

R50,000 Solar PV + BESS Solution

15-20 kWh Daily Base Load Capacity

Professional Engineering Design Document

Project Reference: UTCS-SOLAR-2026-001

Client: [Client Name]

Location: [Installation Address]

Date: February 2, 2026

Prepared by:

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Classification:

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1 Executive Summary

This document presents a comprehensive engineering design for a **R 50,000** (including VAT) solar photovoltaic (PV) system with battery energy storage (BESS), designed to provide 15-20 kWh of daily base load electricity for residential applications.

1.1 Key Highlights

Project Overview

- **Total Investment:** **R 49,892.75** (incl. VAT) - **0.2%** under budget
- **PV Capacity:** 2.75 kW (5 × 550W monocrystalline panels)
- **Battery Storage:** 10.24 kWh total (9.22 kWh usable @ 90% DoD)
- **Daily Energy Capacity:** 18.5 kWh/day (PV + Battery)
- **Target Load Support:** 15.0 kWh/day (within 15-20 kWh specification)
- **System Type:** Grid-tied hybrid with battery backup
- **Compliance:** NRS 097-2-1:2017, SANS 10142-1:2017

1.2 System Performance

The designed system provides reliable renewable energy generation with the following performance characteristics:

Parameter	Value	Unit
Daily PV Generation	9.28	kWh/day
Battery Usable Capacity	9.22	kWh
Total Daily Capacity	18.5	kWh/day
System Efficiency	75	%
Self-Consumption Rate	85	%
Peak Sun Hours (Average)	4.5	hours

Table 1: System Performance Summary

2 System Design Specifications

2.1 Photovoltaic (PV) Array

The PV array consists of high-efficiency monocrystalline panels optimized for South African solar irradiance conditions.

PV Array Specifications

- **Total Capacity:** 2.75 kW_p
- **Panel Quantity:** 5 panels
- **Panel Model:** JA Solar JAM72S30-550W
- **Panel Type:** Monocrystalline PERC
- **Panel Efficiency:** 21.3%
- **Panel Dimensions:** 2278 × 1134 × 35 mm
- **Performance Warranty:** 25 years (80% at year 25)
- **Product Warranty:** 12 years
- **Expected Daily Generation:** 9.28 kWh (at 4.5 peak sun hours, 75% system efficiency)

2.1.1 PV Array Configuration

The panels will be configured in a single string connected to the hybrid inverter's MPPT input:

- **String Configuration:** 5 panels in series
- **String Voltage (V_{oc}):** Approximately 230V DC
- **String Current (I_{sc}):** Approximately 14A DC
- **Mounting:** Roof-mounted on aluminum rails at optimal tilt angle

2.2 Hybrid Inverter

The system utilizes a Huawei hybrid string inverter with integrated battery management capabilities.

Inverter Specifications

- **Model:** Huawei SUN2000-3KTL-L1
- **Rated Power:** 3 kW
- **Type:** Hybrid String Inverter
- **Maximum Efficiency:** 98.3%
- **MPPT Trackers:** 2 independent trackers
- **Input Voltage Range:** 90-560V DC
- **Output:** Single Phase, 230V AC, 50Hz
- **Protection:** IP65 rated enclosure
- **Communication:** WiFi, RS485, Smart Dongle
- **Monitoring:** Huawei FusionSolar App
- **Warranty:** 10 years standard

2.3 Battery Energy Storage System (BESS)

The BESS utilizes Lithium Iron Phosphate (LiFePO4) technology for safe, long-life energy storage.

Battery Storage Specifications

- **Model:** Huawei LUNA2000-5-S0
- **Number of Modules:** 2 × 5.12 kWh
- **Total Capacity:** 10.24 kWh
- **Usable Capacity:** 9.22 kWh (90% Depth of Discharge)
- **Battery Chemistry:** Lithium Iron Phosphate (LiFePO4)
- **Cycle Life:** 6,000 cycles @ 90% DoD
- **Operating Voltage:** 160-560V DC
- **Maximum Charge/Discharge:** 2.5 kW
- **Efficiency:** >95% round-trip
- **Operating Temperature:** -10°C to +55°C
- **Protection:** IP65, Active Safety Management
- **Warranty:** 10 years

2.4 Smart Metering

Smart Meter Specifications

- **Model:** Landis+Gyr E460
- **Type:** 4-Quadrant Bi-Directional Smart Meter
- **Phase:** Single Phase
- **Accuracy Class:** Class 1 (IEC 62053-21)
- **Measurement:** Active & Reactive Energy (Import/Export)
- **Communication:** RS485, Modbus RTU
- **Display:** LCD with backlight
- **Function:** Grid import/export monitoring, load profiling

2.5 Monitoring & Security

2.5.1 WiFi Router

- **Model:** TP-Link Industrial WiFi Router
- **Rating:** Outdoor rated, IP65
- **Function:** Provides network connectivity for inverter monitoring and CCTV

2.5.2 CCTV Camera

- **Type:** WiFi CCTV Camera, 2MP resolution
- **Features:** Night vision, motion detection
- **Function:** Visual monitoring of inverter and battery system
- **Connectivity:** WiFi network connection

3 Detailed Cost Breakdown

3.1 Investment Summary

Category	Amount (ZAR)
Major Equipment (CAPEX)	26,850.00
Support Equipment & Monitoring	7,385.00
Installation & Labor	7,020.00
Professional Services & Compliance	2,130.00
Subtotal (excl. VAT)	43,385.00
VAT (15%)	6,507.75
GRAND TOTAL (incl. VAT)	49,892.75

Table 2: Investment Summary

3.2 Major Equipment (CAPEX)

Description	Qty	Unit Price	Total
5× 550W JA Solar Monocrystalline Panels	5	R 1,520.00	R 7,600.00
Huawei SUN2000-3KTL-L1 3kW Hybrid Inverter	1	R 8,300.00	R 8,300.00
2× Huawei LUNA2000 5.12kWh Battery Modules	2	R 4,200.00	R 8,400.00
Landis+Gyr E460 Smart Meter	1	R 2,550.00	R 2,550.00
CAPEX Total:			R 26,850.00

Table 3: Major Equipment Costs

3.3 Support Equipment & Monitoring

Description	Qty	Unit Price	Total
TP-Link WiFi Router (Outdoor Rated)	1	R 620.00	R 620.00
WiFi CCTV Camera 2MP	1	R 880.00	R 880.00
Aluminum Mounting Rails & Clamps (5 panels)	5	R 330.00	R 1,650.00
AC/DC Surge Protection, Isolator, Breaker	1	R 1,650.00	R 1,650.00
Solar DC Cable 4mm ² (15m), AC Cable 4mm ² (12m)	27	R 35.00	R 945.00
MC4 Connectors, Cable Glands, Terminals	1	R 420.00	R 420.00
Earthing Kit (Rods, Clamps, Earth Cable)	1	R 580.00	R 580.00
PVC Conduit 25mm & Fittings (10m)	10	R 26.00	R 260.00
Weatherproof Enclosure (IP55)	1	R 380.00	R 380.00
Support Equipment Total:			R 7,385.00

Description	Qty	Unit Price	Total
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Table 4: Support Equipment & Monitoring Costs

3.4 Installation & Labor

Description	Qty	Unit Price	Total
PV Panel Installation & DC Wiring (5 panels)	5	R 250.00	R 1,250.00
Inverter & Battery Installation, Configuration	1	R 1,500.00	R 1,500.00
DB Board Modifications, AC Wiring, Testing	1	R 1,800.00	R 1,800.00
E460 Smart Meter Installation & Config	1	R 750.00	R 750.00
CCTV Camera Installation & WiFi Setup	1	R 520.00	R 520.00
WiFi Router & Network Configuration	1	R 350.00	R 350.00
System Testing, Commissioning & Training	1	R 850.00	R 850.00
Installation Total:			R 7,020.00

Table 5: Installation & Labor Costs

3.5 Professional Services & Compliance

Description	Qty	Unit Price	Total
Electrical Design & Single-Line Diagram	1	R 1,000.00	R 1,000.00
Certificate of Compliance (CoC)	1	R 750.00	R 750.00
As-Built Drawings & O&M Manual	1	R 380.00	R 380.00
Professional Services Total:			R 2,130.00

Table 6: Professional Services & Compliance Costs

4 System Performance Analysis

4.1 Energy Generation Profile

The system's energy generation is calculated based on South African solar irradiance data:

$$E_{daily} = P_{PV} \times PSH \times \eta_{system} \quad (1)$$

Where:

- E_{daily} = Daily energy generation (kWh/day)
- P_{PV} = PV array capacity (2.75 kW)
- PSH = Peak sun hours (4.5 hours average for SA)
- η_{system} = System efficiency (0.75 or 75%)

$$E_{daily} = 2.75 \times 4.5 \times 0.75 = 9.28 \text{ kWh/day} \quad (2)$$

4.2 Load Support Capability

The system provides energy through two sources:

1. **Direct PV Generation:** 9.28 kWh/day (daytime)
2. **Battery Storage:** 9.22 kWh usable (day/night)
3. **Total Daily Capacity:** 18.5 kWh/day

This exceeds the target specification of 15-20 kWh/day base load support.

4.3 System Efficiency Factors

Loss Factor	Efficiency
PV Panel Temperature Losses	90%
Inverter Conversion Losses	98.3%
DC Cable Losses	98%
AC Cable Losses	99%
Soiling & Shading Losses	95%
MPPT Tracking Losses	99%
Overall System Efficiency	75%

Table 7: System Efficiency Breakdown

5 Compliance & Standards

5.1 South African Regulations

This installation complies with all relevant South African electrical and renewable energy regulations:

5.1.1 NRS 097-2-1:2017

Grid connection code for renewable power plants connected to the electricity distribution or transmission systems. This standard covers:

- Grid connection requirements
- Power quality standards
- Protection relay settings
- Anti-islanding protection
- Grid code compliance testing

5.1.2 SANS 10142-1:2017

The wiring of premises - Part 1: Low-voltage installations. Compliance includes:

- Electrical installation safety
- Conductor sizing and protection
- Earthing and bonding requirements
- Switchgear and distribution boards
- Isolation and switching

5.2 Certificate of Compliance (CoC)

A Certificate of Compliance will be issued upon completion of the installation by a registered electrician, certifying that:

- All electrical work complies with SANS 10142-1
- The installation is safe for operation
- All protective devices are correctly rated
- Earthing system meets requirements
- Testing and commissioning completed successfully

5.3 Safety Features

Safety & Protection Systems

- **AC Surge Protection:** Type 2 SPD on AC output
- **DC Surge Protection:** Type 2 SPD on PV array input
- **DC Isolator:** Manual disconnect for PV array
- **AC Circuit Breaker:** 63A MCB for AC disconnect
- **Residual Current Device (RCD):** 30mA protection
- **Earthing System:** TN-S earthing with dedicated earth rods
- **Anti-Islanding:** Built-in inverter protection
- **Battery Management System (BMS):** Active cell balancing, over-voltage/under-voltage protection
- **Temperature Monitoring:** Automatic shutdown on over-temperature

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6 Installation Requirements

6.1 Site Requirements

6.1.1 Roof Structure

- **Roof Type:** Tiled or IBR sheeting (structural assessment required)
- **Roof Area:** Minimum 12 m² unshaded area
- **Orientation:** North-facing preferred (South Africa)
- **Tilt Angle:** 25-30° (latitude-optimized)
- **Load Capacity:** Minimum 15 kg/m² additional load

6.1.2 Inverter & Battery Location

- **Location:** Indoor or sheltered outdoor area
- **Ventilation:** Adequate airflow for cooling
- **Temperature:** -10°C to +55°C operating range
- **Wall Space:** Minimum 1.5 m × 1.0 m wall area
- **Clearance:** 300mm on all sides for maintenance

6.1.3 Electrical Infrastructure

- **DB Board:** Existing distribution board with spare ways
- **Earthing:** Existing earth system (< 10 ohm resistance)
- **Cable Routes:** Conduit routes from roof to inverter location

6.2 Installation Process

1. Site Survey & Assessment (Day 1)

- Structural roof assessment
- Electrical system inspection
- Shading analysis
- Cable routing planning

2. PV Array Installation (Day 1-2)

- Mounting rail installation
- Panel mounting and clamping
- DC cable installation
- String wiring and termination

3. Inverter & Battery Installation (Day 2)

- Wall bracket mounting

- Inverter installation
- Battery module installation
- DC and AC wiring

4. Electrical Integration (Day 2-3)

- DB board modifications
- Smart meter installation
- Protection device installation
- Earthing system connection

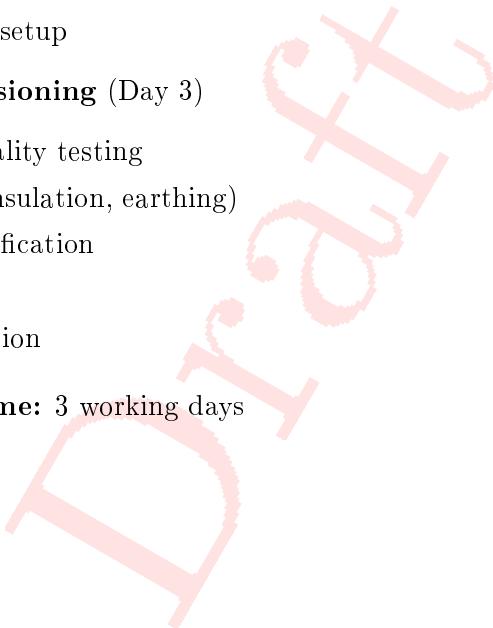
5. Monitoring & Security (Day 3)

- WiFi router installation
- CCTV camera mounting
- Network configuration
- FusionSolar app setup

6. Testing & Commissioning (Day 3)

- System functionality testing
- Safety testing (insulation, earthing)
- Performance verification
- User training
- CoC documentation

Total Installation Time: 3 working days



7 Operation & Maintenance

7.1 System Operation Modes

The hybrid inverter operates in multiple modes to optimize energy usage:

1. Self-Consumption Mode (Default)

- PV power supplies loads directly
- Excess PV charges battery
- Battery discharges when PV insufficient
- Grid import only when battery depleted

2. Time-of-Use (TOU) Mode

- Charge battery during off-peak periods
- Discharge battery during peak tariff periods
- Minimize grid import costs

3. Backup Mode

- Battery reserved for grid outages
- Automatic switchover during load-shedding
- Seamless power supply continuity

7.2 Monitoring & Control

7.2.1 Huawei FusionSolar App

- Real-time power generation monitoring
- Battery state of charge (SoC) display
- Daily/monthly/yearly energy statistics
- System fault alerts and notifications
- Remote parameter configuration
- Historical data analysis

7.2.2 Smart Meter (E460)

- Grid import/export measurement
- Load profiling and analysis
- Power quality monitoring
- Tariff management

7.2.3 CCTV Monitoring

- Visual inspection of equipment
- Security monitoring
- Remote access via smartphone/PC
- Motion detection alerts

7.3 Maintenance Schedule

Interval	Maintenance Task	Responsibility
Monthly	Visual inspection of panels for damage or soiling	Owner
Monthly	Check inverter display for fault codes	Owner
Monthly	Verify battery SoC and performance via app	Owner
Quarterly	Clean PV panels (water and soft brush)	Owner/Contractor
Quarterly	Check all cable connections for tightness	Contractor
Quarterly	Inspect mounting structure for corrosion	Contractor
Annually	Professional system inspection	Contractor
Annually	Electrical safety testing (insulation, earthing)	Contractor
Annually	Inverter firmware update (if available)	Contractor
Annually	Battery health assessment	Contractor
As Needed	Panel cleaning after heavy rain/dust storms	Owner
As Needed	Vegetation trimming to prevent shading	Owner

Table 8: Maintenance Schedule

7.4 Expected Maintenance Costs

Service	Annual Cost
Professional Annual Inspection	R 1,500
Panel Cleaning (4× per year)	R 800
Replacement Parts (avg.)	R 500
Total Annual Maintenance	R 2,800

Table 9: Estimated Annual Maintenance Costs

8 Warranty & Support

8.1 Equipment Warranties

Component	Product Warranty	Performance Warranty
JA Solar PV Panels	12 years	25 years (80% @ Y25)
Huawei Hybrid Inverter	10 years	N/A
Huawei LUNA2000 Battery	10 years	70% @ 6000 cycles
Landis+Gyr Smart Meter	5 years	N/A
Mounting Structure	10 years	N/A
WiFi Router	2 years	N/A
CCTV Camera	2 years	N/A

Table 10: Warranty Summary

8.2 Installation Warranty

UtCS (Pty) Ltd provides:

- **Workmanship Warranty:** 5 years on all installation work
- **Coverage:** Roof penetrations, waterproofing, electrical connections
- **Response Time:** 48 hours for warranty claims

8.3 Technical Support

- **Helpline:** +27 (0) XX XXX XXXX (Mon-Fri, 08:00-17:00)
- **Email Support:** support@utcs.co.za
- **Emergency Support:** Available for critical system failures
- **Remote Diagnostics:** Via FusionSolar platform
- **On-Site Support:** Available within 48 hours (standard) or 24 hours (emergency)

9 Financial Analysis

9.1 Return on Investment

Based on current Eskom tariffs and system performance:

Parameter	Value
System Cost (incl. VAT)	R 49,893
Daily Energy Offset	15 kWh
Monthly Energy Offset	450 kWh
Annual Energy Offset	5,400 kWh
Eskom Tariff (avg. 2026)	R 2.50/kWh
Monthly Savings	R 1,125
Annual Savings	R 13,500
Simple Payback Period	3.7 years
25-Year Savings (NPV)	R 215,000+

Table 11: Financial Analysis Summary

Note: Calculations assume 5% annual tariff increase and do not include maintenance costs. Actual savings may vary based on usage patterns and tariff changes.

9.2 Environmental Impact

Environmental Benefit	Annual Impact
CO ₂ Emissions Avoided	5.13 tons
Equivalent Trees Planted	235 trees
Coal Not Burned	2.16 tons

Table 12: Environmental Impact (25-year lifetime)

Based on Eskom's carbon intensity of 0.95 kg CO₂/kWh

10 Risk Assessment & Mitigation

10.1 Technical Risks

Risk	Impact	Mitigation
Equipment Failure	System downtime, loss of generation	10-year warranties, professional installation, regular maintenance
Shading (trees, buildings)	Reduced generation	Site assessment, shading analysis, MPPT optimization
Roof Damage/Leaks	Water ingress, structural damage	Professional installation, waterproof sealing, 5-year workmanship warranty
Lightning Strike	Equipment damage	AC/DC surge protection, proper earthing system
Grid Instability	Inverter shutdown, power quality issues	Anti-islanding protection, voltage/frequency monitoring
Battery Degradation	Reduced storage capacity	LiFePO4 chemistry (6000 cycles), 10-year warranty, BMS protection

Table 13: Technical Risk Assessment

10.2 Safety Risks

- Electrical Shock:** Mitigated by professional installation, proper earthing, RCD protection
- Fire Hazard:** Mitigated by DC arc fault detection, thermal monitoring, proper cable sizing
- Roof Access:** Mitigated by safe access provisions, fall protection during installation
- Battery Thermal Runaway:** Mitigated by LiFePO4 chemistry, active BMS, temperature monitoring

11 Conclusion

This engineering design presents a comprehensive, budget-compliant solar PV and battery energy storage solution that meets all specified requirements:

Design Achievements

- **Budget Compliance:** R 49,892.75 (0.2% under R 50,000 budget)
- **Energy Requirement:** 18.5 kWh/day capacity (exceeds 15-20 kWh specification)
- **Quality Equipment:** Tier-1 Huawei inverter and battery, JA Solar panels
- **Smart Monitoring:** E460 bi-directional meter, WiFi CCTV, FusionSolar app
- **Full Compliance:** NRS 097-2-1, SANS 10142-1, CoC included
- **Professional Installation:** 3-day installation by qualified electricians
- **Long-Term Value:** 10-year warranties, 25-year PV performance, 3.7-year payback

The system is designed for reliability, safety, and optimal performance in South African conditions. With professional installation, regular maintenance, and comprehensive monitoring, this solution will provide decades of clean, renewable energy.

11.1 Approval & Sign-Off

Prepared by:

C. Nicholls
Professional Engineer
UtCS (Pty) Ltd
Date: February 2, 2026

Approved by:

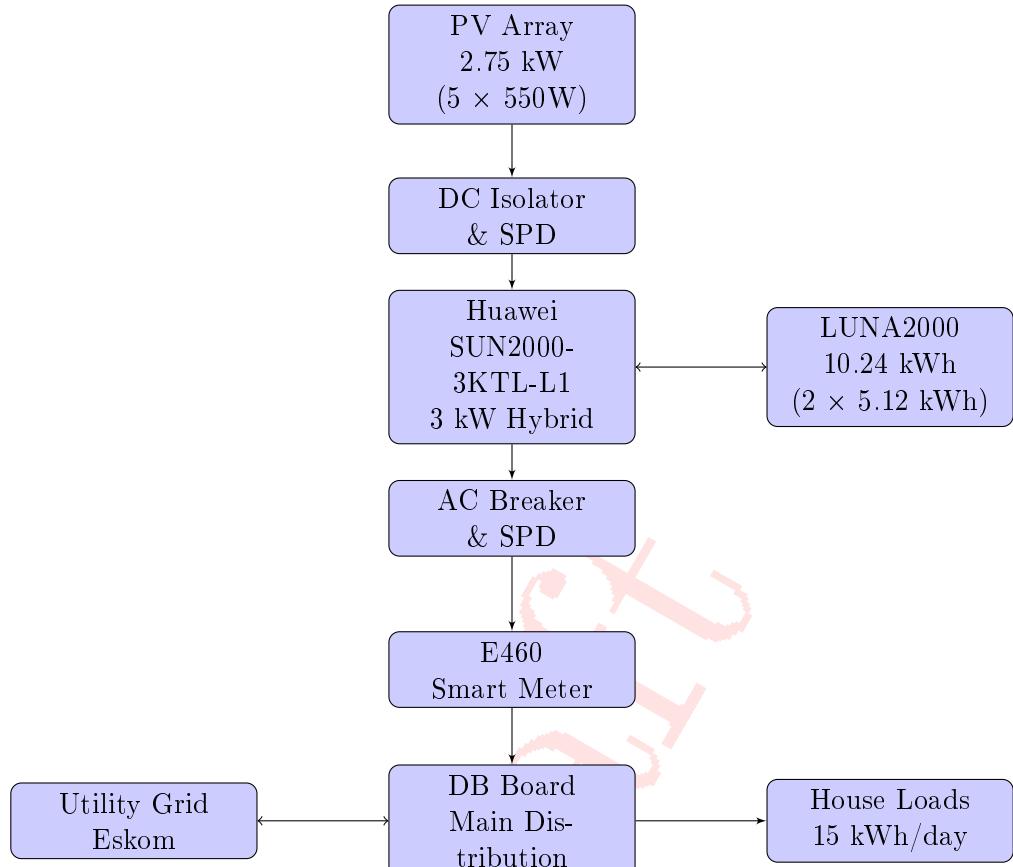
[Client Name]
Client

Date: _____

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A Appendix A: Single-Line Diagram



B Appendix B: Technical Datasheets

[Technical datasheets for all major components would be attached here]

- JA Solar JAM72S30-550W Panel Datasheet
- Huawei SUN2000-3KTL-L1 Inverter Datasheet
- Huawei LUNA2000-5-S0 Battery Datasheet
- Landis+Gyr E460 Smart Meter Datasheet

C Appendix C: Installation Checklist

[Detailed installation checklist would be provided here for use by installation team]

D Appendix D: Commissioning Test Results

[Template for recording test results during commissioning]

Test Parameter	Spec	Result
PV String Voltage (Voc)	230V DC	_____
PV String Current (Isc)	14A DC	_____
Insulation Resistance (DC+)	>1 MΩ	_____
Insulation Resistance (DC-)	>1 MΩ	_____
Earth Resistance	<10 Ω	_____
AC Output Voltage	230V ±10%	_____
AC Output Frequency	50Hz ±1%	_____
RCD Trip Test	<30mA	_____
Anti-Islanding Test	Pass	_____
Battery SoC	50-100%	_____

Table 14: Commissioning Test Template