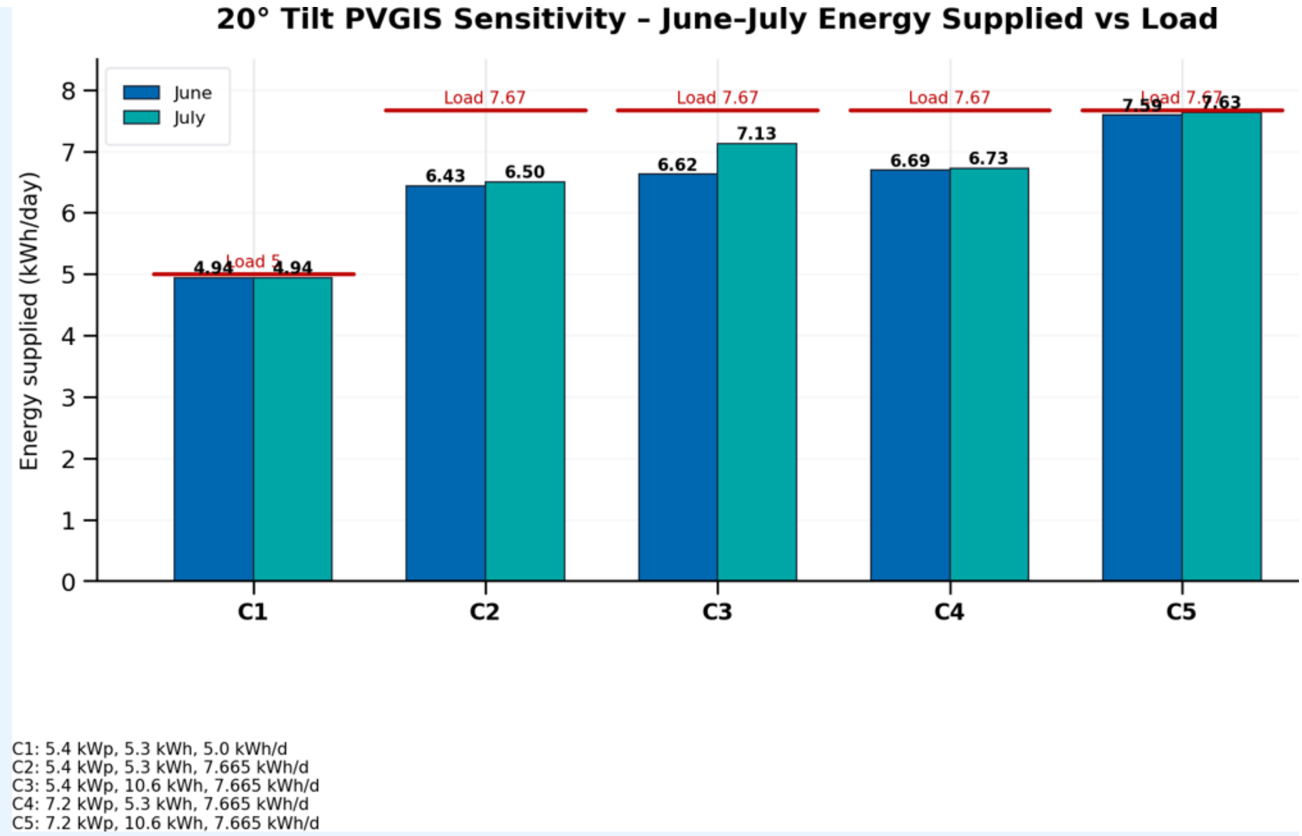


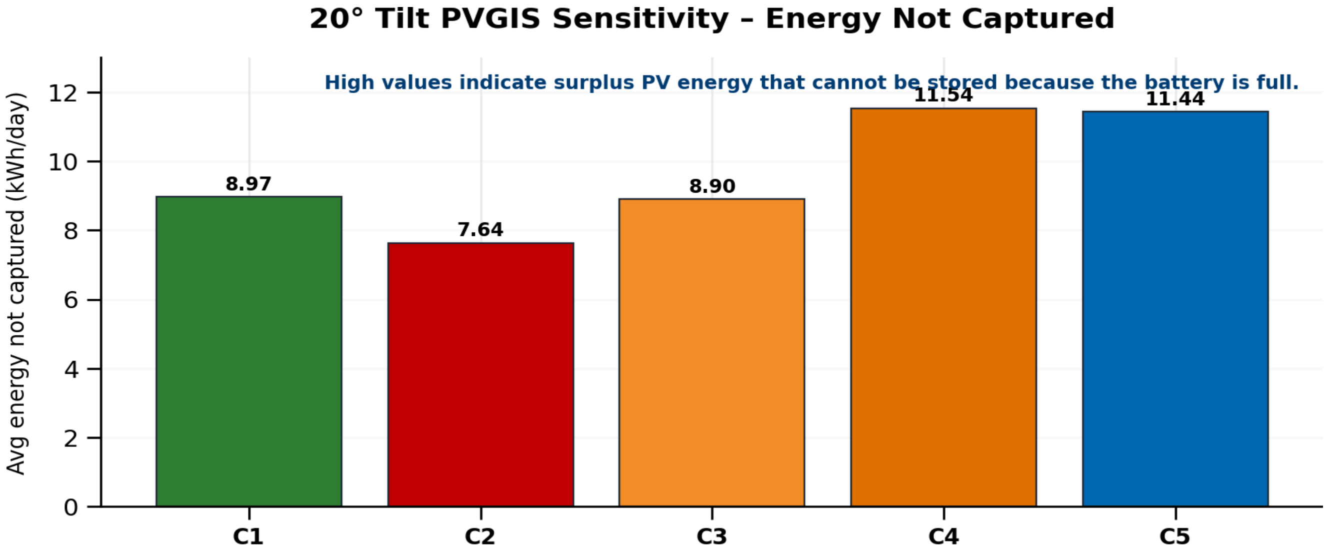
Figure 10-6: 20 degree tilt-angle June–July energy supplied comparison

The PVGIS simulations indicate that a 20 degree module tilt angle maintains acceptable electrical performance. The reduced tilt angle may therefore be adopted from an electrical energy-performance perspective, subject to Civil/Structural confirmation of support structure geometry, wind loading, foundation design and constructability.

10.6 Interpretation of Energy Not Captured

PVGIS “Energy Not Captured” represents surplus PV energy that cannot be stored because the battery is already full and customer demand has already been met. It is therefore not an indicator of PV failure and must not be interpreted in isolation.

Metric	Correct Interpretation
Energy supplied	Energy delivered to the household load
Battery full days	Percentage of days where battery reached full charge
Battery empty days	Percentage of days where battery reached minimum state of charge
Energy not captured	Surplus PV energy unavailable for storage due to full battery
Design implication	Interpret together with battery full, battery empty and energy supplied metrics



C1: 5.4 kWp, 5.3 kWh, 5.0 kWh/d
C2: 5.4 kWp, 5.3 kWh, 7.665 kWh/d
C3: 5.4 kWp, 10.6 kWh, 7.665 kWh/d
C4: 7.2 kWp, 5.3 kWh, 7.665 kWh/d
C5: 7.2 kWp, 10.6 kWh, 7.665 kWh/d

Figure 10-7: Energy Not Captured interpretation

10.7 System Performance Conclusions

- The DRT-approved SHS configuration is suitable for representative 5.0 kWh/day household demand.
- The highest surveyed household demand of 7.665 kWh/day is a stress-test case and should not define the entire fleet design basis.
- High-demand households are primarily constrained by battery storage capacity.
- Additional battery storage provides significant reliability improvement for high-demand households.
- June and July remain the governing winter performance months.
- The 20 degree tilt option is supported electrically, subject to Civil/Structural concurrence.
- PVGIS outputs must be interpreted using complete system performance metrics, not energy not captured alone.

10.8 Final Electrical Performance Recommendation

Design Item	Final Design Position
Standard SHS configuration	5.4 kWp PV array, 5 kW hybrid inverter and 5.3 kWh lithium battery
Primary validation basis	Representative household demand of 5.0 kWh/day
High-demand households	Treat as exceptional cases requiring targeted mitigation
Mitigation options	Additional storage, load management, customer education and essential-load prioritisation
PV module tilt	20 degrees supported electrically, subject to Civil/Structural concurrence
Critical validation period	June and July winter months
Final implementation note	All drawings, BoQ and structural assumptions must align to the final approved tilt angle and equipment selection

The final electrical performance recommendation is to retain the DRT-approved SHS design philosophy for representative households and implement targeted measures for exceptional high-demand households where required. The 20 degree tilt angle may be incorporated into the final design package only once Civil/Structural concurrence is confirmed and all discipline deliverables are aligned.

11. Enclosure Cooling System Requirements and Calculations

Design objective is to minimise enclosure temperature rise above ambient conditions through forced ventilation and solar shielding.

Design Parameters

Parameter	Value
Inverter rating	5 kW hybrid/off-grid inverter
Battery	5.3 kWh $LiFePO_4$ battery
Maximum ambient temperature	40°C
Design enclosure temperature	35°C (battery), 45°C (inverter)
Allowable temperature rise	5–10°C
Installation	Outdoor IP-rated enclosure

Inverter Enclosure Cooling Calculation

Determine inverter heat loss

Inverter efficiency:

$$\eta = 95\%$$

Maximum output:

$$P_{out} = 5000W$$

Input power:

$$P_{in} = \frac{P_{out}}{\eta}$$
$$P_{in} = \frac{5000}{0.95} = 5263W$$

Heat loss:

$$P_{loss} = P_{in} - P_{out}$$
$$P_{loss} = 5263 - 5000$$
$$\boxed{P_{loss} = 263W}$$

Allow 20% design margin:

$$P_{heat} = 263 \times 1.2$$
$$\boxed{P_{heat} = 316W}$$

Required Ventilation Fan Size

Airflow required:

$$Q = \frac{3.16 \times P}{\Delta T}$$

Where:

- Q = airflow (m^3/hr)
- P = heat loss (W)
- ΔT = allowable temperature rise

Assume:

$$\Delta T = 10°C$$
$$Q = \frac{3.16 \times 316}{10}$$
$$Q = 99.9m^3/hr$$

Therefore:

$$\boxed{Required\ airflow \approx 100m^3/hr}$$

Recommended inverter enclosure cooling:

- 1 × 120–150 m^3/hr DC extraction fan
- Filtered intake vent
- Thermostatic fan controller ON at 35°C

Battery Enclosure Cooling Calculation

Battery:

$$E = 5.3kWh$$

Assume maximum charge/discharge efficiency:

$$\eta = 96\%$$

Battery power:

$$P = 5000W$$

Battery losses:

$$P_{loss} = P(1 - \eta)$$
$$= 5000(1 - 0.96)$$

$$\boxed{P_{loss} = 200W}$$

Add BMS losses:

$$20W$$

Design heat:

$$P_{battery} = 220W$$

With 25% safety factor:

$$220 \times 1.25$$
$$\boxed{275W}$$

Battery Enclosure Cooling Requirement

Lithium batteries should operate approximately:

- Charging: 0–45°C
- Preferred: 15–30°C

Assume:

Ambient:

$$40°C$$

Target:

$$30°C$$

Temperature rise:

$$\Delta T = 5°C$$

Airflow:

$$Q = \frac{3.16 \times 275}{5}$$
$$Q = 174m^3/hr$$

Required:

$$\boxed{180 - 200m^3/hrairflow}$$

Battery Enclosure Design Recommendation

Item	Specification
Type	IP65 steel/aluminium enclosure
Cooling	200 m³/hr filtered fan
Control	Digital thermostat
Fan ON temperature	30°C
Fan OFF temperature	25°C
Internal temperature sensor	Required
Fire protection	Battery-rated enclosure

Protection and Safety Requirements (South Africa)

The design should consider:

- SANS 10142-1 — electrical installation requirements
- NRS 097 — inverter/grid interface requirements where applicable
- DC isolation between PV, battery and inverter
- DC-rated breakers/fuses
- Surge protection devices (SPD Type 2 minimum)
- Emergency isolation switch
- Ventilation separation between battery and inverter compartment

Summary of Cooling Loads

Equipment	Heat Loss	Required Cooling
5 kW inverter	~316 W	≥100 m³/hr fan
5.3 kWh $LiFePO_4$ battery	~275 W	≥180–200 m³/hr fan

12.Mashaqiya Telecoms Scope of Work

1. Purpose

The purpose of this scope is to provide a reliable telecommunications solution to support remote monitoring, data acquisition, alarm management, and performance reporting for the Mashaqiya Solar PV Electrification Project. The communications network shall utilise GPRS technology via a cellular modem to enable connectivity between each Solar Home System (SHS) and the monitoring platform.

2. Scope of Work

The Contractor shall:

- Supply, install, configure, test, and commission a GPRS cellular modem for each SHS installation.
- Supply and install a suitable high-gain external antenna and associated accessories to achieve reliable communication performance.
- Configure SIM cards and communication security requirements.
- Integrate the telecommunications equipment with:
  - Solar inverter monitoring interfaces.
  - The monitoring platform.
- Enable remote monitoring of:
  - Energy generation.
  - Battery State of Charge (SOC).
  - Inverter operating status.
  - System alarms and fault notifications.
  - Energy consumption.
- Provide remote access capability for operational support, diagnostics, and firmware updates.
- Conduct end-to-end communication testing to verify successful data transmission to the monitoring platform.
- Provide complete as-built documentation and telecommunications network diagrams.

3. Technical Requirements

The telecommunications system shall:

- Operate on the Vodacom GPRS cellular network within the Mashaqiya project area via data sim cards supplied Contractor.
- Provide data package that is adequate but at the same time not excessive for the utilisation. The data consumption calculations must be submitted to Eskom for verification.
- Utilize an external antenna mounted at a minimum height of 3 m above ground level, or higher where required to achieve acceptable signal strength.
- Use appropriate low-loss RF cable between the antenna and modem.
- Orient antennas toward the serving cellular tower located at **94° True North**.
- Modem to be powered by auxiliary AC supply.
- Support reliable transmission of operational, alarm, and performance data.

- Include surge protection and earthing in accordance with Eskom standards and applicable SANS requirements.
- Be installed within an IP65-rated enclosure together with associated communications equipment.
- Support future migration and be backward compatible to 3G, 4G LTE, NB-IoT, or equivalent communication technologies.

4. Deliverables

The Contractor shall provide:

1. GPRS modem configuration records.
2. SIM card register and settings documentation.
3. Commissioning certificates.
4. Operation and Maintenance Manuals.
5. Commissioning certificates.

5. Commissioning and Handover

The telecommunications system shall be fully commissioned, integrated with the monitoring platform and demonstrated to transmit live operational data, alarms, and performance information from each Solar Home System before final acceptance and handover to Eskom.

13.Bill of Quantities BOQ

Refer to the BOQ advertised as part of the tender enquiry documentation.

Bill of Materials

The Eskom Free Issue material will be delivered to Site, it is the contractors responsibility to ensure safe storage of the Free Issue material.

14. Operation and Maintenance

As part of defects liability

The contractor corrects defects caused by:

Poor workmanship
Incorrect installation
Defective materials
Failure to achieve specified performance

Maintenance services as part of the defects liability period (DLP) that we can add to our scope. Scheduled inspections
Cleaning
Preventive maintenance
Monitoring
Firmware/software updates
Battery health checks
Corrosion inspections

Hybrid Inverter System
The proposed solar photovoltaic (PV) system is a fully off-grid hybrid installation capable of supplying the household independently (provided energy demand is kept within limits). The system harnesses solar energy during daylight hours and stores excess energy in a 5.3 kWh battery bank to supply electricity during periods of low or no solar generation, ensuring continuous power availability.

System Components

The off-grid hybrid system consists of:
5.4 kWp PV array mounted on the carport structure with a 20º tilt and North orientation.

5 kW single-phase hybrid inverter, which converts DC power from the PV array and battery into AC power for the facility.

5.3 kWh battery bank, sized to store sufficient energy for night-time operation or periods of low solar irradiation.

Monitoring and control system providing real-time data on PV production, battery state-of-charge (SOC), total load consumption, etc., allowing automated management of energy distribution.

Integration and Operation

Daytime Operation: Solar power generated by the PV array is first used to supply the household/facility's loads.
Any excess PV energy is stored in the battery bank for later use.
The inverter continuously manages power flow between the PV array, battery, and loads to optimize energy usage and maintain battery health.

Battery Charging and Discharging: The hybrid inverter ensures that the battery is charged whenever PV production exceeds current load demand**.**
When PV production is insufficient to meet the load, the inverter automatically draws power from the battery to supply the facility.
Battery discharge is managed to avoid depletion below 10% SOC, preserving battery life.

Night-Time and Low Irradiance Operation: During periods of no solar generation, the inverter powers the facility directly from the battery**.**
PV generation during low Irradiance, the inverter uses energy from the battery to supply deficit.

System Safety and Control: The inverter includes over-current protection and battery management functions to prevent over-discharge and overcharge.
The system ensures that energy is used efficiently during extended periods of low solar availability.

15. Applicable Standards

SANS 10142-1 — electrical installation requirements

NRS 097 — inverter/grid interface requirements where applicable

IEC 60364-6 : Low Voltage Electrical installations-Verification
IEC 60364-7-712 - Electrical Installations of Buildings: Requirements for Special Installations or Locations – Solar Photovoltaic power supply systems

IEC 60529 Degrees op protection provided by enclosures (IP Code

IEC 60904 Photovoltaic devices – all Parts