NIGERIAN ELECTRIFICATION PROJECT

RURAL ELECTRIFICATION AGENCY

ENERGY = EMPOWERMENT = EFFICIENCY

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA)

OF THE PROPOSED

2 MW SOLAR-HYBRID POWER PLANT AND ASSOCIATED INFRASTRUCTURE

At

AIRFORCE INSTITUTE OF TECHNOLOGY (AFIT), KADUNA STATE UNDER THE NIGERIA ELECTRIFICATION PROJECT (DESERT TO POWER) PHASE II

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
AfDB	African Development Bank
AFIT	Air Force Institute of Technology
ALARP	As Low As Reasonably Practicable
API	Area of Potential Project Influence
AQI	Air Quality Index
ASTM	American Society of Testing and Materials
BAU	Business-As-Usual
BESS	Battery Energy Storage System
BOD	Biochemical Oxygen Demand
BOS	Balance of System
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CEDAW	Convention on the Elimination of All Forms of Discrimination Against Women
CHS	Community Health and Safety
CLO	Community Liaison Officer
CoC	Code of Conduct
COD	Chemical Oxygen Demand
COP21	21st Conference of the Parties (UN Climate Change Conference)
COREN	Council for the Regulation of Engineers in Nigeria
CSP	Concentrated Solar Power
DC	Direct Current
DO	Dissolved Oxygen
DCD	Development Control Department
DtP	Desert to Power
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EEP	Energizing Education Program
EHS	Environment, Health and Safety
EMF	Electromagnetic Field
EMS	Environmental Management Systems
EPC	Engineering, Procurement, and Construction
EPRP	Extended Producer Responsibility Program

EPSRA	Electric Power Sector Reform Act
ESIA	Environmental and Social Impact Assessment
ESMF	Environmental and Social Management Framework
ESMP	Environmental and Social Management Plan
E&S	Environmental and Social
ETP	Energy Transition Plan
FAT	Factory Acceptance Test
FCDA	Federal Capital Development Authority
FEC	Federal Executive Council
FGD	Focus Group Discussion
FGN	Federal Government of Nigeria
FMEnv	Federal Ministry of Environment
GBV	Gender-Based Violence
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	German Society for International Cooperation
GMP	Gender Management Plan
GPS	Geographic Position System
GRM	Grievance Redress Mechanism
HCHO	Formaldehyde
HSE	Health, Safety and Environment
ICC	International Code Council
ICT	Information and Communication Technology
IDA	International Development Association
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
ILO	International Labour Organization
ILO-OSH	ILO Guidelines on Occupational Safety and Health
IPCC	Intergovernmental Panel on Climate Change
IsDB	Islamic Development Bank
ISS	Integrated Safeguards System
IUCN	International Union for Conservation of Nature
KASUPDA	Kaduna State Urban Planning and Development Authority
KEPA	Kaduna State Environmental Protection Authority

KII	Key Informant Interview
LEMP	Labour and Employment Management Plan
LGA	Local Government Area
LPAs	Local Planning Authorities
LPG	Liquefied Petroleum Gas
LRP	Livelihood Restoration Plan
LULC	Land Use and Land Cover
MANCAP	Mandatory Conformity Assessment Programme
MDAs	Ministries, Departments and Agencies
MPPT	Maximum Power Point Tracking
MW	Megawatt
NAF	Nigerian Air Force
NBTE	National Board for Technical Education
ND	Not Detected
NDC	Nationally Determined Contribution
NEMSA	Nigerian Electricity Management Services Agency
NEP	Nigeria Electrification Project
NEPP	National Electric Power Policy
NERC	Nigerian Electricity Regulatory Commission
NESREA	National Environmental Standards and Regulations Enforcement Agency
NGO	Non-Governmental Organization
NiMet	Nigerian Meteorological Agency
NPC	National Population Commission
NSE	Nigerian Society of Engineers
NUC	National Universities Commission
NURP	Nigerian Urban and Regional Planning
O&M	Operations and Maintenance
OHS	Occupational Health and Safety
OEM	Original Equipment Manufacturer
ORP	Oxidation-Reduction Potential
OS	Operational Safeguard
PAPs	Project Affected Persons
PCS	Power Conversion System
PM	Particulate Matter

PMU	Project Management Unit
PPE	Personal Protective Equipment
PS	Performance Standards (IFC)
PSRP	Power Sector Recovery Program
PV	Photovoltaic
QA/QC	Quality Assurance/Quality Control
QHSE	Quality, Health, Safety, and Environment
RAP	Resettlement Action Plan
REA	Rural Electrification Agency
REMP	Renewable Energy Master Plan
RETs	Renewable Energy Technologies
SAS	Standalone Solar Systems
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goals
SEA	Sexual Exploitation and Abuse
SEP	Stakeholder Engagement Plan
SLD	Single-Line Diagram
SON	Standards Organisation of Nigeria
SOPs	Standard Operating Procedures
SPM	Suspended Particulate Matter
SPS	School of Postgraduate Studies
TDS	Total Dissolved Solids
TMP	Traffic Management Plan
ToR	Terms of Reference
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
TVOC	Total Volatile Organic Compounds
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
URPC	Urban and Regional Planning Commission
VAPP	Violence Against Persons (Prohibition) Act
VOCs	Volatile Organic Compounds

VRFB	Vanadium Redox Flow Battery
WHO	World Health Organization
WMP	Waste Management Plan
WTCs	Workshop and Training Centres

EXECUTIVE SUMMARY

ES 1 INTRODUCTION

The Rural Electrification Agency (REA), under the Nigeria Electrification Program (NEP) and the African Development Bank (AfDB)-funded Desert to Power Initiative (Phase II), proposes to develop a 2-MW Solar Hybrid Power Project at the Air Force Institute of Technology (AFIT), Kaduna State.

Nigeria faces a significant electricity supply challenge, with installed generation capacity of approximately 12,522 MW but only about 3,879 MW actually reaching consumers. For a country of over 211 million people, this gap results in power rationing, heavy reliance on diesel generators, and constant disruptions to homes, schools, hospitals, and businesses. The Power Sector Recovery Program estimates the annual economic cost at over US$25 billion. Unreliable power directly affects education, healthcare, and overall welfare, making energy access one of the most direct routes to poverty reduction.

The Rural Electrification Agency (REA), established under Section 88 of the Electric Power Sector Reform Act 2005, is the Federal Government agency responsible for promoting and expanding electricity access in unserved and underserved areas across Nigeria. REA implements the Nigeria Electrification Project (NEP), including the Energizing Education Program (EEP), with funding and technical support from development partners including the African Development Bank (AfDB).

AFIT was selected as a beneficiary institution under the NEP Desert to Power Phase II program. The proposed subproject involves the design, supply, installation, testing, and commissioning of a 2 MW Solar Photovoltaic Power Plant and associated infrastructure, including a ground-mounted solar PV array, Lithium-ion Battery Energy Storage System, inverters, power distribution infrastructure, and a renewable energy training centre.

The project is located within the Air Force Institute of Technology (AFIT), Nigerian Air Force Base, Kawo, Igabi Local Government Area, Kaduna State. The institute is situated in the northern sector of the Kaduna metropolitan area, off the Kaduna-Zaria Expressway, and serves both military and civilian students with a focus on aerospace engineering, technology, and related disciplines.

The Environmental and Social Impact Assessment (ESIA) is required under the Environmental Impact Assessment Act (CAP E12 LFN 2004) and complies with Federal Ministry of Environment guidelines, NESREA regulations, and AfDB Integrated Safeguards System requirements. The objectives include establishing baseline environmental conditions, identifying sensitive receptors, assessing potential impacts, recommending mitigation measures, developing an Environmental

and Social Management Plan (ESMP), and ensuring regulatory compliance and stakeholder engagement.

Legal and Administrative Framework

To establish the proposed 2 MW Solar-Hybrid Power Plant, full compliance with applicable Federal, State, and International laws, regulations, guidelines, and conventions is required. Some of the applicable International Conventions Policies, National Laws and State Regulations reviewed for the project are:

- ✓ **Electricity Act, 2023** – The principal legislation governing the generation, transmission, distribution, and supply of electricity in Nigeria. It promotes a competitive electricity market, encourages private sector participation, supports renewable energy development, and requires electricity projects to comply with environmental and regulatory requirements, including obtaining relevant permits and implementing mitigation measures.
- ✓ **Climate Change Act, 2021** – Provides the legal framework for achieving low greenhouse gas emissions and climate-resilient development in Nigeria.
- ✓ **Environmental Impact Assessment (EIA) Act CAP E12 LFN 2004** – Provides the statutory basis for environmental assessment of projects likely to have significant environmental impacts and mandates approval from the Federal Ministry of Environment (FMEnv).
- ✓ **Land Use Act CAP L5 LFN 2004** – Governs land acquisition, land tenure, and land rights in Nigeria.
- ✓ **National Environmental Standards and Regulations Enforcement Agency (NESREA) Act, 2007 and Sectoral Regulations** – Establishes NESREA as the environmental regulatory authority responsible for enforcing environmental standards and compliance.
- ✓ **Employees' Compensation Act, 2010** – Provides the legal framework for compensation in cases of workplace injury, disease, disability, or death.
- ✓ **Electric Power Sector Reform Act, 2005** – Established the framework for reforming Nigeria's electricity industry and restructuring the power sector.
- ✓ **Public Health Act CAP 103 LFN 1995** – Provides measures for the protection of public health.
- ✓ **Natural Resources Conservation Act CAP 349 LFN 1990** – Provides for the conservation and sustainable management of natural resources and biodiversity.
- ✓ **Penal Code Act CAP 53 LFN 2008** – Provides legal provisions applicable to offences and enforcement.
- ✓ **National Policy on the Environment (2016)** – Establishes Nigeria's environmental management principles and sustainable development objectives.
- ✓ **National Energy Policy (2013)** – Promotes energy security, diversification of energy sources, and increased integration of renewable energy.

- ✓ **Nigeria's Nationally Determined Contributions (NDCs) under the Paris Agreement (Updated 2021)** – Commits Nigeria to reducing greenhouse gas emissions by 20% unconditionally and 47% conditionally by 2030 relative to the business-as-usual scenario, while promoting renewable energy and climate resilience.
- ✓ **Roadmap for Power Sector Reform (2010)** – Provides strategic direction for reforms within Nigeria's electricity sector.
- ✓ **EIA Sectoral Guidelines for the Power Sector (2013)** – Provides sector-specific guidance for environmental assessment of power generation, transmission, distribution, and renewable energy projects.
- ✓ **FMEnv EIA Procedural Guidelines (2017, Updated 2021)** – Defines procedures for ESIA preparation, review, public disclosure, and approval in Nigeria.
- ✓ **Guidelines on Environmental Audit (2010)** – Provides the framework for environmental compliance monitoring and auditing.
- ✓ **FMEnv Abandonment and Decommissioning Guidelines (1995, Updated Framework 2017)** – Provides guidance on facility closure, decommissioning, and site restoration.
- ✓ **Kaduna State Environmental Protection Authority (KEPA) Regulations** – Establish environmental management and pollution control requirements applicable within Kaduna State.
- ✓ **Igabi Local Government**– Provide local administrative requirements applicable to development projects within the project area.
- ✓ **African Development Bank (AfDB) Integrated Safeguards System (ISS, 2023)** – Provides a comprehensive framework for environmental and social risk management through ten Operational Safeguards (OS1–OS10), covering environmental assessment, involuntary resettlement, biodiversity, pollution prevention, labour, stakeholder engagement, and other sustainability issues. This ESIA has been prepared in accordance with the applicable requirements of the 2023 ISS.
- ✓ **IFC Performance Standards on Environmental and Social Sustainability (2012)** – International benchmark for managing environmental and social risks in development projects.
- ✓ **United Nations Framework Convention on Climate Change (UNFCCC, 1992)** – International treaty aimed at stabilizing greenhouse gas concentrations and addressing climate change.
- ✓ **Paris Agreement (2015)** – Global agreement under the UNFCCC to limit global temperature rise and strengthen climate resilience.
- ✓ **International Labour Organization (ILO) Conventions** – International labour standards covering occupational safety and health, workers' rights, equality, and decent work.

- ✓ **International Union for Conservation of Nature (IUCN) Guidelines (1996)** – International guidelines supporting biodiversity conservation and sustainable natural resource management.

ES 2 PROJECT JUSTIFICATION

The justification for the proposed 2 MW Solar-Hybrid Power Plant at the Air Force Institute of Technology (AFIT), Kaduna State, is primarily based on the urgent need to provide stable, reliable, and sustainable electricity supply to public tertiary institutions in order to strengthen research output, technological innovation, academic excellence, and institutional productivity.

Due to several factors related to sourcing power from the national grid, organizations and institutions in Nigeria, including tertiary institutions, face persistent electricity challenges characterized by:

- Frequent outages;
- Unstable grid supply;
- High dependence on diesel generators;
- Escalating operational energy costs;
- Disruptions to laboratory experiments and research;
- Limited power availability for workshops and ICT infrastructure.

Nigeria's power sector inadequacies significantly undermine economic growth and development. With over 100 million people lacking access to grid electricity, the country must connect between 500,000 to 800,000 households annually to achieve universal access by 2030. AFIT currently relies on unreliable grid supply supported by expensive diesel-powered backup generators, which drives up operating costs (approximately ₦300 million monthly), causes regular academic disruptions, and contributes to air and noise pollution.

Justification for the Project

National Energy Transition Imperative: The project aligns with Nigeria's Energy Transition Plan (ETP) 2022, which aims to achieve net-zero carbon emissions by 2060 while eradicating energy poverty. The ETP targets decarbonization across five core sectors: Power, Oil & Gas, Cooking, Transportation, and Industry. The project supports the Power sector goals by expanding off-grid solar deployment to critical infrastructure like universities.

Economic Justification: While solar PV requires significant upfront capital, it offers substantial long-term savings compared to diesel generators. Operating costs are much lower as there is no fuel expenditure, maintenance requirements are reduced (solar modules produce electricity for 25-30 years with gradual degradation), and electricity price volatility is eliminated. Studies

consistently show utility-scale solar PV provides a lower levelized cost of electricity than diesel-powered generation over a 25-year project lifecycle.

Environmental and Climate Justification: Diesel-based generation produces greenhouse gas emissions and local pollutants. Replacing diesel with solar PV reduces carbon emissions, noise pollution, and spill risks associated with fuel handling. The project directly contributes to Nigeria's NDC commitment to cut carbon emissions by 20-30% by 2030.

Social and Developmental Justification: Reliable electricity supports enhanced research capacity, improved learning conditions, digital transformation, campus safety, and better water and sanitation services. The project will also develop local technical capacity in renewable energy, provide a live demonstration facility for students, and create short-term employment during construction.

Strategic Alignment: The project fulfills REA's mandate to expand reliable electricity access and promote renewable energy solutions in public institutions. It demonstrates scalable institutional renewable deployment and serves as a model for other tertiary institutions.

Project Benefits:

- Enhanced power availability and reliability
- Economic productivity through reduced downtime
- Job creation during construction and operation
- Clean energy transition and reduced emissions
- Improved campus security through street lighting
- Skills development and technical training
- Stimulation of local economies through spin-off enterprises

Project Options and Alternatives

Project Options (Build vs. No Build):

- **No Project Option:** Rejected - perpetuates energy poverty with no socioeconomic benefits
- **Delay Project Option:** Rejected - no impediments justify postponement
- **Implement Project Option:** Recommended because it delivers clean, reliable energy and maximizes value

Site Alternatives: The selected site within AFIT was chosen based on immediate land availability, high solar irradiation, no resettlement requirements, and proximity to load centers.

Power Generation Alternatives:

- **Continued Reliance on Diesel Generators:** Environmentally unsustainable, economically burdensome, rejected
- **Grid-Only Supply:** Does not resolve reliability challenges, rejected
- **Solar PV:** Best balance of environmental sustainability, economic viability, and strategic alignment, preferred option

Technology Alternatives:

- **Concentrated Solar Power (CSP):** Requires more land, higher costs, higher water consumption
- **Photovoltaic (PV) Solar Panels:** More flexible, lower installation and maintenance costs, preferred option

Battery Alternatives: Lithium-ion batteries are preferred over lead-acid, flow, and nickel-cadmium batteries due to longer lifespan, higher efficiency, deeper discharge capability, and declining costs.

Envisaged Sustainability: The project incorporates technical sustainability (certified personnel, quality assurance, performance monitoring), environmental sustainability (low-impact operation, waste management protocols), economic sustainability (lifecycle cost savings, local economic development), and social sustainability (stakeholder engagement, grievance redress mechanism, health and safety measures).

ES 3 PROJECT DESCRIPTION

The proposed development involves the engineering design, procurement, construction, installation, commissioning, operation and maintenance of a 2-MW solar-hybrid power plant with an integrated Battery Energy Storage System (BESS) within the main campus of the Air Force Institute of Technology (AFIT), situated at the Nigerian Air Force Base, Kawo, Kaduna State. The facility will be interconnected with the Institute's existing electrical distribution network to provide a reliable and sustainable source of electricity for academic, administrative and ancillary facilities across the campus.

The photovoltaic (PV) solar farm will comprise modules mounted on galvanized steel support structures approximately 1.5 metres high. The support assemblies will be connected with angled brackets to steel columns driven into the ground and arranged in arrays that reflect site topography and relevant biological considerations. The PV modules will be electrically connected through wire harnesses and combiner boxes, with underground DC cables feeding the power conversion system.

Project Components:

- Solar PV modules (at least 2,000 units, 415.0 W each)
- Inverters with sufficient aggregate capacity to convert the solar PV output from direct current to alternating current for distribution through the campus electrical network
- Step-up transformer (approximately 415V/11kV configuration)
- Power station/control room
- Underground DC and AC armored cabling
- Smart metering and monitoring systems
- Perimeter security fencing and access control
- Drainage infrastructure
- Battery Energy Storage System (BESS)

Design Characteristics: The system uses polycrystalline silicon PV panels mounted on fixed structures with a tilt angle of 9.0 degrees. The pitch distance is 3.04 meters, with a ground coverage ratio of 32%. The facility will generate direct current (DC) electricity converted to alternating current (AC) through inverters before distribution.

Associated Infrastructure:

- **Access Roads:** 4.0-meter-wide gravel roads totaling 404.09 meters, with drainage ditches
- **Perimeter Fencing:** 1,135.42 meters of chain link fence, 2.0 meters high with 3.0 meters between posts
- **Buildings:** Renewable energy workshop/training centre, residential quarters for security and maintenance staff, guard house, and office/control centre
- **Transmission Line:** Underground 11kV cables to the institution's load center

Implementation Phases:

Pre-Construction Phase (1-2 months):

- Detailed engineering design (plant layout, structural design, electrical single-line diagrams)
- Site surveys and geotechnical investigations
- Procurement and regulatory approvals
- Mobilization of approximately 10 EPC personnel
- Site clearing and grading (minimal vegetation removal)

Construction Phase (6-8 months):

- Installation of mounting structures using pile-driving or shallow concrete foundations
- Installation of PV panels onto mounting frames
- Electrical works including DC cable routing, combiner box installation, inverter installation, earthing and lightning protection

- Testing and commissioning (visual inspection, insulation testing, inverter configuration, performance verification)

Operational Phase (25-year design life):

- Electricity generation through direct conversion of solar irradiance
- Preventive maintenance (panel cleaning, vegetation management, electrical component inspection)
- Corrective maintenance (repair of broken-down equipment)
- Condition-based maintenance (real-time monitoring)
- Performance monitoring via SCADA or web-based systems

Decommissioning Phase:

- Systematic electrical isolation and safe shutdown
- Dismantling of PV arrays, inverters, transformers, and batteries
- Recycling of components through certified facilities
- Site rehabilitation (removal of foundations, back-filling, re-vegetation)

Manpower Requirements: The project will require an estimated workforce of approximately 31-45 workers during construction (20 low-skilled, 10-15 semi-skilled, 6-8 skilled), with preference given to local hires. Operational phase will require 1-2 technicians and 1 O&M supervisor, supplemented by existing campus support staff.

Water Use and Supply: Water is primarily required for periodic cleaning of PV panels to prevent dust build-up. During rainy season, cleaning is estimated to occur not more than three times. During dry season (November to March), cleaning frequency is planned bi-weekly but may increase due to high dust generation. Each PV panel requires approximately 5 litres of water per cleaning cycle, sourced from the university's existing water distribution system.

Health and Safety: REA will implement all reasonable precautions to guarantee worker health and safety, including physical hazard prevention, trip and fall protection, dust exposure control, and electrical hazard management. Only trained and certified personnel will work in potential risk areas. A detailed Occupational Health and Safety Plan has been developed as part of the ESMP.

Emergency Preparedness: The facility will incorporate DC and AC isolation measures, rapid shutdown functionality, inverter protection systems, portable fire extinguishers (CO_2 and dry chemical), emergency shutdown buttons, fire-resistant cable routing, smoke detectors, and lightning protection. Coordination will be established with the institution's Safety Unit and local fire services.

Waste Management: Waste streams from the project include general rubbish, vegetal waste, scrap metals, excavated materials, damaged/expired PV panels, expired inverters, faulty cables, and damaged batteries. All wastes will be managed according to regulatory requirements, with hazardous wastes (batteries, oils, contaminated materials) handled through licensed contractors and e-waste returned to manufacturers under Extended Producer Responsibility schemes.

Contribution to Sustainable Development: The project aligns with several UN Sustainable Development Goals including SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action). By showcasing a replicable clean energy model, the project serves as a catalyst for decentralized renewable energy integration and supports Nigeria's Energy Transition Plan objectives.

ES 4 DESCRIPTION OF THE EXISTING ENVIRONMENT

The ESIA was undertaken during the 2026 wet season and followed a multidisciplinary approach consistent with the requirements of the Federal Ministry of Environment (FMEnv) ESIA Procedural Guidelines. A reconnaissance visit to the project site was conducted on ***Tuesday, 14 July 2026***, while the scoping workshop, site verification and detailed field investigations were carried out on ***Wednesday, 15 July 2026***. Laboratory analyses of environmental samples were subsequently undertaken at the Kano State Ministry of Environment and Climate Change Pollution Control Laboratory, Tarauni, Kano State, using standard analytical procedures supported by Quality Assurance and Quality Control (QA/QC) protocols. To strengthen the baseline and account for seasonal variability, the wet season data were complemented with secondary environmental data sourced from the ESIA of the **2 MW Solar Power** Project at Federal University of Education, Zaria, Kaduna State. This approach enabled comparison between historical and current environmental conditions and improved confidence in the baseline assessment.

The study adopted a combination of desktop review, reconnaissance survey, direct field measurements, laboratory analysis, ecological surveys, stakeholder consultations, key informant interviews, traffic survey and socio-economic questionnaire administration. Environmental sampling employed systematic and simple random sampling techniques depending on the environmental component being investigated. All sampling locations were geo-referenced using a Global Positioning System (GPS).

Considering the relatively small footprint of the proposed 2-MW Solar Hybrid Power Project, a 1-km radius Area of Influence (AoI) was established for both biophysical and socio-economic investigations. The environmental baseline programme comprised:

Climate and Meteorology: The project area lies within the Northern Guinea Savannah climatic zone, with a distinct wet season from April to October and dry season from November to March. Rainfall analysis from 1960 to 2025 shows considerable variability, with August being the wettest month (approximately 310-315mm). Temperature data from 2000 to 2025 indicates a gradual warming trend, with minimum temperatures rising from about 15°C to over 17°C, likely linked to increasing urbanization. Relative humidity averages between 54% and 73%, while wind speeds range from 7.18 to 8.82 m/s.

Air Quality and Noise: Field measurements across twenty sampling points showed generally good air quality. Particulate matter (PM2.5) averaged 8.47 μg/m³, well below both FMEnv and WHO guidelines. The Air Quality Index ranged from "Good" to "Moderate," with no readings in unhealthy categories. Formaldehyde and volatile organic compounds were consistently low. Noise levels ranged from 27.3 to 83.0 dB(A), with all readings below the 90 dB(A) FMEnv limit, though some locations near roads and institutional facilities recorded intermittent elevated daytime noise.

Soil Characteristics: The soil is predominantly ferruginous, brownish to reddish-brown, with sandy loam texture and low humus content. Laboratory analysis of twelve soil samples revealed slightly acidic conditions (pH 6.13-6.94) with low salinity and oxidizing conditions. Heavy metal concentrations were generally low, with iron dominating, while chromium was not detected and lead occurred only at trace levels. Oil, grease, and BTEX were not detected, confirming no petroleum contamination. The soils support moderate natural fertility.

Groundwater and Surface Water: Groundwater from five boreholes was clear, tasteless, and odourless, with generally acceptable physical characteristics. However, some samples showed slight acidity and elevated iron levels (0.02-0.38 mg/L), with four samples exceeding the FMEnv limit of 0.07 mg/L. Cadmium, lead, and mercury showed minor exceedances at some locations. These exceedances should be monitored and considered in the project's water-use and environmental management measures.

Biodiversity: The project area lies within a modified Guinea Savannah ecosystem dominated by agricultural land use. Vegetation includes scattered mature trees (shea, locust bean, neem, mango), shrubs, and grasses. No threatened or endangered species were observed. Fauna is limited to grazing cattle, birds, and active termite mounds, with no wildlife corridors or breeding sites identified.

Socio-Economics: The survey of 41 respondents (65% male, 35% female) showed a youthful population (82.5% under 45 years), predominantly educated (80% with HND/B.Sc.). Most respondents (68.4%) earn ₦120,000 monthly or above. Boreholes supply water to 95.1% of the population, while 97.5% rely on the national grid for electricity. Health facilities include primary

health centres, clinics, and hospitals, with malaria (91.2%) and typhoid (41.2%) as the most common diseases. Most respondents (89.7%) did not expect negative impacts from the project.

ES 5 ASSOCIATED AND POTENTIAL IMPACTS

This section identifies and evaluates the potential environmental and social impacts of the proposed project throughout its lifecycle, using a systematic assessment methodology that combines impact magnitude and receptor sensitivity.

Impact Assessment Approach: The assessment employed a modified Leopold Interaction Matrix, considering project activities against environmental receptors. Impact significance was categorized as Major, Moderate, Minor, or Negligible, determined by combining impact magnitude (Negligible to High) with receptor sensitivity (Low to High).

Positive Impacts Identified:

- Enhanced academic and research activities through reliable power supply
- Reduced fossil fuel consumption and carbon emissions
- Significant cost savings on diesel-generated power (currently ~₦300 million monthly)
- Creation of direct and indirect employment (approximately 31-45 workers during construction, 15 during operation)
- Improved campus security through street lighting
- Establishment of a renewable energy training centre
- Contribution to Nigeria's climate commitments (20-30% carbon reduction by 2030)

Negative Impacts - Pre-Construction Phase:

- Minor loss of vegetation and habitat (impact significance: Minor)
- Temporary air quality and noise impacts from site clearing (Minor)
- Potential soil degradation and erosion (Minor)
- Worker safety risks during mobilization (Minor)

Negative Impacts - Construction Phase:

- Increased noise levels affecting surrounding environment (Moderate)
- Potential gender discrimination and GBV risks (Moderate)
- Influx of workers with associated social and health risks (Moderate)
- Occupational health and safety hazards (Moderate)
- Air quality impacts from construction equipment (Minor)
- Potential soil and groundwater contamination (Minor)
- Traffic and road safety impacts (Minor)

Negative Impacts - Operational Phase:

- Visual landscape changes from solar panels (Minor)
- Occupational health and safety risks (Moderate)
- Gender-based violence and discrimination risks (Moderate)
- Groundwater abstraction for panel cleaning (Minor)

- Waste generation from spent batteries and components (Minor)

Cumulative Impacts: Overall cumulative impacts on road traffic, noise levels, and groundwater availability are considered low, given the limited scale of activities and existing developments in the area.

Risk and Hazard Assessment: Fire and explosion from electrical faults and battery thermal runaway (High risk), electrocution (Moderate risk), and occupational hazards (Moderate risk) were identified as key project risks requiring management.

ES 6 MITIGATION MEASURES

This chapter presents comprehensive mitigation measures for all identified negative impacts and enhancement measures for positive impacts, organized by project phase and receptor type.

Pre-Construction Mitigation:

- Vegetation clearing limited to required areas only, with clear demarcation
- Bush burning prohibited; mechanical clearing preferred
- Re-vegetation of unused cleared areas using native species
- Soil conservation through topsoil stockpiling and erosion controls
- Use of maintained equipment meeting noise and emission standards
- Speed limits of 15-20 km/h on unhardened roads to reduce dust
- Provision of appropriate PPE to all workers

Construction Mitigation:

- Excavation works not conducted during aggressive weather
- Regular water sprinkling for dust suppression
- Construction activities limited to daytime hours (8am-5pm weekdays, 9am-1pm weekends)
- Equipment turned off when not in use; regular maintenance ensured
- Spill control and response plans implemented
- Hazardous materials stored with secondary containment
- Worker training on safe handling of hazardous substances
- Employment open and fair, prohibiting underage workers (under 18)
- Implementation of the EEP GBV Action Plan
- Worker codes of conduct signed; regular GBV training and refreshers
- Separate sanitary facilities for men and women
- Traffic management plan with signage, speed limits, and driver competency assessments
- Health and safety plan with daily toolbox talks, safety officers, and PPE provision
- Awareness education on GBV/SEA/HIV/AIDS for workers and community
- NEP Grievance Redress Mechanism implemented for community concerns

Operational Mitigation:

- Low-level, shielded lighting to reduce light spillage
- Appropriate PPE and safety signage maintained
- Medical insurance provided for employees
- Waste management plan implemented; spent batteries returned to manufacturers under Extended Producer Responsibility
- Water conservation plan for PV panel cleaning
- Continued GBV mitigation through the EEP GBV Action Plan
- Implementation of Standard Operating Procedures
- Grievance mechanism for employee concerns maintained

Enhancement Measures for Positive Impacts:

- Energy conservation measures implemented (switching off appliances, energy-saving bulbs)
- Power distribution priority to academic buildings during learning hours
- Local procurement targets included in Labour and Employment Management Plan
- Training and skills development for local workforce prior to construction
- Gender Management Plan to ensure women benefit from the project

ES 7 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

This section details the comprehensive management framework for implementing mitigation measures, monitoring environmental performance, and ensuring accountability throughout the project lifecycle.

ESMP Objectives:

- Promote environmental and social management
- Ensure compliance with legal and regulatory requirements
- Incorporate environmental and social management into project design
- Provide action plan for environmental and social commitments
- Maintain records of environmental and social performance

Management Roles and Responsibilities:

- REA-PMU: Overall oversight and supervision
- AFIT Director of Physical Planning: Site supervision and ESMP oversight
- AFIT Site Engineer: Direct supervision and compliance monitoring
- EPC Contractor (Construction): Implementation and reporting
- O&M Contractor (Operations): Implementation and reporting
- FMEnv and Kaduna State Ministry of Environment: Regulatory monitoring

- Kaduna State Ministry of Women Affairs and Social Development: GBV monitoring

Additional Management Plans Required:

- Emergency Preparedness and Response Plan ($2,000)
- Traffic Management Plan ($2,000)
- Waste Management Plan ($3,000)
- Occupational Health and Safety Plan ($2,000)
- Local and Employment Management Plan ($1,500)
- Erosion and Sediment Control Plan ($2,000)
- Water Conservation Plan ($1,000)
- EEP Gender Action Plan ($2,000)
- Stakeholder Engagement Plan ($2,000)

Monitoring Programme:

- Air quality and noise: Monthly monitoring during construction
- Groundwater quality: Quarterly monitoring
- Soil quality: Quarterly monitoring
- Solid waste management: Monthly monitoring
- Health and safety: Daily monitoring, quarterly reporting
- Training compliance: Quarterly monitoring
- Housekeeping: Daily monitoring, quarterly reporting
- Stakeholder engagement: Quarterly monitoring

Total ESMP Budget: $66,700

- Pre-construction management: $4,000
- Construction management: $13,500
- Commissioning management: $700
- Operations management: $9,000
- Additional management plans: $17,500
- Capacity building: $3,000
- Monitoring and evaluation: $19,000

Stakeholder Engagement:

The plan establishes a Stakeholder Engagement Plan (SEP) with:

- Stakeholder identification and analysis (government, regulators, communities, institutions)
- Information disclosure through meetings, workshops, and written communications
- Consultation mechanisms including one-on-one meetings, focus groups, and forums
- Grievance Redress Mechanism for community and stakeholder concerns
- Communication tools including newsletters, emails, meetings, and print media

Grievance Redress Mechanism:

A project-specific GRM has been developed, providing:

- Clear channels for raising concerns
- Structured response procedures
- Accessibility for vulnerable groups and people with disabilities
- Documentation and tracking of all grievances
- Timely resolution at the lowest appropriate level

ES 8 REMEDIATION PLAN AFTER DECOMMISSIONING/CLOSURE

This section addresses the end-of-life phase of the project, describing decommissioning activities and the environmental and social management measures required for site closure and restoration.

Decommissioning Activities:

- Dismantling and removal of PV panels, mounting structures, cables, inverters, transformers, and batteries
- Removal of sub-surface installations (underground cables)
- Waste generation and management
- Rehabilitation of impacted environmental components

Management Approach:

- Development of a decommissioning plan approved by FMEnv and relevant authorities
- Risk assessment to identify hazards and special safety concerns
- Implementation of Health, Safety and Environment plan
- Third-party notifications before demolition
- Consideration of socio-economic impacts, including employment termination
- Community capacity building for decommissioning opportunities

Battery Management:

- Lithium-ion batteries classified as hazardous waste
- Extended Producer Responsibility policy adopted: manufacturers responsible for take-back and recycling
- Damaged batteries handled with special expertise (flammable risk)
- Development of end-of-life management plans by the institution
- Engagement of NESREA-certified recycling companies

Abandonment Plan:

- Identification of components to be abandoned or removed
- Methods for abandonment or re-use of equipment
- Mitigation of environmental impacts during abandonment
- Site rehabilitation including re-vegetation with native species
- Close-out report prepared and archived

Decommissioning Mitigation Measures:

- Excavation works not conducted in aggressive weather
- Stockpiles appropriately covered to prevent erosion
- Hazardous materials stored with secondary containment
- PV panels and batteries returned to manufacturers for recycling
- Impacted areas re-vegetated with native species
- Dust suppression measures implemented
- Noise suppression equipment fitted on machinery
- Decommissioning activities limited to daytime hours
- Worker training on safe handling of hazardous materials
- Implementation of waste management plan
- Traffic management plan for transportation of dismantled equipment
- Health and safety plans implemented; PPE provided
- Safety officer engaged to monitor compliance

Roles and Responsibilities:

- Decommissioning Contractor: Implementation of environmental and social measures
- REA-PMU: Supervision of contractor activities
- AFIT Site Engineer/Manager: Direct monitoring and compliance oversight
- Director of Works and Physical Planning: Joint supervision and improvement suggestions
- FMEnv/Kaduna State Ministry of Environment: Approval and monitoring

ES 9 SUMMARY AND CONCLUSION

This chapter provides a comprehensive overview of the entire ESIA process, summarizing key findings and concluding on the environmental acceptability of the proposed project.

Project Context:

The proposed 2MW Solar-Hybrid Power Plant at AFIT Kaduna is part of the Federal Government's Energizing Education Programme (EEP) under the Nigeria Electrification Project. The project aims to provide reliable, sustainable electricity to the university, enhancing teaching, research, and institutional performance while reducing dependence on unstable grid supply and expensive diesel generators (currently costing ~₦300 million monthly).

Key Findings:

- The environmental baseline shows generally good conditions with no significant degradation
- Air quality is good, with all parameters within regulatory limits
- Groundwater quality is generally suitable for various uses
- Soil quality shows no contamination, with low heavy metal concentrations
- The project area has low to moderate ecological sensitivity
- The community is supportive of the project (89.7% not expecting negative impacts)

Positive Impacts:

- Enhanced academic and research activities
- Reduced carbon emissions and fossil fuel consumption
- Significant cost savings on energy
- Employment creation (31-45 during construction, 15 during operation)
- Improved campus security through street lighting
- Renewable energy training centre
- Contribution to Nigeria's climate commitments

Negative Impacts.

All identified negative impacts are minor to moderate in significance and can be effectively mitigated:

- Temporary air quality, noise, and soil impacts during construction
- Occupational health and safety risks
- Potential gender-based violence and discrimination
- Social impacts from workforce influx
- Visual landscape changes
- Waste management challenges (especially batteries)

Conclusion.

The ESIA has been conducted in accordance with FMEnv guidelines and AfDB Safeguard Policies. The assessment demonstrates that:

1. **Environmental Acceptability:** The project is environmentally acceptable with proper mitigation measures in place.
2. **Mitigation Feasibility:** All identified negative impacts can be mitigated to acceptable levels (negligible to minor residual significance) through implementation of recommended measures.
3. **No Significant Issues:** The project does not trigger any physical or economic displacement, no cultural resources are affected, and there are no protected or endangered species at the site.
4. **ESMP Framework:** An Environmental and Social Management Plan has been established to ensure effective implementation of mitigation measures and long-term monitoring.
5. **Regulatory Compliance:** The project meets Nigerian regulatory requirements and international best practices.

CHAPTER ONE
INTRODUCTION

1.1 Project Background

The Government of the Federal Republic of Nigeria has identified access to reliable, affordable, and sustainable electricity as a critical enabler of economic development, social inclusion, educational advancement, and environmental sustainability. Despite significant investments in the electricity sector, many public institutions continue to experience inadequate and unreliable power supply due to grid instability, rising electricity demand, ageing transmission and distribution infrastructure, and the high operating costs of fossil fuel-based backup generation. These challenges are especially significant for tertiary educational institutions, where uninterrupted electricity is essential for teaching, research, digital learning, laboratory operations, administration, healthcare services, security systems, and other critical campus activities.

Recognizing these challenges, the Federal Government of Nigeria (FGN), through the Rural Electrification Agency (REA), has continued to implement strategic renewable energy programmes aimed at expanding access to clean and reliable electricity across underserved communities and public institutions. Key REA initiatives include the Nigeria Electrification Programme (NEP), designed to bridge the national energy-access deficit; the Energizing Education Programme (EEP), which focuses on the education sector; and the Desert to Power Initiative (Phase II), which seeks to accelerate renewable energy deployment across northern Nigeria by harnessing the region's abundant solar energy resources. These initiatives support utility-scale and institutional solar photovoltaic (PV) projects designed to improve electricity reliability, reduce dependence on fossil fuels, lower greenhouse gas emissions, and strengthen national energy security.

The Nigeria Electrification Programme forms part of the African Development Bank's broader engagement in Nigeria's power sector and has laid the foundation for subsequent large-scale renewable energy interventions. Notably, the Nigeria Electrification Programme (NEP) is a precursor to the Desert to Power Initiative, a transformative regional renewable energy programme aimed at harnessing the abundant solar resources of Northern Nigeria to expand electricity access, stimulate economic growth, and strengthen climate resilience.

As part of this initiative, REA proposes the development of a ***2-MW Solar-Hybrid Power Plant*** Project at the Air Force Institute of Technology (AFIT), Kaduna State. The proposed project will comprise a ground-mounted solar photovoltaic array, battery energy storage system, inverter stations, transformer and switchgear facilities, monitoring and control systems, underground electrical cabling, perimeter security infrastructure, and ancillary facilities required for the safe generation, storage, and distribution of electricity. The facility will be interconnected with the existing campus electrical distribution network to provide a reliable, renewable, and environmentally sustainable source of electricity for the university.

The proposed development forms part of the Federal Government's commitment to increasing renewable energy penetration within the national energy mix while supporting Nigeria's Energy Transition Plan (2022), Nationally Determined Contributions (NDCs) under the Paris Agreement,

Sustainable Development Goals (SDGs), and other national policy objectives relating to climate resilience, low-carbon development, and universal access to electricity. By replacing a significant proportion of conventional grid electricity and diesel-generated power with renewable energy, the project is expected to contribute to improved energy security, reduced operating costs, enhanced institutional resilience, and lower greenhouse gas emissions.

The Rural Electrification Agency (REA) commissioned ***Bolben Energy and Environmental Services Limited***, an accredited environmental management firm, to conduct the Environmental and Social Impact Assessment (ESIA) for the proposed project.

Consequently, and in accordance with applicable national environmental legislation, relevant environmental regulations and sectoral guidelines issued by the Federal Ministry of Environment (FMEnv), applicable Nigerian electricity sector regulations, the environmental and social safeguard requirements of the African Development Bank (AfDB), international good industry practice (GIIP), and internationally recognized environmental management principles, this ESIA has been undertaken to establish the existing environmental and socio-economic conditions within the project area, assess the potential impacts associated with the proposed development throughout its lifecycle, and recommend measures to avoid, minimize, mitigate, or compensate for adverse impacts while enhancing positive project outcomes. The study adopts a multidisciplinary approach involving field reconnaissance, geo-referenced site surveys, baseline environmental sampling and laboratory analyses, stakeholder consultations, engineering review, spatial analysis, and regulatory compliance assessment. The assessment integrates engineering, environmental, ecological, social, occupational health and safety, and climate resilience considerations to ensure that the proposed 2-MW Solar Photovoltaic Power project is implemented in an environmentally responsible, socially acceptable, technically feasible, and economically sustainable manner.

1.2 Project Overview

The Air Force Institute of Technology (AFIT), Kaduna is a tertiary institution with a blend of military and civilian staff and students. AFIT is accredited by the National Board for Technical Education (NBTE), National Universities Commission (NUC), Council for the Regulation of Engineers in Nigeria (COREN) and Nigerian Society of Engineers (NSE). The Institute conducts undergraduate and postgraduate programmes in Aerospace Engineering and allied disciplines.

Like most public institutions in Nigeria, AFIT currently relies on an unreliable grid supply supported by diesel-powered backup generators. This drives up running costs, contributes to air and noise pollution within the campus, and causes regular disruptions to academic and administrative work. The FGN, through REA and the Energizing Education Program, identified AFIT as a priority beneficiary for a dedicated clean energy solution under the Nigeria Electrification Project (Desert to Power – Phase II).

The proposed project at AFIT involves the design, supply, installation, testing, and commissioning of a 2 MW Solar Photovoltaic (PV) Power Plant and associated infrastructure. The main components of the proposed project are:

- A ground-mounted, utility-scale solar PV array with an installed generation capacity of 2 MW;
- A Lithium-ion Battery Energy Storage System (BESS) for energy storage and supply stability;
- Inverters, charge controllers, and associated power conditioning equipment;
- A powerhouse building to house electrical and control equipment;
- Low-voltage distribution lines and smart meters to connect the Institute's beneficiary loads; and
- Site fencing, access roads, drainage, and other civil infrastructure within the project footprint.

The objectives of this project are to:

- Improve the reliability, quality, and sustainability of power supply at AFIT to support academic, research, and administrative work;
- Reduce the Institute's dependence on the national grid and on diesel generators, cutting running costs and emissions; and
- Contribute to Nigeria's move toward renewable and low-carbon energy, in line with the Federal Government's power sector commitments.

1.3 The Proponent

REA is a Federal Government agency established under the Electric Power Sector Reform Act (EPSRA) 2005 and now operating within the framework of the Electricity Act 2023, with a mandate to promote and expand electricity access in unserved and underserved rural, peri-urban, and institutional settings across Nigeria. REA designs and implements electrification initiatives that complement the national grid through decentralized, market-oriented power systems, including off-grid and mini-grid solutions that draw on renewable energy technologies. The Federal Government has mandated REA to implement the Nigeria Electrification Project (NEP), including the Desert to Power component and the Energizing Education Programme (EEP).

1.4 Project Location

The proposed 2MW Solar Photovoltaic Power Plant and Associated Infrastructure is located within the Air Force Institute of Technology (AFIT) boundary inside the Nigeria Air Force Base, Kawo, Igabi Local Government Area, Kaduna State, Nigeria. The coordinates fall within:

Point 1: Latitude 10.6189462 and Longitude 7.4359615

Point 2: Latitude 10.6197695 and Longitude 7.4387289

Point 3: Latitude 10.6172334 and Longitude 7.4400739

Point 4: Latitude 10.6163274 and Longitude 7.4370849

1.4.1 National and Regional Context

The state is in the Northern part of Nigeria's high plains. The vegetation cover is Sudan Savannah type, characterized by scattered short trees, shrubs and grasses. The soil is mostly loamy to sandy. The state is bordered by seven states: Zamfara for 117 km (73 miles) and Katsina for 161 km (100 miles) to the north, Kano to the north-east for 255 km, Bauchi and Plateau to the east, Nasarawa and Abuja Federal Capital Territory (for 45 km) to the south, and Niger to the west. Kaduna state is located between latitude 10°38'58" N and 10°25'36" N and to longitude 7°22'14" E and 7°32'00" E.



Figure 1.1: Map of Nigeria Showing the Location of Kaduna State.

1.4.2 Igabi Local Government

Igabi LGA covers approximately 3,222 square kilometres in the central zone of Kaduna State. It experiences a tropical savanna climate with distinct wet and dry seasons and an average annual temperature of about 28°C-32°C.

- Population: Estimated at over 630,000 residents, making it one of the most populous local government areas in Kaduna State.
- Ethno-Religious Profile: The population consists primarily of Hausa, Fulani, and Gbagyi ethnic groups, alongside other resident communities attracted by its proximity to the capital city.
- Administrative Wards (12): Afaka, Birnin Yero, Gadan Gayan, Gwaraji, Igabi, Kerawa, Kwarau, Rigachikun, Rigasa, Sabon Birnin Daji, Turunku, and Zangon Aya.



Figure 1.2: Map of Kaduna Showing Igabi LGA (Highlighted in Light Blue Colouration)

1.4.3 Project Layout

The Air Force Institute of Technology (AFIT) is located in the Kawo area in the northern section of Kaduna metropolis, north-central Nigeria, just off the Kaduna-Zaria Expressway. Its coordinates are approximately **latitude 10.6200040 and longitude 7.4356110**. As part of a military installation, campus access is tightly controlled through guarded checkpoints at the entrances.

Campus Layout & Key Zones

The AFIT campus blends military structure with university-style academic facilities and is arranged into the following primary functional sectors:

Academic & Research Zone

- Faculties and departments: Hosts specialized academic schools including the Faculty of Air Engineering; Faculty of Ground & Communication Engineering; Faculty of Computing; Faculty of Sciences; and Faculties of Social & Management Sciences.
- School of Postgraduate Studies (SPS): Facilities for advanced research, aerospace vehicle design, and postgraduate training.
- Laboratories and hangar infrastructure: Specialized engineering workshops, aerodynamics labs, foundry areas, and aircraft maintenance hangars for practical aeronautical and mechatronics training.
- School of Basic and Remedial Studies: Provides preparatory programs such as IJMB and pre-degree courses.

Administrative Sector:

- Administrative core: Offices for the Commandant, Provost, Deans, and military administrative staff.
- Parade grounds and ceremonial areas: Central open spaces used for military parades, matriculation, pass-out ceremonies, and official gatherings.

Residential Sector: This sector houses:

- Student hostels: Separate accommodation blocks for civilian and military students, including civilian halls within the base precincts.
- Staff quarters: On-base housing for military officers, instructors, and resident academic staff.

Support Facilities & Recreation

- Library and IT center: Central e-library services and computing labs supporting distance and on-campus learning.

- Medical and commercial facilities: Access to the Nigerian Air Force Base Medical Centre, sports complex, officers' mess, and internal catering services.

Plate 1.1 shows the Airforce Base Front Gate Entrance and;
Plate 1.2 shows the AFIT Entrance Gate.



Plate 1.1: Airforce Base Entrance
***Source** : Bolben Ltd. Fieldwork Survey, 2026.*

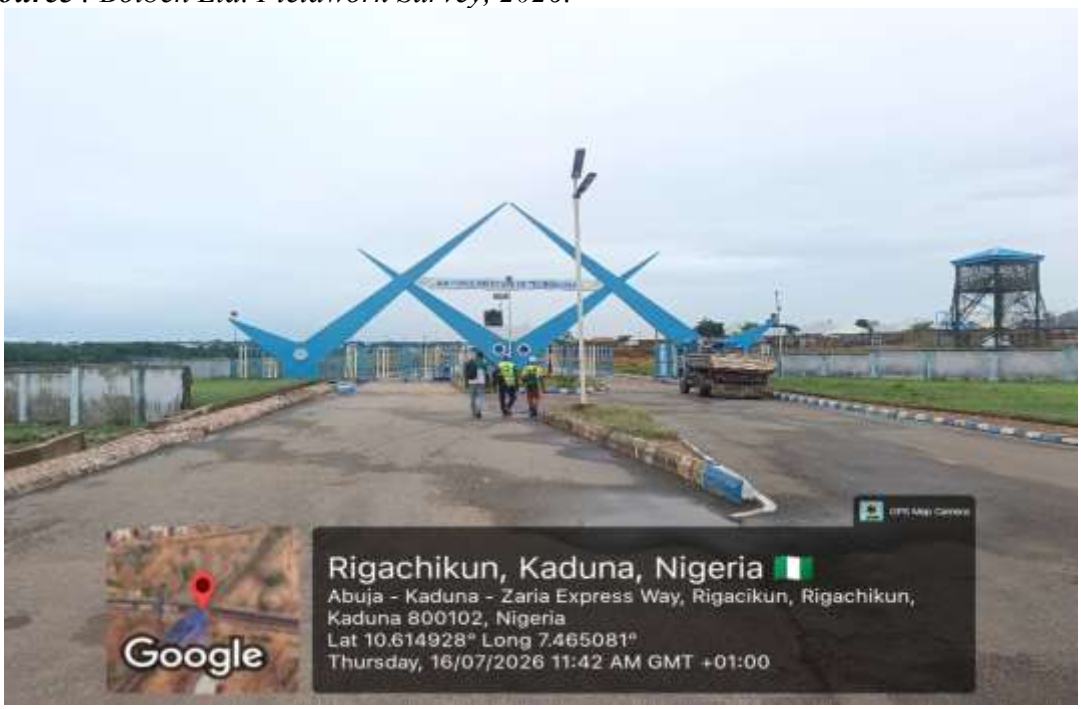


Plate 1.2: AFIT Entrance Gate

1.5 Rationale and Objectives of the ESIA Study

The proposed 2 MW Solar-Hybrid Power Plant project falls under renewable energy developments and requires environmental impact assessment under the provisions of the Environmental Impact Assessment Act (CAP E12 LFN 2004). The Act mandates that public and private projects likely to have significant environmental effects undergo a comprehensive impact assessment before implementation. In addition, the project must comply with the Federal Ministry of Environment EIA Procedural Guidelines, National Environmental Standards and Regulations Enforcement Agency Regulations, the Climate Change Act, and the AfDB Integrated Safeguards System.

The ESIA provides a structured, participatory framework for identifying, predicting, evaluating, and managing potential impacts linked to development activities. For this 2MW Solar Photovoltaic Power Plant at AFIT, the specific objectives of the ESIA are to:

- Establish the existing environmental and socio-economic baseline within the Project Area of Influence (AoI);
- Identify environmentally and socially sensitive receptors within and around the project site;
- Assess potential positive and negative impacts during pre-construction, construction, commissioning, operation, and decommissioning;
- Check compliance with applicable national environmental laws, regulations, and AfDB safeguard requirements;
- Carry out stakeholder engagement, including consultation with Project Affected Persons (PAPs) and other interested parties;
- Identify environmental, social, health, and economic risks early to help refine project design;
- Determine whether a Resettlement Action Plan (RAP) or Livelihood Restoration Plan (LRP) is needed;
- Recommend practical mitigation measures to avoid, reduce, or offset adverse impacts;
- Develop an Environmental and Social Management Plan (ESMP) covering the full project lifecycle; and
- Provide a clear basis for regulatory review, disclosure, and ongoing compliance monitoring.

This ESIA is a required part of the project approval process and ensures that environmental and social risks are properly identified, assessed, and managed before project implementation.

1.6 Scope of the ESIA Study/Terms of Reference

The scope of the ESIA study covers the following:

- Review of applicable local and international laws, regulations, standards, and industry codes that apply to the proposed Project.

- Description of all activities that will be carried out during project development and implementation.
- Desktop review of relevant documents on the Project and the environment where it will be located, including the NEP Environmental and Social Management Framework (ESMF), among others.
- Field data collection covering the biophysical and socio-economic components of the Project's Area of Influence.
- Consultations with relevant stakeholders, including government institutions, project affected persons, and AFIT management representatives. Details of stakeholder consultations are documented in Chapter 4 of this report.
- Laboratory analysis of field samples, impact identification and evaluation, and development of appropriate mitigation measures and an Environmental Management Plan.
- Perimeter survey of the project site, including the preparation of survey maps.
- Report preparation and disclosure.

1.6.1 Spatial Scope

The ESIA covers the project footprint and the Area of Potential Project Influence (APPI), including adjacent buildings, boreholes, drainage pathways, and access roads.

1.6.2 Temporal Scope

This covers all aspects of the project from pre-construction through construction, operation with a 25-year lifespan, and decommissioning.

1.6.3 Thematic Scope

This includes the Physical environment (climate, air quality, soil, water, noise); Biological environment (flora and fauna); Socio-economic environment (population, livelihoods, health, land use); Occupational health and safety; Climate change implications; and Cumulative impacts.

The assessment was conducted using one-season wet-season baseline data and available secondary information. The study covered both suggested sites, and no significant limitations were encountered that compromise the integrity of the EIA.

1.7 ESIA Study Approach / Methodology

This ESIA was carried out in line with the Federal Ministry of Environment (FMEnv) EIA Procedural Guidelines for off-grid and mini-grid projects under the Nigeria Electrification Project (NEP). The study also follows the African Development Bank (AfDB) Integrated Safeguards System and relevant international best practices.

The methodology used for the ESIA included:

- Reconnaissance survey to understand site-specific environmental and social conditions;
- Desktop review of relevant program and regulatory documents;

- Scoping consultations with the Institute authorities and key stakeholders to identify major issues and concerns;
- Field data collection on noise, air quality, soil, groundwater, vegetation, wildlife, and socio-economic conditions;
- Laboratory analysis of collected samples;
- Identification and assessment of environmental and social risks;
- Development of mitigation measures and preparation of the Environmental and Social Management Plan (ESMP);
- Report preparation and submission; and
- Facilitation of regulatory review and public disclosure.

The general methodology used in this ESIA is shown in Figure 1.3. Detailed descriptions of each activity are presented in the chapters that follow. The process was carried out to ensure transparency, regulatory compliance, technical rigour, and effective stakeholder participation throughout the assessment.



Figure 1.3: Schematic Presentation of the General ESIA Methodology

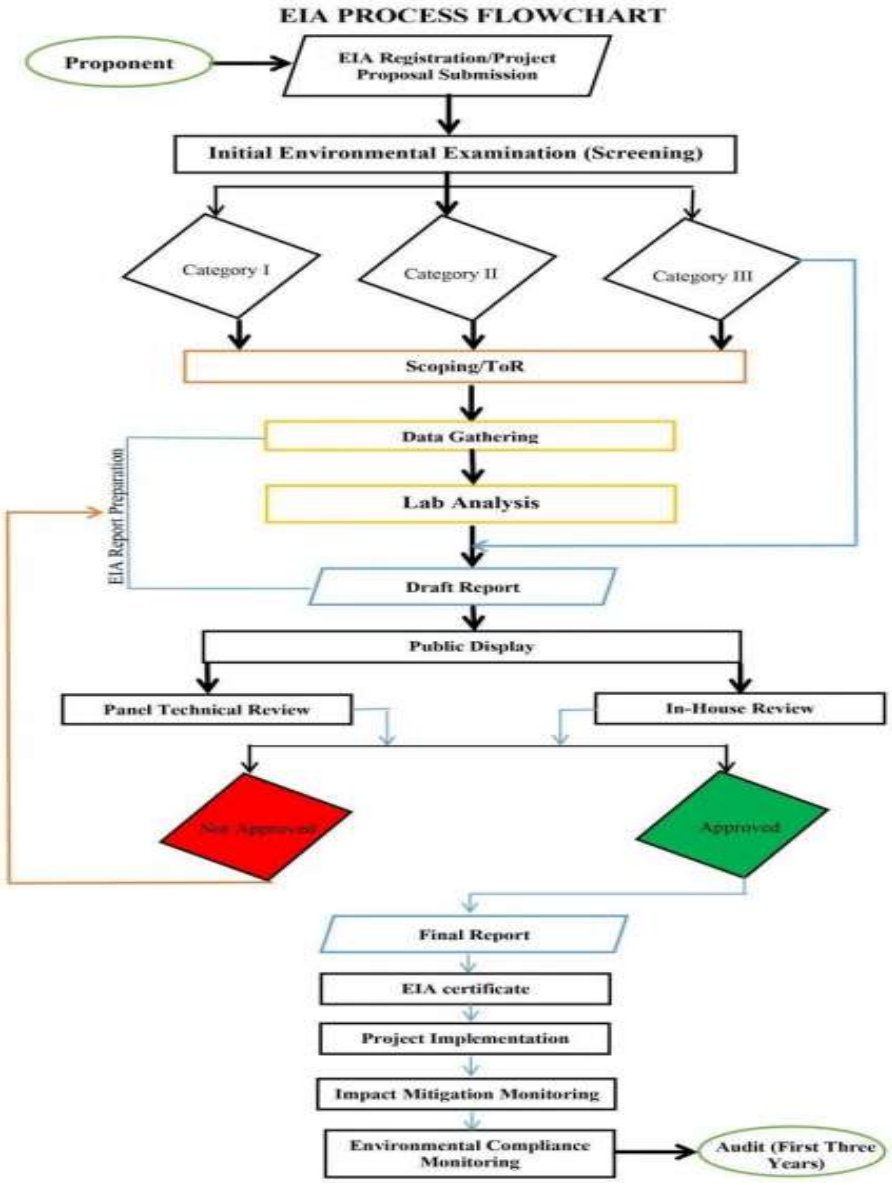


Figure 1.4: Federal Ministry of Environment EIA Flowchart

***Source**: Environmental Assessment Department, Federal Ministry of Environment*

1.7.1 Limitations of the ESIA Study

This ESIA was conducted in line with FMEnv EIA Guidelines and the AfDB's safeguard requirements. It was designed to identify, predict, and evaluate potential environmental and social impacts of the proposed 2MW Solar Photovoltaic Power Plant at AFIT, and to recommend appropriate mitigation measures. That said, some limitations are inherent in any ESIA process, and professional assumptions have been applied where necessary to fill information gaps. Potential sources of uncertainty include:

- The level of engineering detail available at the time of assessment, particularly where final design specifications are still being refined;
- Natural variability in environmental parameters like weather conditions, ecological distribution, and socio-economic dynamics;
- Predictive limitations built into impact assessment methods; and
- Constraints on baseline data collection, especially given seasonal variation in some environmental parameters.

As a result, there may be some uncertainty around the exact magnitude, duration, or spatial extent of certain predicted impacts. However, these uncertainties are not expected to change the overall conclusions of this assessment. To manage them, a comprehensive Environmental and Social Management Plan (ESMP) has been developed with monitoring mechanisms, adaptive management provisions, and clear institutional responsibilities. This makes it possible to identify and respond to any unforeseen impacts as they arise.

1.8 Policy, Legal and Administrative Framework

The proposed 2MW Solar Photovoltaic Power Plant at AFIT, Kaduna, is subject to a range of national policies, laws, and administrative frameworks, as well as the safeguard requirements of the AfDB as co-financier. This section covers only those instruments that are directly relevant to the project, and explains how each one applies. The project will comply with all applicable requirements throughout its life cycle.

1.8.1 National Policy Frameworks

1.8.1.1 Constitution of the Federal Republic of Nigeria, 1999

Section 20 of the Constitution makes it a state objective to protect Nigeria's air, land, water, forests, and wildlife. Sections 33 and 34 guarantee rights to life and human dignity, which extend to a safe working and living environment. This ESIA is prepared in part to uphold these constitutional obligations, particularly as they apply to the University community and to workers during construction.

1.8.1.2 National Policy on the Environment (Revised 2016)

The National Policy on the Environment requires that all development activities protect the natural and built environment and manage resources efficiently. As a development activity on the AFIT campus, the proposed solar PV plant must be planned and implemented to minimize environmental disruption and promote sustainable resource use, consistent with this policy's overarching goal of balancing development with environmental protection.

1.8.1.3 National Electric Power Policy (NEPP), 2001

The NEPP provided the policy foundation for Nigeria's power sector reform, leading directly to the EPSRA 2005 and the creation of REA. It is the policy basis on which the Energizing Education

Programme and this type of captive institutional renewable energy project rest. REA's mandate to plan and implement this subproject flows from the reform trajectory initiated by the NEPP.

1.8.1.4 National Climate Change Policy for Nigeria, 2021-2030

This Policy commits Nigeria to low-carbon and climate-resilient development. The proposed 2 MW solar PV plant directly supports this commitment: replacing diesel-based backup generation with renewable energy reduces the Institute's greenhouse gas emissions and contributes to Nigeria's nationally determined contributions under the Paris Agreement.

1.8.2 National Legal Framework

1.8.2.1 Environmental Impact Assessment Act No. 86, 1992 (CAP E12 LFN 2004)

This Act is the primary legal basis for this ESIA. It requires an environmental impact assessment before commencing any development likely to have significant environmental effects. The proposed power plant at AFIT is classified as a Category II (B) project under FMEnv's categorization. This report is prepared in compliance with the Act and with the procedural and sectoral guidelines issued by FMEnv under its authority.

1.8.2.2 Electric Power Sector Reform Act (EPSRA), 2005

The EPSRA established REA under Section 88 as the project proponent, giving it the mandate to develop off-grid and institutional power infrastructure. Part IV of the Act covers licensing for electricity generation above defined thresholds. The proposed 2 MW plant is a captive installation serving AFIT's internal load; the applicable licensing position under the Act will be confirmed with the Nigerian Electricity Regulatory Commission (NERC) during project development.

1.8.2.3 Land Use Act CAP 202, Laws of the Federation of Nigeria 2004

The Land Use Act CAP 202 LFN 2004 plays a foundational role in shaping urban and regional planning in Nigeria ‘s cities and towns by centralizing land administration and governance while enabling structured development. The Act vests ownership of urban land in state governors, who grant statutory rights of occupancy. This centralizes decision-making for urban expansion and infrastructure projects, reducing fragmented ownership disputes common in large cities and towns (Ofubu, 2018). Furthermore, by embedding conditions (e.g., building heights, land subdivision, road setbacks, etc.) in Certificates of Occupancy, the Act enables enforceable zoning regulations, ensuring orderly urban growth and preventing incompatible land uses (Aribigbola, 2008; Ofubu, 2018).

The provisions of the Land Use Act limit individual land holdings, aiming to curb speculative practices that inflate land prices and hinder affordable housing development. Also, by transferring land ownership from indigenous communities to the state, the Act seeks to reduce ethnic-based land conflicts in urban areas, facilitate equitable access for non-indigenous populations, and provide the legal backbone for implementing regional plans, including Master Plans for towns and

cities. Through conditions in occupancy certificates, the Act indirectly supports environmental protection by mandating compliance with development standards such as setbacks and green spaces. In essence, the Act constitutes the governing policy for land acquisition in all states in Nigeria. As is the case with most national and state laws on compulsory acquisition of land in the public interest or for a public purpose, the legislation enables the State to acquire land. However, the Act also specifies the procedures the State must follow to clear land and defines the compensatory measures required for affected people.

The Act governs all land administration in Nigeria. Within Kaduna, land is vested in the State Government and administered by the Executive Governor. AFIT holds its campus under an institutional right of occupancy. Since the entire project footprint sits within land already allocated to AFIT, the Act's provisions on land acquisition, revocation, and compensation are not expected to be triggered. The Act nonetheless provides the governing land tenure framework for the project site.

1.8.2.5 Nigerian Urban and Regional Planning Act, CAP N138, Laws of the Federation of Nigeria 2004.

The Nigerian Urban and Regional Planning (NURP) Act CAP N138, LFN 2004 was essentially a reform of the preceding Town and Country Planning Law of 1946 which focused on separate regions. The NURP Act was aligned closely with provisions of the Land Use Act of 1978, which centralized land administration through legislation with national coverage. The six parts of the Act cover different aspects of physical planning and the procedures and institutions outlined to attain it beginning with Part 1 Plan Preparation and Administration; Part 2 Development Control; Part 3 Additional Control in Special Areas; Part 4 Acquisition of Land and Compensation; Part 5 Renewal, Rehabilitation, and Upgrading; and, Part 6 Appeals. The law was designed to be the source of subsisting laws to be enacted in all 36 states of Nigeria, with basic provisions for an institutional framework, types of plans and operational principles that mirror it directly. It states the main institutional framework for this as follows:

a Local purposes of the initiation, preparation and implementation of the national Master Plans, the Federal, State and Local governments shall establish and maintain respectively - (a) a National Urban and Regional Planning Commission; (b) a State Urban and Regional Planning Board in each of the States of the Federation and the Federal Capital Territory, Abuja; and (c) a Local Planning Authority in each of the local government areas and the area councils of the Federation".

The administrative structure provides for an umbrella national institution known as Urban and Regional Planning Commission (URPC) domiciled at the national level and four parallel institutions replicated at the national, state, and local levels and the Federal Capital City, Abuja.

This includes the Urban and Regional Planning Boards in the 36 states, the Federal Capital Development Authority (FCDA) in Abuja, the Local Planning Authorities (LPAs), the Development Control Departments (DCDs), and the Appeals Tribunals. The URPC is the main policy institution responsible for urban planning policies for the country, preparing national Master Plans, conducting research, as well as being the anchor for coordinating the activities of other institutions in the states.

In Specific terms, the Act aims at overseeing a realistic, purposeful planning of the country to avoid overcrowding and poor environmental conditions.

- Section 30 (3) requires a building plan to be drawn by a registered architect or town planner.
- Section 39 (7) establishes that an application for land development would be rejected if such development would harm the environment or constitute a nuisance to the community.
- Section 72 provides for the preservation and planting of trees for environmental conservation.

1.8.2.6 Climate Change Act of 2021

The Climate Change Act was enacted in November 2021 in order to provide Nigeria with a legal framework to achieve its climate goals, achieve long-term social and economic sustainability, and resilience. The law sets a target for net zero GHG emissions for year 2050 - 2070. While the Act provides this broad timeline for long-term sustainability, Nigeria ‘s broader Energy Transition Plan (ETP) aims for a specific, more ambitious net-zero target by 2060 (Federal Government of Nigeria, 2021a). The Act mandates the government to set a National Climate Change Action Plan and a five- year carbon budget (with quantified annual objectives) accordingly. Both of these are to be validated by the Federal Executive Council.

Nigeria’s ETP is a home-grown, data-backed, multi-pronged strategy developed for the achievement of net-zero emissions in terms of the nation’s energy consumption, sets out a timeline and framework for the attainment of emissions’ reduction across 5 key sectors; Power, Cooking, Oil and Gas, Transport and Industry, affecting about 65% of Nigeria’s emissions within its scope.

At the core of the ETP are the following imperatives:

- Lifting 100 million Nigerians out of poverty and driving economic growth;
- Bringing modern energy services to the full population;
- Managing the expected long-term job loss in the oil sector due to the reduced global fossil-fuel demand;
- Playing a leadership role for Africa by promoting a fair, inclusive and equitable energy
- Transition in Africa that will include Gas as a ―transitionary fuel‖; and,
- Streamlining existing and new government related energy transition initiatives.

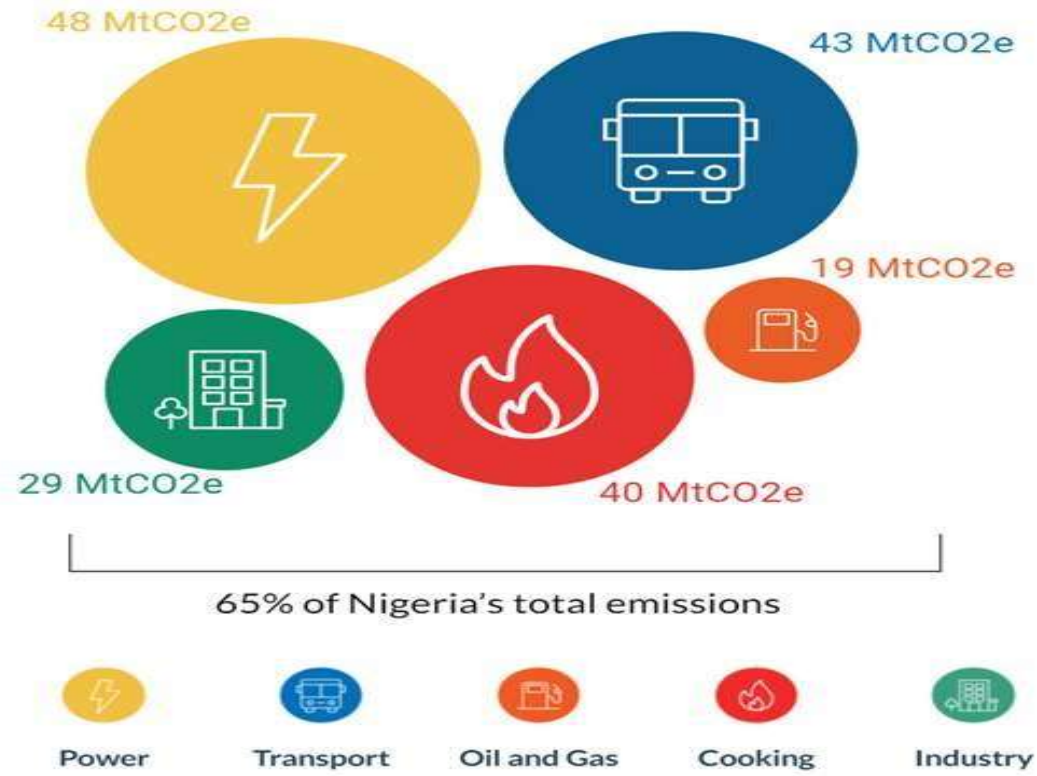


Figure 1.5: The Nigeria Energy Transition targets a net zero environment by 2060
(**Source**: FGN, 2021a)

Nigeria's net-zero pathway will result in significant net job creation with up to 340,000 jobs created by 2030 and up to 840,000 jobs created by 2060 driven mainly by the Power, Cooking and Transport sectors (Figure 1.6). Gas will play a critical role as a transition fuel in Nigeria's net-zero pathway particularly in the Power and Cooking sectors. Nigeria's energy transition creates significant investment opportunities such as the establishment and expansion of industries related to solar energy, hydrogen, and electric vehicles.

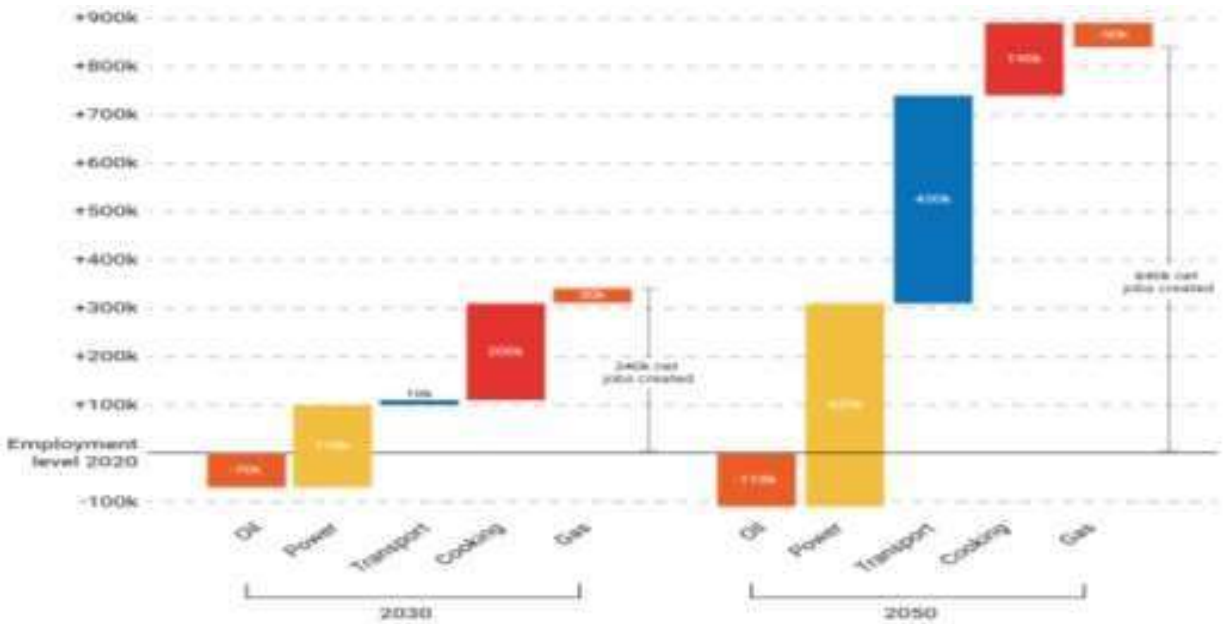


Figure 1.6: Net job creation per sector under Nigeria's net-zero scenarios for 2030 and 2060 (Source: FGN, 2021a)

1.8.2.7 NESREA Act, 2007, and Applicable Subsidiary Regulations

The NESREA Act empowers the Agency to enforce environmental standards and prohibit unauthorized discharge of hazardous substances (Section 27). The following subsidiary regulations issued under the Act apply directly to project activities:

- National Environmental (Energy Sector) Regulations, 2014 (S.I. 63) - sets environmental standards for energy generation facilities, including solar installations;
- National Environmental (Electrical/Electronic Sector) Regulations, 2011 (S.I. 23) - applies to the procurement, installation, and end-of-life management of PV modules, inverters, and battery storage;
- National Environmental (Noise Standards and Control) Regulations, 2009 (S.I. 35) - sets permissible noise levels applicable to construction activities and operational equipment on campus;
- National Environmental (Air Quality Control) Regulations, 2013 (S.I. 64) - governs dust and exhaust emissions from construction plant and vehicles;
- National Environmental (Sanitation and Wastes Control) Regulations, 2009 (S.I. 28) - applies to construction waste management and site housekeeping; and
- National Environmental (Surface and Groundwater Quality Control) Regulations, 2010 (S.I. 22) - relevant to the risk of battery chemical leakage affecting drainage or groundwater near the site.

1.8.2.8 Harmful Waste (Special Criminal Provisions) Act (CAP H1 LFN 2004)

This Act prohibits the unlawful dumping or depositing of harmful waste on land, in water, or in the air. It applies directly to the management of spent PV modules, battery components, and other hazardous waste generated by the project. The contractor and plant operator working on the project within the university must ensure all such materials are properly stored, transported, and disposed of through licensed channels.

1.8.2.9 Factories Act (CAP F1 LFN 2004), Labour Act (CAP L1 LFN 2004), and Employee Compensation Act, 2010

These three instruments govern the welfare, safety, and rights of workers engaged on the project. The Factories Act requires construction and operational sites to meet occupational health and safety (OHS) standards. The Labour Act sets conditions for wages, recruitment, and the protection of women and young persons. The Employee Compensation Act requires compulsory insurance covering all workers in the event of injury or death. Together, they apply to the construction contractor's workforce and, during operation, to AFIT's plant maintenance staff.

1.8.2.10 National Commission for Museums and Monuments Act

This Act protects cultural heritage and requires that any artefact or antiquity discovered during excavation be reported to the National Commission for Museums and Monuments within seven days. Although no cultural heritage sites are known within the project footprint, ground disturbance during civil works creates a residual risk of chance finds. A chance-find procedure is included in the ESMP in line with this requirement.

1.8.2.11 FMEnv EIA Procedural Guidelines and EIA Sectoral Guidelines (Energy Sector)

The EIA Procedural Guidelines set out the required steps for preparing and submitting an ESIA in Nigeria. The Sectoral Guidelines for the Energy Sector provide additional technical requirements for power generation projects. This ESIA and its ESMP have been structured to comply with both documents, which also govern the formal regulatory submission to FMEnv.

1.8.2.12 Violence Against Persons (Prohibition) Act, 2005.

The Violence Against Persons (Prohibition) Act (VAPP) was passed into law in May 2015. The Act was necessitated by advocacy for the protection of persons against different forms of violence. It strengthens legal protection against rape, female genital mutilation, partner battery, stalking, harmful widowhood practices, and other forms of physical, sexual, psychological and domestic violence, including harmful traditional practices and discrimination. It also provides protection and remedies for victims and punishment for offenders.

1.8.2.13 Penal Code Act of Nigeria 2004

The Act makes it an offence punishable with up to 6 month's imprisonment for any person who:

- Violates the atmosphere in any place to make it noxious to the health of persons in general dwelling or carry on business in the neighborhood, or passing along a public way; or
- Does any act which is, and which he knows or has reason to believe to be, likely to spread the infection of any disease dangerous to life, whether human or animal.

Other National Regulations that are applicable to this project include:

- National Guideline and Standard for Environmental Pollution Control (1991)
- Abandonment Guideline (FMEnv Sectoral Guidelines, 1995)
- Electricity (Private Licences) Regulations, 1965;
- Electricity (Annual Returns) Regulations, 1974;
- Electricity Installation Regulations, 1996;
- Electricity Supply Regulations, 1996;
- Energy Commission of Nigeria Act, Cap 109 LFN 1990;
- Utilities Charges Commission Act No. 104 of 1992;
- Trade Union Act (2005)
- Trade Dispute Act (2004)
- Public Health Law Act (CAP 103 LFN 47 1995)

1.8.3 State Legislation, Policy and Regulations

1.8.3.1 Kaduna State Legislation and Local Government Byelaws

The project site sits within Igabi Local Government Area making it subject to the administrative authority of the Kaduna State Government alongside federal oversight.

1.8.3.2 Kaduna State Environmental Protection Law No. 7 of 2010

Initially cited as Edict No. 1 of 1998, the Kaduna State Environmental Protection Authority Law No. 7 of 2010 confers on the Authority general responsibility for all matters relating to the environment. Of specific relevance to the proposed 2 MW Solar-Hybrid Power Plant at AFIT, KEPA is expected to:

- Enact and enforce State regulations, procedures, guidelines and environmental standards for effective -prevention, remediation, control and monitoring of point and non-point source of pollution and degradation;
- Implement, and review environmental policy in the State and in particular to demand and review environment impact assessment and statement and for new development projects and to also demand review environmental audit reports for existing developments and such other operations which are deemed to have significant impact on the environment;

- Prepare in accordance with the State policy and Law on the environment periodic master plans for the development and financial requirements for implementation of such plans;
- Prevent or stop any act or omission which consequences are likely to diversely affect the environment and to generally deal with any discharge either solid, liquid or gaseous materials deposited willfully or otherwise in the environment and to deal generally with any violation which the Authority may deem hazardous to the environment and the ecosystem, and shall in particular:
    - monitor the whole parts of the State for any such discharge;
    - cause the Responsible parties to stop or remove such discharge;
    - remove or cause or be removed such discharge at the expense of the defaulting party;
    - penalty to be paid in accordance with appropriate regulations;
    - reinstate, rehabilitate or cause the effect environment to be removed
    - to its original state at the expense of the responsible parties;
    - approve landscaping for all and drainage plans on new developments; and,
    - grant final approval.
- Monitor environmental quality, conduct programmes for continuing surveillance and of regular periodic inspection of actual or potential contaminants of point and non-point sources of environmental pollution in accordance with the laid down regulations as the Authority may deem fit;
- To liaise with Federal, State, Local Government and other public and private authorities, agencies and institutions engaged in environmental planning and functions;
- Research, collect information and research findings in various environment disciplines.
- Develop libraries and archives, and to establish and maintain a database on environment; Stimulate public interest on environment by public awareness, campaign and generally encourage environmental education programmes in schools, mass media and other formal and informal sectors;
- Where feasible, conduct training programmes for industrial, commercial and public institutions and or recruit or train environmental extension workers and staff of the Authority for the purpose of effective mobilization of the public towards environmental education and awareness;
- Issue permits, licenses, approvals and to issue certification and operation levies for the issuance of such permits, license, approval and certifications as the authority may from time to time prescribe.
- Establish and maintain close liaison and linkages with major research and scientific institutions, professional associations, experts and consultants as well as government and non-governmental organizations in the field of environment; investigate and ascertain all

violation of this law and, or relevant rules and regulations under the law and prosecute or to be prosecuted such violators;

- Demand to access to any public or private property or premises at all reasonable time enter upon for the purpose of inspecting and investigating for ascertaining any violations or potential violations;
- Establish Zonal Offices in the State and constitute joint consultative committee with the Federal and Local Governments, for the purpose of operating, administering and enforcing the provision of any existing law and regulations and or any enactment relating to environment generally.

1.8.3.3 Kaduna State Urban Planning & Development Authority (KASUPDA), 2018

The Kaduna State Urban Planning and Development Authority (KASUPDA) Act of 2018 tasked KASUPDA with regulating orderly growth in designated urban areas of the state like Kaduna, Zaria, Kafanchan, etc. KASUPDA formulates state urban planning policies aligned with national frameworks, preparing master plans, local plans, and subject-specific strategies (e.g., zoning, renewal, etc.), and also exercises development control by issuing planning permits, approving building layouts, and enforcing compliance to prevent unauthorized constructions and slum proliferation. Furthermore, the Authority oversees physical developments, outdoor advertisements (in collaboration with LGAs), and subdivision approvals, sealing violations and imposing sanctions like fines or demolition. It conducts research on urban trends including transport infrastructure standards/development, and engages stakeholders through public inquiries for plan adoption.

The Authority is led by a Board Chairman and members (appointed by the Governor of the State), and also maintains a Planning Permit Tribunal for disputes and generates revenue via fees, grants, and levies. It advises on land use, urban renewal, and integrates climate resilience, ensuring sustainable aesthetics and liveability amid Kaduna's urban population growth. This mandate, rooted in the 2018 Act, positions KASUPDA as Kaduna's primary enforcer of spatial order, bridging policy with on-ground execution for economic vitality and safety.

1.8.3.4 Kaduna State Environmental Protection Authority (KEPA) Regulations 1-7, 2011

In exercise of the powers conferred upon KEPA by Section 13 of Kaduna State Environmental Protection Law No. 7 of 2010, a number of regulations were made to further guide persons and corporate entities whether public or private, on environmental matters. These regulations, which took effect on 1st January 2011, are all relevant and applicable (fully or in part) to the proposed TPEZs projects development within Kaduna. They include:

- Kaduna State Environmental Protection Authority: Solid Waste Management Regulation No. 1;

- Kaduna State Environmental Protection Authority: Control of Water Pollution Sources Regulation No. 2;
- Kaduna State Environmental Protection Authority: Effluent Limitation and Management Regulation No. 3;
- Kaduna State Environmental Protection Authority: Environmental Impact Assessment and Audit Regulation No. 4;
- Kaduna State Environmental Protection Authority: Bush Burning Control Regulation No. 5;
- Kaduna State Environmental Protection Authority: Control and Management of Hazardous Substances Regulation No. 6; and,
- Kaduna State Environmental Protection Authority: Special Work Places Regulation No.

Specifically, Regulation No. 4 stipulates that ―any person, corporate body or unincorporated or Authority including Government Agencies that intend to embark on a new development or the extension/expansion of existing development shall prepare and submit an Environmental Impact Assessment (EIA) Report and obtain a permit/certificate from KEPA before embarking on the project‖. This provision, along with the other regulations, mandates KEPA to enforce and place punitive measures on defaulters, including fines and/or jail terms.

1.8.4 Applicable International Conventions and Standards/Best Practices

Nigeria is signatory to several international conventions and agreements relating to industry, development, and environmental management. In certain cases, conventions and agreements have influenced policy, guidelines and regulations and must be complied with during the planning, construction, and operation of the project. Among several of such conventions, treatises and agreement are those with a direct bearing on this project's environmental, social, or operational characteristics are cited here.

1.8.4.1 UN Framework Convention on Climate Change (UNFCCC), 1992, and the Paris Agreement, 2016

Nigeria's commitments under the UNFCCC and the Paris Agreement require a transition toward low-carbon energy. The proposed solar PV plant directly advances this by replacing diesel generation at AFIT with a zero-emission renewable source, reducing the University's carbon footprint across its operational lifetime.

1.8.4.2 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes, 1989

The Basel Convention regulates the generation, management, and cross-border movement of hazardous waste. It applies to this project because PV modules and lithium-ion battery components may contain hazardous materials classified as controlled waste at end-of-life. The project's waste

management plan must ensure these materials are handled and disposed of in line with the Convention's requirements.

1.8.4.3 Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW), 1979, and the Maputo Protocol, 2003

CEDAW and the Maputo Protocol require that women's rights are protected and that women are not disadvantaged in development processes. For this project, they are relevant to the stakeholder consultation process, which must include women on campus, and to the labour management procedures, which must ensure non-discriminatory conditions for female workers.

1.8.4.4 ILO Guidelines on Occupational Safety and Health Management Systems (ILO-OSH 2001)

The International Labor Organization (ILO) is a tripartite organization consisting of trade unions, governments and companies, and is part of the United Nations system. In 1998, the ILO produced the Declaration on Fundamental Principles and Rights at Work. In the Declaration, ILO member states including Nigeria agreed that they should all respect, promote, and realize core labour standards (whether they have been ratified or not). The core labour standards consist of five standards, laid out in eight conventions:

- Freedom of association and the effective recognition of the right to collective bargaining (Convention No. 87 & No. 98)
- The elimination of all forms of forced and compulsory labour (Convention No. 29 & No. 105)
- The effective abolition of child labour (Convention No. 138 & No. 182)
- The elimination of discrimination in respect of employment and occupation (Convention No. 100 & No. 111)

REA as well as its contractors shall comply with these requirements, as well as the following internationally recognized labour rights: the right to a living wage based on a regular working week that does not exceed 48 hours; humane working hours with no forced overtime; a safe and healthy workplace free from harassment; and a recognized employment relationship with labour and social protection.

1.8.4.5 IEC Technical Specification 62257 - Renewable Energy Systems for Rural Electrification

The IEC TS 62257 series sets international best-practice standards for the design, installation, and operation of solar PV and hybrid power systems. It provides a relevant technical reference for the EPC contractor during detailed engineering and commissioning of the AFIT Solar Power Plant.

1.8.4.6 United Nations (UN) published guiding Principles on the Human Environment in 1972

The United Nations Conference on the Human Environment was held in Stockholm, Sweden, from 5 to 16 June 1972. At the end of this conference, the participating states adopted the Stockholm Declaration, which contained the 26 Guiding Principles on the Human Environment. It was the first major international agreement to place environmental issues at the forefront of global concerns, and it led to the creation of the United Nations Environment Programme (UNEP).

Some of the guiding principles that are relevant to the 2MW Solar Hybrid Power Plant project at AFIT, showing how they apply across the construction, operation, and decommissioning phases of the project are on Table 1.1:

Table 1.1 - Some of the guiding principles applicable to the project and how they apply across the construction, operation, and decommissioning phases.

Principle	Construction Phase	Operation Phase	Decommissioning Phase
2 – Safeguard natural resources	Land clearing and soil disturbance must be minimized.	Efficient use of solar energy reduces fossil fuel reliance.	Recycling of panels and metals protects resources.
5 – Preserve ecosystems	Avoid damage to vegetation and local biodiversity during site prep.	Low ecological sensitivity site ensures minimal disruption.	Site restoration after dismantling ensures ecosystem recovery.
6 – Pollution prevention	Dust, noise, and waste managed via ESMP.	No emissions during operation; major reduction in generator pollution.	Proper disposal of hazardous waste (batteries, panels).
8 – Economic development	Local employment during construction.	Reliable power supply boosts academic productivity.	Reuse/recycling industries benefit economically.
10 – Environmental education	Awareness programs for workers on safe practices.	University research and training in renewable energy.	Lessons learned inform future projects.
12 – Planning	ESIA ensures environmental considerations integrated into project design.	Continuous monitoring of air, noise, and water quality.	Decommissioning plan ensures orderly closure.
13 – Rational management of resources	Efficient procurement and use of construction materials.	Rational use of renewable solar energy.	Recycling ensures rational end-of-life resource use.
15 – Human settlement	Construction avoids disruption to university operations.	Improves living and study conditions on campus.	Restored land can be repurposed for institutional use.
17 – Environmental assessment	ESIA conducted before project approval.	Monitoring ensures compliance with standards.	Decommissioning assessment ensures safe closure.

Principle	Construction Phase	Operation Phase	Decommissioning Phase
21 – Sovereignty and responsibility	Nigeria exercises sovereign right to develop solar energy.	Responsibility to ensure no harm to neighboring communities.	Compliance with Basel Convention on waste disposal.
23 – Developing countries	Special consideration for Nigeria's energy deficit.	Solar project supports equitable access to clean energy.	Knowledge transfer strengthens local capacity.
24 – International cooperation	IFC and AfDB safeguards applied.	Technology transfer and global best practices in renewable energy.	Recycling partnerships may involve international firms.

1.8.4.7 The Paris Agreement 2015

The Paris Agreement was adopted on 12th December, 2015 at the UN Climate Change Conference (COP21) in Paris. It officially entered into force on 4 November 2016, after the required number of countries ratified it. Nigeria signed the agreement on 22nd September, 2016 and ratified same on 16th May 2017. The Paris Agreement (2015) is a legally binding international treaty on climate change. Its overarching aim is to unite all countries in tackling global warming and its impacts
The Paris Agreement (2015) aligns very closely with the Solar PV Power project at AFIT because the project directly supports the Agreement's central goals by reducing emissions through renewable energy use, supporting Nigeria's NDC commitments, enhancing resilience by providing reliable and clean power, as well as attracting climate finance and international cooperation.

1.8.4.8 Nationally Determined Contributions (NDCs) 2021

Nationally Determined Contributions (NDCs) made under the Paris Agreement embodies the country's efforts to reduce national emissions and to adapt to the effects of climate change. If fully implemented, these efforts will pave way for a low carbon economy and result in sustainable reduction in emissions. Projects of this nature represent an important milestone in tackling the challenges of climate change. Over the years, these targets have become increasingly ambitious, expanding beyond energy and oil into waste, agriculture, and health.

NDC 1.0 (2015): Emissions Target: Pledged a 20% unconditional reduction and a 45% conditional reduction in greenhouse gas (GHG) emissions below Business-As-Usual (BAU) levels by 2030. Primarily focused on energy, transport, and agriculture.
NDC 2.0 (2021) Emissions Target: Kept the 20% unconditional reduction by 2030, but increased the conditional reduction target (dependent on international support) from 45% to 47% below BAU. The scope was expanded to add waste and water resources sectors for the first time, while integrating gender mainstreaming across all policies.

NDC 3.0 (2025 Submission) Emissions Target: Commits to a 29% reduction by 2030 and a 32% reduction by 2035 (relative to 2018 levels). It also sets an overarching, economy-wide pathway to reach Net-Zero emissions by 2060. It Encompasses 4 GHGs and 11 pollutants. It pledges a 60%

reduction in deforestation, expands electric mobility, and integrates health climate-resilience (e.g., establishing clean energy access in hundreds of primary healthcare facilities by 2030)

The proposed project is directly aligned with Nigeria's Nationally Determined Contribution. By generating electricity from renewable solar energy, displacing fossil-fuel-based generation, improving energy access, reducing greenhouse gas emissions, and enhancing climate resilience, the project contributes to Nigeria's commitments under the Paris Agreement and supports the country's transition towards a low-carbon and climate-resilient economy by:

- Increasing Renewable Energy Generation and Improving Energy Efficiency: The project generates electricity from solar photovoltaic technology, thereby increasing the proportion of renewable energy in Nigeria's electricity mix and supporting the country's transition towards a low-carbon energy system. Modern solar PV systems incorporate efficient inverters, smart controls and battery energy storage systems that reduce transmission losses and improve overall energy efficiency compared with conventional off-grid diesel generation.
- Reducing Greenhouse Gas Emissions and Reducing Air Pollution: Electricity generated from solar PV replaces electricity that would otherwise be supplied by diesel generators or fossil-fuel-based grid generation thereby contributing to Nigeria's national emission reduction targets. Also, by replacing diesel-powered generation, the project contributes to improved general local air quality.
- Supporting Nigeria's Energy Transition Plan (ETP): The project aligns with Nigeria's Energy Transition Plan (2022) by accelerating investment in renewable energy infrastructure, promoting decentralized electricity supply and reducing reliance on fossil fuels in the power sector. The project contributes to the AfDB's objective of improving electricity access, stimulating economic development and supporting climate-resilient growth in participating countries, including Nigeria.

1.8.4.9 Solemn Declaration on Gender Equality in Africa 2004

The Solemn Declaration on Gender Equality in Africa was adopted by the AU Assembly in 2004, calling for member states' continual action toward achieving gender equality and reinforcing their commitment to international and regional women's rights instruments. In addition to calling for wider ratification of the Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa, it also addresses state responsibility for tackling violence against women and gender-based discrimination.

1.8.4.10 The IFC Performance Standards 2012

The IFC Performance Standards (PS) are the International Finance Corporation’s (part of the World Bank Group) benchmark for managing environmental and social risks in private sector projects. They are widely adopted globally, especially for projects seeking international financing, and they often complement or overlap with the World Bank’s Environmental and Social Standards

(ESS). IFC PS and World Bank ESS are similar and are often required by international lenders, investors, and development banks but IFC PS are more private-sector oriented. However, compliance with both frameworks demonstrates robustness of the EISA. There are eight core standards, each addressing a specific area of environmental and social risk management as follows:

- **PS1 – Assessment and Management of Environmental and Social Risks and Impacts:** Project owners are required to manage the environmental and social performance of their business activity, which should also involve communication between the REA, its workers, and the local communities directly affected by the project activity. This requires the development of a good management system, appropriate to the size and nature of the business activity, to promote sound and sustainable environmental and social performance as well as lead to improved financial outcomes. It requires ESIA, ESMP, stakeholder engagement, and monitoring, thus this Standard is applicable.
- **PS2 – Labor and Working Conditions:** For any business, its workforce is a valuable asset and a sound worker-management relationship is a key component of the overall success of the enterprise. By protecting the basic rights of workers, treating workers fairly, and providing them with safe and healthy working conditions, REA and their contractors can enhance the efficiency and productivity of their operations and strengthen worker commitment and retention.
- **PS3 – Resource Efficiency and Pollution Prevention/Abatement:** Increased industrial activity and urbanization often generate increased levels of pollution to air, water, and land that may threaten people and the environment at the local, regional, and global level. This Performance Standard applicable as the project promotes renewable energy generation while minimizing greenhouse gas emissions. Measures will be implemented to optimize water and energy use, control dust and noise, manage construction and hazardous waste, prevent soil and groundwater contamination, and ensure environmentally sound management of spent solar panels, batteries, transformers and electronic waste during operation and decommissioning..
- **PS4 – Community Health, Safety, and Security:** Business activities can increase the potential for community exposure to risks and impacts arising from equipment accidents, structural failures, and releases of hazardous materials as well as impacts on a community's natural resources, exposure to diseases, and the use of security personnel. This PS is triggered and REA shall implement traffic management, emergency preparedness and response, GBV/SEA/SH prevention measures, community awareness programmes, security management procedures and emergency response plans for the project.
- **PS5 – Land Acquisition and Involuntary Resettlement:** Land acquisition due to implementation of a project may result in the physical displacement (relocation or loss of shelter) and/or economic displacement (loss of access to resources necessary for income generation or as means of livelihood) of individuals or communities. Involuntary resettlement occurs when affected individuals or communities do not have the right to

refuse land acquisition and are displaced, which may result in long-term hardship and impoverishment as well as environmental damage and social stress. This Performance Standard is not triggered as the project will be sited on university land and no form of displacement is expected.

- **PS6 – Biodiversity Conservation and Sustainable Management of Living Natural Resources:** PS6 – Biodiversity Conservation and Sustainable Management of Living Natural Resources: Protecting and conserving biodiversity, including genetic, species and ecosystem diversity, is fundamental to sustainable development. Although site preparation may result in vegetation clearing, the project is located on land with limited sensitive ecological receptors and no threatened or endangered species have been identified within the footprint. REA shall minimize habitat loss, restore disturbed areas, prevent unnecessary damage to flora and fauna, and promote sustainable land management.
- **PS7 – Indigenous Peoples:** PS7 – Indigenous Peoples: Indigenous Peoples are recognized as social groups with identities distinct from other groups in national societies and are often among the marginalized and vulnerable. The project is located within an existing institutional campus, and no Indigenous Peoples as defined under IFC PS7 have been identified within the project footprint. REA shall nevertheless ensure that stakeholder engagement remains inclusive and culturally respectful throughout project implementation.
- **PS8 – Cultural Heritage:** Cultural heritage encompasses properties and sites of archaeological, historical, cultural, artistic, and religious significance as well as unique environmental features and cultural knowledge, innovations, and practices of communities embodying traditional lifestyles, which are protected for current and future generations. This PS is not triggered because the project will be sited within university land and no known cultural heritage resources have been identified within the project area. A Chance Finds Procedure should be incorporated into construction contracts and implemented throughout excavation works because construction activities may uncover archaeological or cultural materials.

1.8.4.11 African Development Bank - Integrated Safeguards System (ISS)

The African Development Bank (AfDB) has its own set of Environmental and Social Safeguards Policies, which guide how projects financed by the Bank must manage environmental and social risks. is designed to promote the sustainability of project outcomes by protecting the environment and people from the potentially adverse impacts of projects. These policies are consolidated under the Integrated Safeguards System (ISS). It requires that all activities comply with the safeguard requirements of the ISS during project implementation. The safeguards aim to:

- Avoid adverse impacts of projects on the environment and affected people, while maximizing potential development benefits to the extent possible.

- Minimize, mitigate, and/ or compensate for adverse impacts on the environment and affected people when avoidance is not possible.
- Help borrowers/clients to strengthen their safeguard systems and develop the capacity to manage E&S risks.

The revised African Development Bank Integrated Safeguards System (ISS) makes environmental and social sustainability a core requirement of every Bank funded project, while driving inclusive growth across Africa. It replaces the 2013 version and has been effective since 31 May 2024. The revised ISS brings the Bank in line with other multilateral development banks on issues like community health and safety, gender-based violence, and stakeholder engagement for high-risk operations. It also sets out environmental and social standards for value chains, outlines processes for resettlement financing, and defines borrower eligibility for financial assistance. By clarifying the Bank's roles, responsibilities, and accountability to borrowers and clients, the ISS underscores its commitment to responsible development — using Africa's natural capital wisely and protecting community rights and well-being. The ISS is similar to the World Bank's ESS and IFC Performance Standards, but tailored to African contexts. The safeguards overlap with World Bank ESS and IFC PS and it ensures compliance with African regional sustainability standards, which emphasize biodiversity, community well-being, and climate resilience.

This project shall be funded by the African Development Bank (AfDB). Therefore, the AfDB safeguard systems will be integrated in the project cycle as well as other national and international environmental and social protection requirements, in order to comply with international best practices. Both main environmental and social requirements that the project needs to comply with are described in the following sections. The key Operational Safeguards (OS) that are applicable to the 2MW Solar Hybrid Power Plant project at AFIT are highlighted in the table 1.2:

Table 1.2: Applicability of the AfDB ISS to the Proposed Project

AfDB Safeguard	Scope / Requirement	Triggered?	Relevance to this Project	Report Section(s)
OS1 - Environmental and Social Assessment	Requires screening, categorisation, ESIA preparation, stakeholder consultation, ESMP development, disclosure, and monitoring.	Yes	Construction and operation of a 2 MW solar plant on an institutional campus involves specific environmental and social impacts. A full ESIA is required.	Ch.1; Ch.3-6; Ch.8-9
OS2 - Involuntary Resettlement, Land Acquisition and Compensation	Avoid or minimise land acquisition and displacement; prepare a RAP where needed.	No - Not Triggered	Project sits entirely on land already held by AFIT. No displacement, land acquisition, or loss of livelihood is anticipated.	Ch.4; Ch.6

AfDB Safeguard	Scope / Requirement	Triggered?	Relevance to this Project	Report Section(s)
OS3 - Biodiversity and Ecosystem Services	Protect natural habitats and biodiversity; apply the mitigation hierarchy.	No - Screened Out	The site is an already-developed campus with no natural habitat or critical ecosystem within the project footprint.	Ch.4; Ch.6
OS4 - Pollution Prevention and Resource Efficiency	Control pollution; manage hazardous materials; promote resource efficiency.	Yes	Construction generates dust, noise, and waste. PV panels and battery components require careful handling during installation and at end-of-life.	Ch.5; Ch.6; Ch.7
OS5 - Labour Conditions, Health and Safety	Fair labour practices; OHS compliance; worker grievance mechanism; no child or forced labour.	Yes	A construction workforce will be engaged. OHS risks include electrical installation, working at height, and heavy equipment operation.	Ch.6; Ch.7
OS6 - Community Health, Safety and Security	Assess risks to communities; implement traffic safety and emergency preparedness.	Yes	Construction traffic and site activities may temporarily affect staff, students, and visitors on the AFIT.	Ch.6; Ch.7
OS7 - Vulnerable Groups	Identify and protect vulnerable groups; ensure inclusive stakeholder engagement.	Yes	Campus users include female students and staff, persons with disabilities, and others whose interests must be reflected in consultation and project design.	Ch.5; Ch.6-7
OS8 - Cultural Heritage	Protect cultural heritage; implement a chance-find procedure.	Low Risk - Conditional	No known heritage sites within the footprint. Ground disturbance creates residual chance-find risk, managed through a procedure in the ESMP.	Ch.5; Ch.8

1.8.5 Institutional Framework

The key institutions with statutory or functional roles in the planning, approval, and oversight of the proposed project are summarized in Table 1.3.

Table 1.3: Key Institutions and their Roles in the Proposed Project

Institution	Role in Relation to the Project
Federal Ministry of Environment (FMEnv)	Lead EIA regulatory authority. Receives, reviews, and approves this ESIA and issues the Environmental Impact Statement required before project implementation.
Federal Ministry of Power	Policy oversight for the power sector, providing the institutional context within which REA implements the Energizing Education Programme.
Rural Electrification Agency (REA)	Project Proponent. Responsible for implementation, EPC procurement, safeguard compliance, and management of the Project Management Unit (PMU) with E&S specialists.
Nigerian Electricity Regulatory Commission (NERC)	Licensing authority under the EPSRA. The applicable licence category for the proposed captive installation will be confirmed during project development.
NESREA	Enforces national environmental regulations during construction and operation, including those on waste, noise, air quality, and hazardous materials.
Kaduna State Environmental Protection Authority (KEPA)	State-level environmental regulator. Reviews the ESIA submission, enforces environmental standards, and monitors compliance within the Territory.
Igabi Local Government Council	Local authority for the project area. Enforces sanitation and waste management requirements and serves as a community liaison point.
Air Force Institute of Technology (AFIT)	Host institution and beneficiary. AFIT's Works and Physical Planning unit coordinates site access and will be responsible for long-term plant operation and maintenance.
African Development Bank (AfDB)	Co-financier. Provides project supervision, monitors compliance with ISS safeguard requirements, and ensures disclosure obligations are met.

1.9 REA HSE Policy

Rural electrification Agency is aware that occupational health and safety as well as community health and safety issues likely to occur during construction, operation and maintenance of the solar power project. Workers may be exposed to physical hazards, trip and fall hazards, exposure to dust during site clearing, risk of electrical hazards and other related danger. Rural electrification Agency shall implement all reasonable precautions that will guarantee the health and safety of workers throughout the project implementation stages. Rural electrification Agency has developed a preventive and protective measure that prioritizes eliminating of hazard, controlling of hazard, minimizing of hazard and the use of personal protective equipment (PPEs).

It is the duty of Rural electrification Agency to ensure that only trained and certified personnel are allowed to work in areas where there is potential risk of harm. However, all workers will be trained on risk identification and hazard perception. A detailed occupation health and safety plan has been developed and presented in Chapter Seven as part of the Environmental and Social Management Plan (ESMP) for the solar project. A summary of REA HSE Policy is as follows: -

Commitment to Safety: The policy emphasizes protecting employees, contractors, and communities from workplace hazards during rural electrification projects.

Environmental Protection: It outlines measures to minimize environmental impact, including responsible waste management, pollution prevention, and sustainable use of resources.

Compliance with Regulations: The agency commits to adhering to Nigerian laws, international standards, and industry best practices in health, safety, and environmental management.
Risk Management: Procedures are established for identifying, assessing, and mitigating risks associated with electrification projects, including construction and maintenance activities.

Training and Awareness: Staff and contractors are required to undergo regular HSE training to ensure safe practices and environmental responsibility.

Emergency Preparedness: The policy includes frameworks for emergency response, accident reporting, and corrective actions to prevent recurrence.

Continuous Improvement: REA pledges to monitor performance, audit compliance, and update practices to improve safety and sustainability outcomes.

1.10 Structure of the Report

Chapter 1 – Introduction: summarizes project overview and background. It also presents the objectives of the study, and the EIA scope of work.
Chapter 2 – Project Justification/Alternatives: describes the need for the project, potential, value, benefits and envisaged sustainability. The project and process related alternatives considered during project concept and design stages are also discussed.
Chapter 3 – Project Description: describes the design basis of the proposed project, process description and site location, preparation and construction, and project plant operations.
Chapter 4 – Description of the Environment: summarizes the physical environment (air, surface water, ground water, and soil), biodiversity, and socioeconomic conditions in the project area.
Chapter 5 – Potential Environmental and Social Impacts: discusses and analyses the potential impacts resulting from project activities during construction and operational phases.
Chapter 6 – Mitigation/Measures: describes the mitigation measures recommended for the identified impacts.
Chapter 7 – Environmental and Social Management Plans (ESMP): provides site specific management plans that list the required actions to be taken, performance targets and required records to be kept. Implementation and Monitoring: provides roles and responsibilities for implementation, monitoring actions, frequency and cost estimate.
Chapter 8 – Decommissioning/Abandonment
Chapter 9 –Conclusions and recommendations: summarizes conclusions drawn during the analysis and provides recommendations for future work.
References – A full list of the published sources used in the report.
Appendices.

CHAPTER TWO
PROJECT JUSTIFICATION

2.1 Introduction

This chapter presents the justification and need for the proposed **2-Megawatt (MW) Solar Photovoltaic (PV) Power Plant at Air Force Institute of Technology (AFIT)** which is situated within Nigerian Airforce Base (NAF), Kawo, Kaduna to be implemented by the Rural Electrification Agency (REA). It articulates the technical, economic, environmental, institutional, and strategic imperatives that necessitate the project, in accordance with the requirements of the Federal Ministry of Environment (FMEnv) ESIA Procedural Guidelines, which require clear demonstration of project rationale and public interest value.

2.2 Justification and Need for the Project

As the largest economy in Sub-Saharan Africa, Nigeria's growth trajectory is paradoxically undermined by the inadequacy of its power sector. Although the country possesses the technical capacity to generate approximately 12,522 MW from existing thermal and hydro plants, operational inefficiencies restrict output to roughly 4,000 MW. For a population exceeding 200 million, this output is grossly insufficient.

Compounding this is Nigeria's status as the country with the largest off-grid population in Africa. Over 100 million people lack access to grid electricity. The disparity is starkly geographic; urban access rates sit at approximately 86%, whereas rural access languishes at just 41.1% (Mshana and Miyares, 2019). To achieve universal electricity access by 2030, Nigeria must connect between 500,000 to 800,000 households annually, a target unattainable through grid extension alone.

Nigeria is committed to achieving the 17 Sustainable Development Goals (SDGs) under the United Nations' 2030 Agenda for Sustainable Development, particularly Goal 7, which aims to ensure universal access to affordable, reliable, and clean energy. Unreliable power supply disrupts academic productivity, research output, and institutional efficiency. Diesel backup generation, while necessary, imposes high fuel costs; noise pollution; local air emissions (NOx, SO_2, particulate matter); as well as the attendant maintenance burdens. The proposed solar PV installation directly addresses these reliability constraints by providing a dedicated, decentralized, and predictable energy source.

In response, the Federal Government has pivoted toward renewable energy policy as a strategic lever to diversify the energy mix, reduce fossil fuel dependency, and bridge the supply-demand gap. This policy direction provides the regulatory backbone for decentralized solar solutions. Furthermore, international momentum toward decarbonization underscores the timeliness of this project. By aligning domestic energy deficits with global sustainability goals, the proposed solar power plant represents a critical intervention.

The justification for the proposed project is further discussed under the following headings:

- National Energy Transition Imperative.
- Economic Justification.
- Environmental and Climate Justification.
- Social and Developmental Justification.

- Strategic Alignment with Rural Electrification Objectives.

2.2.1 National Energy Transition Imperative

Nigeria's Energy Transition Plan (ETP) 2022 entails a comprehensive, data-driven strategy to achieve net-zero carbon emissions by 2060 while simultaneously eradicating energy poverty. It requires scaling up renewable power, adopting cleaner cooking and transportation methods, and transitioning the oil and gas sector. The plan targets decarbonization across five core sectors:

- Power: Expanding grid capacity, off-grid solar, and mini-grids to achieve universal access, while deploying solar power to critical infrastructure like schools and hospitals.
- Oil & Gas: Utilizing natural gas as a critical transition fuel while reducing emissions through the elimination of gas flaring and minimizing fugitive methane emissions.
- Cooking: Transitioning the population away from traditional biomass (firewood and charcoal) to Liquefied Petroleum Gas (LPG) in the short term, eventually shifting to electric cooking stoves and biogas.
- Transportation: Shifting to zero-emission vehicles, promoting electric mobility (e-mobility), and expanding public transport infrastructure.
- Industry: Decarbonizing industrial manufacturing, particularly in high-emission sectors like cement, by improving energy efficiency and switching to zero-emission heating fuels.

The proposed project aligns with the Nigeria Energy Transition Plan (ETP), 2022 as it supports national renewable energy and decentralization objectives by:

- ✓ Reducing demand pressure on the national grid;
- ✓ Demonstrating institutional-scale solar deployment;
- ✓ Contributing to Nigeria's renewable energy targets;
- ✓ Supporting the country's net-zero emissions by 2060 therefore aligns with national climate and energy reform priorities.

Nigeria's Energy Transition Plan (ETP) (2022) explicitly emphasizes reducing dependence on diesel generators because diesel-based electricity is expensive, carbon-intensive, and detrimental to public health and energy security. The ETP identifies renewable energy, particularly solar PV, as a key technology for achieving universal energy.

2.2.2 Economic Justification

Although the initial capital cost for the installation of a 2MW Solar Hybrid Power Plant facility is substantially higher than purchasing diesel generators, it represents a long-term capital investment with recurring operational savings over a project life of 25 years or more. This is because:

i. There is reduced or no fuel cost as operating diesel generators incur significant recurrent expenditure which is the largest cost component for energy generation using diesel engines;
ii. Maintenance requirements for the Solar PV facility is expected to be generally lower due to fewer moving parts compared to diesel-generators (solar modules typically continue producing electricity for 25–30 years with gradual degradation; inverters typically 10–15 years; BESS commonly 10–15 years depending on chemistry and cycling).
iii. Reduced generator operation lowers maintenance and replacement costs;
iv. Electricity price volatility associated with diesel fuel is eliminated.

In contrast, diesel generation incurs continuous expenditure on fuel, lubricants, maintenance, and periodic engine overhauls or replacement, causing the cost of electricity to increase substantially.

The savings on these costs could further improve AFIT's:

- ✓ Budgetary predictability;
- ✓ Allocation of resources toward academic development;
- ✓ Financial sustainability of other campus operations.

Studies undertaken by international energy and development organizations have consistently shown that utility-scale Solar Photovoltaic (PV) systems generally offer a lower levelized cost of electricity than diesel-powered generation over a long-termed project lifecycle (IRENA, 2022; IEA, 2024). While the exact cost depends on fuel prices, generator efficiency, maintenance requirements and financing assumptions, numerous international studies have consistently demonstrated that utility-scale solar PV provides a lower lifetime cost of electricity than diesel generation, making it the more economically sustainable option (IRENA, 2022; IEA, 2024; Lazard, 2024). From this analysis and based on prevailing retail prices for diesel in the FCT (over ₦1,700 per litre) and typical generator operating characteristics, it is safe to say that the expected cost of operating diesel-powered generators is higher compared to utility-scale solar photovoltaic systems over a 25-year operating life.

2.2.3 Environmental and Climate Justification

Diesel-based generation produces greenhouse gas emissions and local pollutants. Replacing diesel with solar PV:

- Reduces carbon emissions;
- Reduces noise pollution;
- Minimizes spill risks associated with fuel handling.

As a renewable energy project, it contributes directly to climate mitigation objectives and enhances environmental stewardship within the academic community.

2.2.4 Social and Developmental Justification

Reliable electricity within the institution's environment supports:

- Enhanced research capacity;
- Improved learning conditions;
- Digital transformation and ICT expansion;
- Improved campus safety and security;
- Better water and sanitation services powered by electricity.

Additionally, the project will:

- Develop local technical capacity in renewable energy installation and maintenance;
- Provide a live demonstration facility for students in engineering and environmental sciences;

- Create short-term employment during construction.

The project thus yields both direct and indirect social benefits.

2.2.5 Strategic Alignment with Rural Electrification Objectives

The mandate of the Rural Electrification Agency includes expanding reliable electricity access and promoting renewable energy solutions in public institutions. The project:

- Demonstrates scalable institutional renewable deployment;
- Serves as a model for other tertiary institutions;
- Supports decentralized energy systems in northern Nigeria.

The proposed solar power project therefore fulfills strategic institutional and national objectives simultaneously.

In summary, many public institutions in Nigeria, experience irregular grid electricity supply; frequent outages and voltage instability; high reliance on diesel generators; and elevated operational energy costs. Academic institutions require stable power for ICT infrastructure and data centers. The proposed Solar PV Power project at Air Force Institute of Technology (AFIT), Kaduna by REA represents a necessary, beneficial, and sustainable intervention that addresses immediate institutional challenges while advancing broader national development priorities as it will directly address these reliability constraints by providing a dedicated, clean, decentralized, and reliable energy source.

In view of the above, the implementation of the Solar Power Project at Air Force Institute of Technology (AFIT) is fully justified.

2.3 The Value of the Project

The project is co-financed by the African Development Bank and the funding covers Engineering, Procurement, and Construction (EPC) as well as Operations & Maintenance (O&M) contracts. These contracts will be awarded to competitively selected EPC contractors who will build, operate, and maintain the power plants at each site. While the project is primarily for institutional consumption, non-monetary value is realized through:

- Reduced operating expenditures;
- Reallocation of savings to academic development;
- Potential energy research commercialization;
- Contribution to the Nigeria's NDC commitment to cut carbon emission by 20% by the year 2030, under the Paris Agreement;
- Avoided GHG emissions and improved environmental performance; and
- Reduced generator maintenance expenditure.

2.4 Project Benefits

The proposed project is expected to yield a broad spectrum of socioeconomic, environmental, and technical benefits, including but not limited to:

- Enhanced Power Availability: Reliable electricity supply for domestic, commercial, and industrial applications;
- Economic Productivity: Reduction of downtime and operational costs for businesses

dependent on stable power;
- Job Creation: Direct and indirect employment opportunities during construction, operation, and maintenance phases;
- Clean Energy Transition: Reduction in greenhouse gas emissions and displacement of fossil fuel-based backup generation;
- Energy Equity: Provision of affordable, safe, and clean electricity to host communities and underserved populations;
- Community Safety: Installation of street lighting to enhance security and extend productive hours;
- Skills Development: Capacity building and technical training for local manpower in solar PV operations and maintenance;
- Multiplier Effects: Stimulation of local economies through spin-off enterprises and improved commercial activity.

2.5 Envisaged Sustainability

To ensure that the project delivers enduring value without unintended adverse consequences, a multi-dimensional sustainability framework has been established. This framework governs technical delivery, environmental stewardship, financial viability, and social inclusion.

2.5.1 Technical Sustainability

The solar PV system is engineered for remote, decentralized deployment. Design, installation, and commissioning will be executed by certified personnel in strict adherence to international standards (IEC) and local grid codes. The Rural Electrification Agency (REA), as project proponent, will enforce rigorous quality assurance protocols, including routine performance monitoring and preventive maintenance schedules. This ensures operational continuity beyond the initial project lifecycle.

In addition, the project will be implemented through a qualified and experienced Engineering, Procurement and Construction (EPC) contractor selected by REA through a transparent and competitive procurement process. An Engineering Procurement and Construction (EPC) Framework shall be developed and the selection process will follow pre-established technical, financial, and performance criteria consistent with national procurement standards and international best practices. Under this framework:

- REA's qualified engineers will provide oversight during design and construction;
- The EPC contractor will assume full responsibility for detailed engineering design;
- All equipment procurement will comply with approved technical specifications and international standards (e.g., IEC-certified components);
- Installation will adhere to quality assurance and quality control (QA/QC) protocols;
- Testing and commissioning will follow structured acceptance procedures;
- Performance guarantees will be contractually binding.

This structured EPC approach shall ensure that system design is optimized, construction quality is verified, and long-term performance risks are minimized. Additionally, technical sustainability is reinforced by requiring the EPC contractor to:

- Conduct detailed site-specific engineering studies;
- Prepare structural, electrical, and protection system designs;
- Undertake geo-technical assessments to ensure stable mounting foundations;
- Provide grid interconnection studies;
- Develop protection coordination and earthing designs.
- Develop a comprehensive Operation Manuals and Maintenance Manuals; Equipment datasheets; Protection and control schematics; Emergency response procedures; Preventive maintenance schedules etc;
- Ensure that all installations undergo Factory Acceptance Tests (FAT) and Site Acceptance Tests (SAT) prior to commissioning as well as conducting Performance Ratio Verification and system output validation before handover.

Equipment Quality Assurance, OEM Standards and Regulatory Compliance
Technical sustainability is strengthened through the use of equipment from reputable Original Equipment Manufacturers (OEMs) with proven performance, warranties, spare parts availability, and technical support to ensure long-term reliability and reduce the risk of failure. All major components, including solar PV modules, inverters, batteries, transformers, switchgear, and protection devices, shall comply with relevant international standards and Nigerian regulatory requirements. Equipment shall be certified by the Standards Organisation of Nigeria (SON) and meet Mandatory Conformity Assessment Programme (MANCAP) requirements, where applicable. Electrical installations shall also be inspected and certified by the Nigerian Electricity Management Services Agency (NEMSA) prior to commissioning to ensure compliance with national safety standards. Installation, testing, commissioning, and maintenance shall be carried out by qualified and certified personnel in accordance with NEMSA requirements and industry best practices to ensure safe and reliable operation.

2.5.2 Environmental Sustainability

The project represents an inherently low-impact intervention. By displacing diesel generator usage, it contributes to a net reduction in local air pollution and national carbon emissions. All phases of the project will be governed by the REA's Health, Safety and Environment (HSE) Policy and Emergency Preparedness Plan. Compliance with the National Environmental Standards and Regulations Enforcement Agency (NESREA) and World Bank environmental safeguards is mandatory. Waste management, particularly regarding used batteries and electronic components, will follow approved recycling and disposal protocols. The recommendations of the Environmental and Social Impact Assessment (ESIA) will be strictly implemented to ensure mitigation of all residual risks.

The project will generate solar-related electronic waste (e-waste) and spent batteries at the end of their operational life. Appropriate measures will be implemented for the collection, storage, transportation, recycling, and disposal of obsolete solar panels, batteries, inverters, and other electrical components in accordance with applicable national regulations and industry best practices. Preference will be given to licensed recyclers and authorized waste management facilities for the handling of end-of-life equipment. An end-of-life management plan will be developed and implemented to minimize environmental and health risks associated with solar e-waste and battery disposal.

2.5.3 Economic and Commercial Sustainability

Although solar PV requires significant upfront capital expenditure, lifecycle cost analysis strongly favors this technology over continued reliance on diesel generators. Fuel costs are eliminated, maintenance requirements are minimal, and price volatility is removed. Furthermore, the project catalyzes local economic development through the creation of skilled and semi-skilled jobs in manufacturing, installation, operations, and maintenance. This workforce development component strengthens the local labor market and builds domestic capacity for Nigeria's broader energy transition.

2.5.4 Social Sustainability

The social sustainability of the proposed Solar PV Project is strongly anchored in its stakeholder engagement framework. By conducting consultations during the ESIA process, the Project has ensured that all relevant stakeholders are given the opportunity to contribute their perspectives at an early stage. This participatory approach not only enhances inclusiveness but also builds trust and transparency, laying a solid foundation for long-term relationships with the university community, residents, and other interested parties.

In addition, the establishment of a grievance redress mechanism (GRM) by REA provides a structured communication channel for stakeholders to raise concerns. This mechanism ensures that grievances are addressed promptly and fairly, thereby reducing potential conflicts and fostering social harmony. Even though anticipated issues are minimal, the GRM demonstrates a proactive commitment to safeguarding stakeholder interests.

Overall, these measures early consultations, continuous engagement, and the GRM collectively contribute to the Project's social sustainability. They ensure inclusiveness, responsiveness, and fairness, while promoting mutual trust between the Project developers and stakeholders. This participatory governance model enhances the Project's resilience and strengthens its social license to operate. Details of the stakeholder consultations conducted to date are presented in ***Chapter 4 of this report.***

Occupational Health and Safety (OHS) and Community Health and Safety (CHS) considerations are integral to the proposed project. Occupational health and safety measures will be implemented to protect workers from hazards associated with construction, electrical installations, equipment handling, and maintenance activities. Community health and safety measures will focus on managing risks related to increased traffic, restricted access to work areas, electrical safety, emergency preparedness, and other project-related activities that may affect surrounding communities. Appropriate mitigation measures, training, monitoring, and stakeholder awareness programs will be implemented throughout the project lifecycle to ensure the health and safety of workers and the public.

2.6 Project Options and Alternatives

2.6.1 Project Options

Three strategic options were evaluated prior to project approval: No Project, Delay Project, and Implement Project. Each was assessed based on feasibility, urgency, and socioeconomic impact.

The "No Project" Option.
This option implies the complete abandonment of the proposed intervention. While it incurs no direct capital cost, it perpetuates the status quo of energy poverty. The socioeconomic benefits, including employment, local contracting, equipment supply, and improved productivity, would remain unrealized. Given the acute need for power in the target location. This option offers no strategic value.

Decision: **Not Recommended.**

The "Delay Project" Option.
Project deferment is typically warranted in cases of civil unrest, funding shortages, or widespread public opposition. In this instance, no such impediments exist. The project site is stable, stakeholder buy-in is secured, and the demand for electricity is immediate. To delay implementation would be to postpone development benefits without justification.

Decision: **Not Recommended.**

The "Implement Project" Option.
Proceeding with implementation ensures the timely delivery of clean, reliable energy to the project area. This option maximizes value for the proponent, the host community, and the government by catalyzing economic activity and improving quality of life. It represents the most prudent and beneficial course of action.

Decision: **Recommended.**

2.6.2 Project Alternatives

2.6.2.1 Site Alternatives.

The proposed location within the Institute, was selected based on a multi-criteria assessment. The site offers: Immediate land availability with minimal acquisition requirements; High solar irradiation levels suitable for PV generation; No requirement for resettlement or complex land rights arbitration; Proximity to load centers with inadequate grid supply. These factors render alternative sites less viable. The site within the Nigerian Airforce Base (NAF Base) was considered good for the project based on the following factors on *Table 2.1.*

Table 2.1 - Factors for site consideration and selection

Factors	Suitability
Technical Suitability	The site meet the technical design requirements without requiring major civil engineering modifications. These include: Proximity to existing campus distribution network; Adequate solar exposure with minimal shading; Stable soil conditions for mounting structures; Ease of access for construction and maintenance; The land area is sufficient for a 2MW installation.
Environmental Sensitivity Screening	The site is considered environmentally low-risk and suitable for renewable infrastructure as they: Are not within a protected area or ecological reserve; Do not affect critical habitats; Do not involve tree felling of significant ecological value; Do not interfere with natural drainage systems; Are outside known erosion-prone or flood-prone zones.
Social and Land-Use Compatibility	The considered location will not require resettlement, compensation, or livelihood restoration because the sites: Are within the institution-owned land; Do not require land acquisition; Do not displace communities or livelihoods; Do not restrict public access to communal resources; Are compatible with existing institutional land use.
Economic Considerations	Locating the project within the campus: Eliminates land purchase costs; Minimizes transmission infrastructure costs; Reduces right-of-way complications; Simplifies project permitting; Lowers overall capital expenditure.
Security and Operational Considerations	Siting the project within the institution guarantees: Controlled access and perimeter security; Reduced risk of vandalism; Ease of monitoring and maintenance; Long-term land tenure certainty.
Climate and Environmental Resilience Considerations	The selected site supports climate-resilient design because: Terrain allows proper drainage management; No floodplain encroachment; Adequate wind stability for structural anchoring; Minimal vegetation clearing required; Soil conditions suitable for non-invasive foundation systems.
Space availability	In the absence of a contiguous and sufficient land area for 2-MW installation, designating and utilizing both locations will ensure that the project remains feasible.

Source *- Bolben Energy & Environmental Services Limited.*

2.6.2.2 Power Generation Alternatives

Option A – Continued reliance on Back-up Diesel-powered Generators:

- **Technical Consideration:**

Diesel generators provide dispatchable and reliable power independent of grid performance. However, they require continuous fuel supply, regular maintenance, and periodic engine overhaul.

- **Economic Implications:**

Although capital cost is relatively lower than the other options, lifecycle cost is substantially higher due to recurring fuel expenses and maintenance requirements. Exposure to fuel price volatility poses financial sustainability risks.

- **Environmental Implications:**

Diesel combustion produces significant greenhouse gas emissions (CO_2), nitrogen oxides (NOx), sulphur dioxide (SO_2), particulate matter, and noise pollution. There are also risks associated with fuel storage, spills, and disposal of used oil and filters. Long-term operation would increase the university's carbon footprint and air pollution burden.

Option B – Grid-Only Supply: This option assumes reliance solely on electricity supplied through the national grid without dedicated on-site generation.

- **Technical Consideration:**

Grid supply eliminates on-site fuel handling and emissions. However, grid electricity is characterized by voltage fluctuations, load shedding, and outages. Exclusive reliance on the grid may compromise operational reliability for critical academic and research facilities.

- **Economic Implications:**

While capital cost is minimal, the risk of unreliable supply may necessitate continued backup diesel use, thereby reintroducing environmental and economic disadvantages.

- **Environmental Implications:**

Environmental impacts are indirect and depend on the national generation mix, which still includes fossil fuel sources. The institution has limited control over upstream emissions.

Installation of Solar Photovoltaic (PV) – Proposed Option: The proposed option involves installation of a 2-MW ground-mounted Solar Hybrid system within the campus in addition to the existing energy infrastructure.

- **Technical Consideration:**

Solar PV provides clean, renewable electricity with minimal mechanical components and low maintenance requirements. While generation is daytime-dependent, it shall be integrated with the national grid and battery storage to enhance reliability.

- **Economic Implications:**

Though capital-intensive initially, solar PV offers low operating costs, predictable long-term energy pricing, and substantial savings from diesel displacement over its 25-year lifespan.

- **Environmental Implications:**

Operational emissions are zero. Noise levels are negligible, and there is no fuel handling risk. Environmental impacts are largely limited to land use footprint and end-of-life component management, which are manageable through proper planning.

Table 2.2: Environmental Trade-Off Analysis

Option	Continued reliance on Back-up Generators and Diesel Generation	Grid Only	Grid + Solar PV
Emissions	High	Medium	Minimal
Noise	High	Low	Minimal
Land Use	Minimal	None	Moderate
Waste	Fuel Waste	None	End-of-life panel waste
Reliability	High (fuel dependent)	Moderate - Low	High (with grid/battery)
Climate Alignment	Poor	Moderate	Strong
Lifecycle Cost	High	Moderate	Low
Regulatory Burden	High	Moderate	Low

Source *- Bolben Energy & Environmental Services Limited.*

'Option A – Continued reliance on Back-up Generators and Diesel Generation' is technically feasible but it is environmentally unsustainable, economically burdensome over the long term, and inconsistent with national renewable energy and climate transition objectives, while Grid-only supply reduces on-site environmental impacts but does not resolve reliability challenges. It also does not contribute directly to renewable energy expansion within the institution. However, Solar PV offers the best balance of environmental sustainability, economic viability, regulatory compliance, and alignment with Nigeria's renewable energy and climate commitments.

Based on the above comparative analysis, Option C – Solar PV is the most environmentally sound, economically sustainable, and strategically aligned power generation alternative for the project. It is therefore the preferred alternative

2.6.2.3 Technology Alternatives:

Solar Power Technology Alternatives

The solar technologies considered for the proposed power plant at AFIT are:

- Concentrated Solar Power (CSP) Systems
- Photovoltaic (PV) Solar Panels

However, the preferred option for the proposed power plant is the use of PV Solar Panel since it is highly flexible and requires low installation and maintenance cost in comparison to CSP technology. Water requirement for PV system is also low when compared to CSP system.

The comparison between CPS and PV Solar technologies considered for the Project is summarized in *Table 2.3*

Table 2.3: Comparison between CSP and PV Solar Technology

Features	CSP Technology	PV Technology
Description .	CSP technology uses concentrated radiation from the sun, to heat a liquid substance which is used to generate steam which in turn passes through a steam-turbine to generate electricity. CSP Technology produces electricity through indirect means. Energy output with CSP technology is of AC type	PV technology uses sunlight through the 'photovoltaic effect' to generate direct electric current (DC). PV Technology produces electricity through direct means. Energy output with PV technology is of DC type but commonly converted to AC through an inverter.
Applications/Scale	CSP is used for utility scale power generation, mostly for Grid Connections, and also supporting conventional thermal power and desalination plants.	PV technology is suitable for off grid small and medium-sized applications, and for utility scale applications
Land requirement	CSP technology is best suited for areas of high direct normal solar radiation. CSP technology requires about 4 hectares of land per MW of capacity	PV technology has a wider geographical area of application. PV technology requires about 2 hectares of land per MW of capacity
Land requirement	CSP technology is best suited for areas of high direct normal solar radiation. CSP technology requires about 4 hectares of land per MW of capacity	PV technology has a wider geographical area of application. PV technology requires about 2 hectares of land per MW of capacity
Cost	CSP technology has a high installation and maintenance cost compared to PV	PV technology has a low installation and maintenance cost in comparison to CSP
Construction Time	CSP plant construction is technical more complex than PV	Utility scale PV plants are easier to install and require less time than CSP for Plant construction
Water Requirement	Water requirement is variable depending on the CSP technology option adopted. CSP may utilize wet, dry, and hybrid cooling techniques	Typically requires less water than CSP technology. Water is occasionally required for cleaning of dust from the panels
Design Options	Less flexible in comparison to PV technology. Can be hybridized with fossil fuels like natural gas.	Highly flexible and adaptable to the project specific requirement
Average life span	25 years	25 years
Efficiency	Power production efficiency of CSP technology is as high as 45%	Power production fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or AC, through the use of inverters.
Environmental Risks	CSP systems have been recorded to pose environmental risks to bird species, which may be killed by the intense heat generated by the concentrated solar radiation which is reflected off the mirrors.	PV systems are considered to be generally benign.

2.6.2.4 PV Panel Alternatives

Solar PV panel is an assembly of photovoltaic cells, also known as solar cells. It is an essential component of a PV system that converts sunlight directly into direct current (DC) electricity. To achieve a required voltage and current, a group of PV panels (also called PV modules) are wired into large array that called PV array. PV panels can be wired together in series and/or parallel to deliver voltage and current in a particular system requires.

The types of solar cells that are commonly used in PV technology are:

i) Monocrystalline silicon;
ii) Poly-crystalline silicon; and
iii) Thin film.

The typical appearance of each of these PV panels is shown in Figures 2.1 to 2.4. Based on the consideration of cost and efficiency, polycrystalline silicon PV panels are envisaged to be used for the proposed Project.



Figure 2.1: Typical appearance of mono-crystalline silicon PV panels



Figure 2.2: Typical Appearance of Polycrystalline Silicon PV Panels



Figure 2.3: Typical appearance of Thin-Film CdTe panels

2.6.2.5 Battery Types Alternative

The proposed solar power plant in AFIT is an off-grid system, which will involve the storage of power. Storage allows the PV array to continue providing power even when the demand is down, instead of having to disconnect and refrain from generating power. The batteries for the proposed power plant would be required to meet the demands of heavy cycling (charging and discharging) and irregular full recharging. There are a variety of battery types fitted for these requirements; however, four (4) of these batteries are the best available technology for solar power plants. These are: lead-acid, lithium-ion, flow, and nickel-cadmium batteries.

Following the careful consideration of factors such as safety, charging cycles, depth of discharge and life span, lithium-ion batteries are envisioned to be used as the preferred battery for the proposed solar power plant.
An overview of the battery types considered for the Project is provided below:

- ***Lead-Acid Batteries***

These are the oldest and cheapest form of batteries used in solar systems. They are widely used in Solar PV installations due to their wide availability and ability to work in a wide range of conditions. They internally convert hydrogen and oxygen into water and do not require maintenance. However, proper disposal of end-of-life lead-acid batteries is important. The lead-acid battery life is typically 3-10 years.

- ***Lithium-Ion Batteries***

Lithium-ion batteries can deliver more cycles in their lifetime than lead-acid. They can be lighter and more self-contained than lead-acid batteries. They are solid, and do not require refills or maintenance. The most important benefit lithium-ion provides for solar is its high charge and discharge efficiencies, which help harvest more energy. Lithium-ion batteries also lose less capacity when idle, which is useful in solar installations where energy is only used occasionally.

Lithium-ion batteries usually have longer lifespan when compared to the lead-acid batteries, average of 5 years.

- ***Flow Batteries***

The vanadium redox flow battery (VRFB) is the most common technology in this type of batteries. In VRFB, the vanadium electrolyte does not degrade over time, so they can last much longer than other technologies. With other technologies, adding more batteries is the only way to increase hours of storage; however, adding more electrolyte (vanadium) can increase battery size in VRFB. The VRFB has no cycling limitations, and batteries can be charged and discharged completely without impact on their lifespan. They can last up to 20 years. The recycled vanadium in flow batteries is not toxic and can be reused repeatedly for other purposes, such as in making steel. However, the high cost of vanadium and ion selective membrane within the cell will lead to significant cost implications for the Project.

- ***Nickel-cadmium Batteries***

Nickel cadmium or NiCd batteries are as old as the lead-acid batteries. Though they may not have the energy density (the power) of other technologies, they provide long life and reliability without complex management systems. They are also as cheap as lead-acid batteries.
NiCd batteries are rugged batteries with a high life span of up to 20 years. However, the major disadvantage of NiCd batteries is the relatively low energy density and susceptibility to self-discharge. Thus, making NiCd batteries an unreliable alternative for the proposed Project.

Updated Technology Assessment (2025-2026 Context):
While the original design proposed Hoppecke Lead-Acid batteries for lower upfront costs, market data from 2025-2031 forecasts indicates a decisive industry shift toward Lithium-Ion.

Feature	**Lead-Acid (Traditional)**	**Lithium-Ion (Modern Standard)**
Initial Cost	Lower	Higher (but declining rapidly)
Lifecycle Cost	Higher (due to shorter lifespan)	Lower (better long-term value)
Maintenance	Moderate (regular watering/checks)	Negligible (sealed systems)
Lifespan (Cycles)	Shorter (1,200–1,800 cycles)	Longer (4,000–6,000+ cycles)
Depth of Discharge	50% (usable capacity limited)	80-100% (fully usable)
Efficiency	70-80%	90-98%

Decision for Implementation:
Based on current Nigerian market trends (2025-2031) and the long-term operational strategy of the project, Lithium-Ion batteries are now recommended for the project.

CHAPTER THREE
PROJECT DESCRIPTION

3.1 Introduction

This chapter describes in detail the technology and design of the proposed solar project to be constructed, installed and operated. Information on the application, ancillary facilities, stage by stage development, project schedule, life span, consumables is contained in this chapter. It also discusses the project anticipated waste streams, operations, decommissioning and project implementation plan.

3.2 Project Location

The proposed 2MW Solar Photovoltaic Power Plant and Associated Infrastructure is located within the Air Force Institute of Technology (AFIT) boundary, Nigeria Air Force Base, Kawo, Igabi Local Government Area (LGA), Kaduna State, Nigeria. The AFIT is a specialized higher institution located within the Nigerian Air Force Base in Kaduna. It serves both military and civilian students and focuses on aerospace engineering, technology, science, management, and related disciplines. AFIT plays an important role in producing technical manpower for the Nigerian Air Force and Nigeria's broader aviation and engineering sectors. The coordinates fall within:

Point 1: Latitude 10.6189462 and Longitude 7.4359615

Point 2: Latitude 10.6197695 and Longitude 7.4387289

Point 3: Latitude 10.6172334 and Longitude 7.4400739

Point 4: Latitude 10.6163274 and Longitude 7.4370849



Plate 3.1: Proposed Project Site

3.2.1 Kaduna State

The state is in the Northern part of Nigeria's high plains. The vegetation cover is Sudan Savannah type, characterized by scattered short trees, shrubs and grasses. The soil is mostly loamy to sandy. The state is bordered by seven states: Zamfara for 117 km (73 miles) and Katsina for 161 km (100 miles) to the north, Kano to the north-east for 255 km, Bauchi and Plateau to the east, Nasarawa and Abuja Federal Capital Territory (for 45 km) to the south, and Niger to the west. Kaduna state is located between latitude 10°38'58" N and 10°25'36" N and to longitude 7°22'14" E and 7°32'00" E.

3.2.2 Igabi Local Government

Igabi Local Government Area covers an area of approximately 3,222 square kilometers in the central zone of Kaduna State. It experiences a tropical savanna climate with distinct wet and dry seasons and an average annual temperature around 28°C–32°C.

- Population: Estimated at over 630,000 residents, making it one of the most populous local government areas in Kaduna State.
- Ethno-Religious Profile: The population consists primarily of Hausa, Fulani, and Gbagyi ethnic groups, alongside other resident communities attracted by its proximity to the capital city.
- Administrative Wards (12): Afaka, Birnin Yero, Gadan Gayan, Gwaraji, Igabi, Kerawa, Kwarau, Rigachikun, Rigasa, Sabon Birnin Daji, Turunku, and Zangon Aya.

3.2.3 Project Site and Layout

The Air Force Institute of Technology (AFIT), also known as the Air Force University, is situated inside the in the Kawo area of Kaduna, Nigeria. Geographic Position: Located in the northern sector of the Kaduna metropolitan area, off the Kaduna–Zaria Expressway and near the Kawo Flyover corridor. The solar project shall be situated on 10Ha of land within the Institute and geographically on the following coordinates: Lat 10.620004^0, Long 7.435611^0.

Security & Access: Because it resides within a military installation, access to the campus is strictly regulated through guarded military checkpoints at the main base entrance gates (such as the Kawo/Air Force Base Gate).

Campus Layout & Key Zones

The AFIT campus combines military discipline with university-style academic infrastructure. The campus layout is organized into primary functional sectors:

Academic & Research Zone

- Faculties & Departments: Houses specialised academic centers, including the Faculty of Air Engineering, Faculty of Ground & Communication Engineering, Faculty of Computing, Faculty of Sciences, and Faculties of Social & Management Sciences.
- School of Postgraduate Studies (SPS): Dedicated facilities for advanced research degrees, aerospace vehicle design, and specialized post-graduate training.
- Laboratories & Hangar Infrastructure: Includes specialized engineering workshops, aerodynamics labs, foundry sessions, and aircraft maintenance hangars used for practical aeronautical and mechatronics instruction.
- School of Basic and Remedial Studies: Hosts preparatory programs like IJMB and pre-degree courses.

Administrative Sector: The administrative core accommodating the offices of the Commandant, Provost, Deans, and military administrative staff.

- Parade Grounds & Ceremonial Areas: Central open grounds used for military parades, matriculation, pass-out ceremonies, and official assemblies.

Residential Sector: This sector houses:

- Student Hostels: Separate accommodation blocks for civilian and military students, including the and civilian residential halls located within base precincts.
- Staff Quarters: On-base quarters provided for military officers, instructors, and resident academic personnel.

Support Facilities & Recreation

- Library & Information Technology Center: A central e-library network and computing labs supporting distance learning and academic research.
- Medical & Commercial Facilities: Access to the Nigerian Air Force Base Medical Centre, sports complex, officers' mess, and internal cafeteria services.

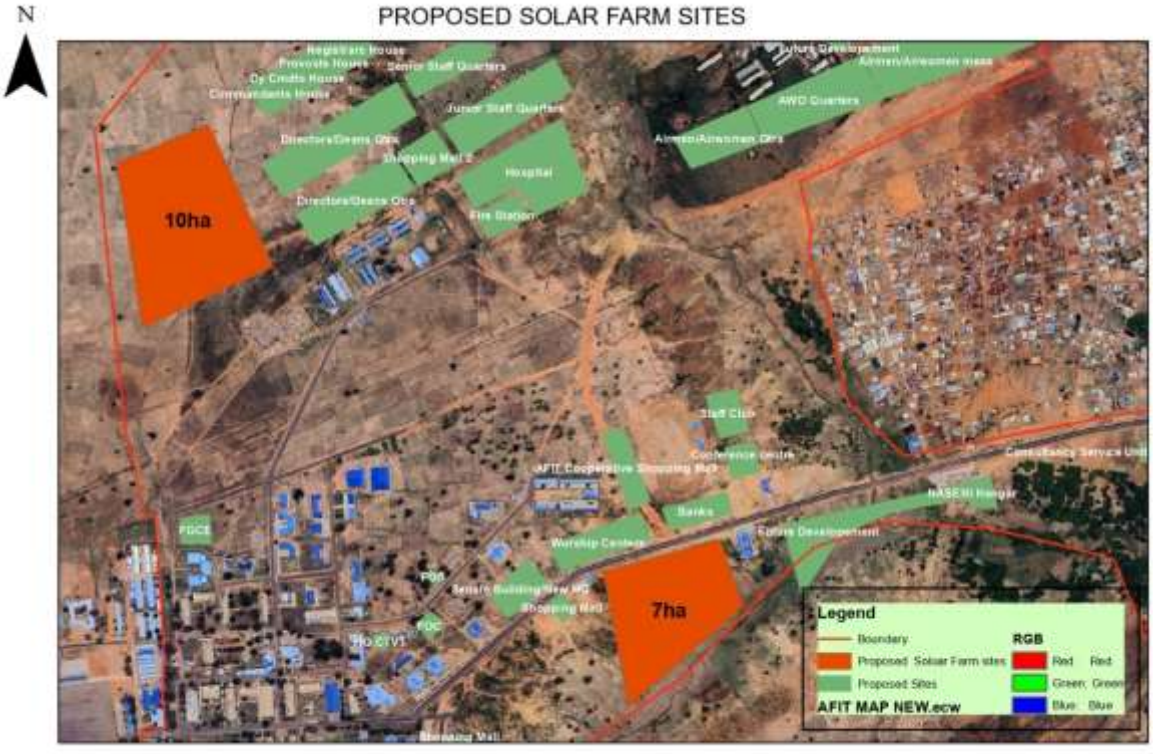


Figure 3.1: AFIT Layout indicating the proposed project site (10 hectares)

3.3 Project Overview

The proposed solar project is a photovoltaic (PV) solar farm installation which will be installed on a galvanized steel support structure of about 1.5 meters height. PV modules will be mounted in table form that will connect, via angled brackets, to steel columns which will be driven into the ground. These assemblies will be organized into arrays; placement of the arrays within the facility

site will be based on constraints including topography and biological considerations. The PV Modules are electrically connected by wire harnesses and combiner boxes that collect power from several rows of modules and feed the power conversion system (PCS) via underground DC cables.

3.3.1 Project Components

The proposed facility will comprise:

- Solar PV modules (at least 2000 units depending on wattage rating).
- Inverters totaling 1 MW capacity.
- Step-up transformer (approximately 415V/11kV configuration as required).
- Power Station - Control room/powerhouse structure.
- Underground DC and AC armored cabling.
- Smart metering and monitoring systems.
- Perimeter security fencing and access control.
- Drainage infrastructure.
- Battery Energy Storage System (BESS).

The main characteristic of the fixed mounted structure is presented on Table 3.1.

Table 3.1: Main characteristics of the fixed mounting structure

Fixed structure characteristics	
Structure type	1H
Tilt angle	9.0 °
Poles type	Bi pole
Pitch distance	3.04 m
Designed for	MONOFACIAL modules
Fixed structure characteristics	
Minimum ground clearance	0.5 m
Gap between modules in the axis direction	0.0 mm
Gap between modules in the pitch direction	0.0 mm

*(**Source**: REA EEP 3 FEED)*

Table 3.2 gives a summary of the project's characteristics and figure 3.2 shows the electrical configuration of the PV plant.

Table 3.2: Key Project Characteristics

Main characteristics	
Location	Nigeria, Kaduna
Rated power (AC)	4180.0 kWac
Peak Power (DC)	5018.3 kWdc
Ratio DC/ AC	1.20
Civil characteristics	
Suitable plot area	15. 02 ha
Ground coverage ratio (GCR)	32.00 %
Structure type	Fixed structure
Pitch distance	3.07m
Electrical characteristics	

Main characteristics	
PV modules 335.0 (Wp)	14980
Power station (up to 1980.0 kW)	3
Number of inverters (up to 110.0 KVA)	38
Environmental Characteristics	
Gaseous Emissions	None
Discharges	Uncontaminated storm water to be diverted around plant, to be made discharged to natural watercourses as appropriate.
Noise	< 15 dB(A) at nearest noise sensitive premises ≤ 15 dB(A) at plant boundary
Roads	An existing single road offering access to the field will be rehabilitated within the university to link the plants perimeter. All other means of transportation will be held within the boundaries of the field.

*(**Source**: REA EEP 3 FEED)*

The advantages of solar energy include its non-polluting nature; it is non-depletable, reliable, and free fuel. The disadvantages of solar energy are that the solar energy concentration is very dilute, so collectors with large surface area are needed. In addition, solar radiation is neither constant nor continuous for terrestrial applications (i.e. low-capacity factor). The solar energy received depends on latitude, season, time-of-day, and atmospheric conditions.

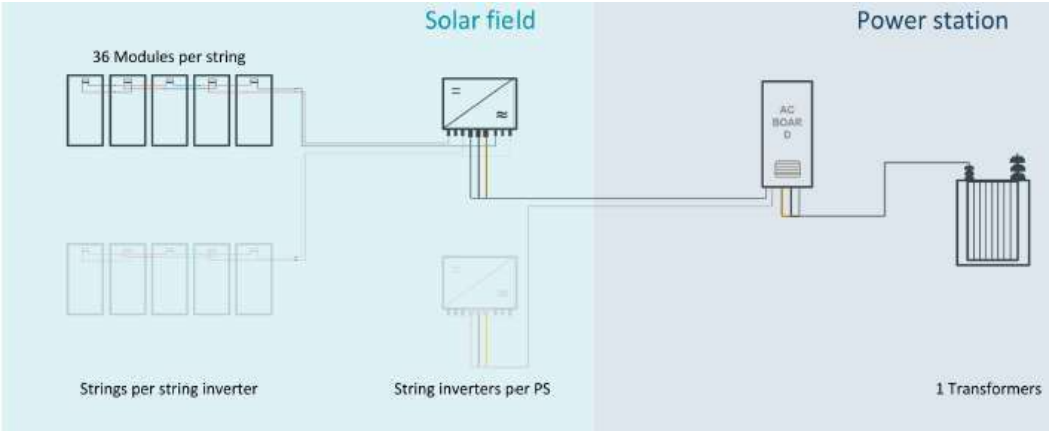


Figure 3.2: Simplified Electrical Configuration Diagram
*(**Source**: REA Desert to Power Initiative (Phase II) Front End and Engineering Design)*

3.3.2 Description of Associated Components of the Project

Solar PV Farm (*Solar PV Modules)*

A PV cell is a semiconductor device that converts sunlight into electricity using photovoltaic effect. Multiple cells can be combined to form a PV module. The efficiency of a PV module is measured by its ability to absorb light particles called photons. The more photons that are absorbed, the more efficient the panel is at converting light into electricity.

The proposed solar farm would consist of arrays modules, mounted on fixed structures to obtain a total project capability of about **5,000** (kWp) of direct current (DC). The feedstock (solar radiation) is readily available as a byproduct from sunlight, and the long-term supply is guaranteed. The panels are generally considered to have a lifetime of upwards of 25 years (Alsema, E.A., de Wild-Scholton, M.J., & Fthenakis, V.M. (2006).

The selected minimum reference photovoltaic module has a peak power of 415.0 W, and the technology of the cells is Si-poly. The features of the photovoltaic module are shown in Table 3.3, an example picture of a Monofacial Si-poly module is shown in Figure 3.3.

Table 3.3: Photovoltaic module characteristics

Main characteristics	
Technology	Si-poly
Type of module	Monofacial
Maximum voltage	1500 V
Standard test conditions (STC)	
Peak power	415.0 W
Efficiency	18.79 %
MPP voltage	39.3 V
MPP current	10.55 A
Open circuit voltage	47.8 V
Short circuit current	11.14 A
Temperature coefficients	
Power coefficient	-0.370 %/°C
Voltage coefficient	-0.291 %/°C
Current coefficient	0.050 %/°C
Mechanical characteristics	
Length	2108.0 mm
Width	1048.0 mm
Thickness	0.04 mm
Weight	24.9 kg



Figure 3.3: Example of a Monofacial Si-poly photovoltaic module
(Source: REA EEP 3 FEED)

Inverters

Inverters are installed in the containers or outside on proper mounting solution. Inverter receives DC electrical energy that flows from photovoltaic panels and transforms it into AC electrical energy that is passed to the national grid. The inverter adapts itself to the photovoltaic string to get the maximum electrical energy available and pass it to the grid. This method is called Maximum Power Point Tracking (MPTT).

In Figure 3.4, a commonly used photovoltaic inverter for utility-scale PV plant. is presented, and its characteristics detailed in table 3.4. The single line diagram for the inverter is shown in figure 3.5.



Figure 3.4: Example of string photovoltaic inverter
(Source: REA EEP 3 FEED)

Table 3.4: Inverter characteristics

Inverter characteristics	
Main characteristics	
Inverter type	**STRING**
Maximum DC to AC conversion efficiency	98.79 %
Input side (DC)	
MPPT search range	880- 1300 V
Maximum input voltage	1500 V
Output side (AC)	
Rated power	110.0 kVA
Power at 30 C (datasheet)	110.0 kVA
Power at 50 C (datasheet)	100.0 kVA
Output voltage	800 V
Output frequency	50 Hz

(Source: REA EEP 3 FEED)

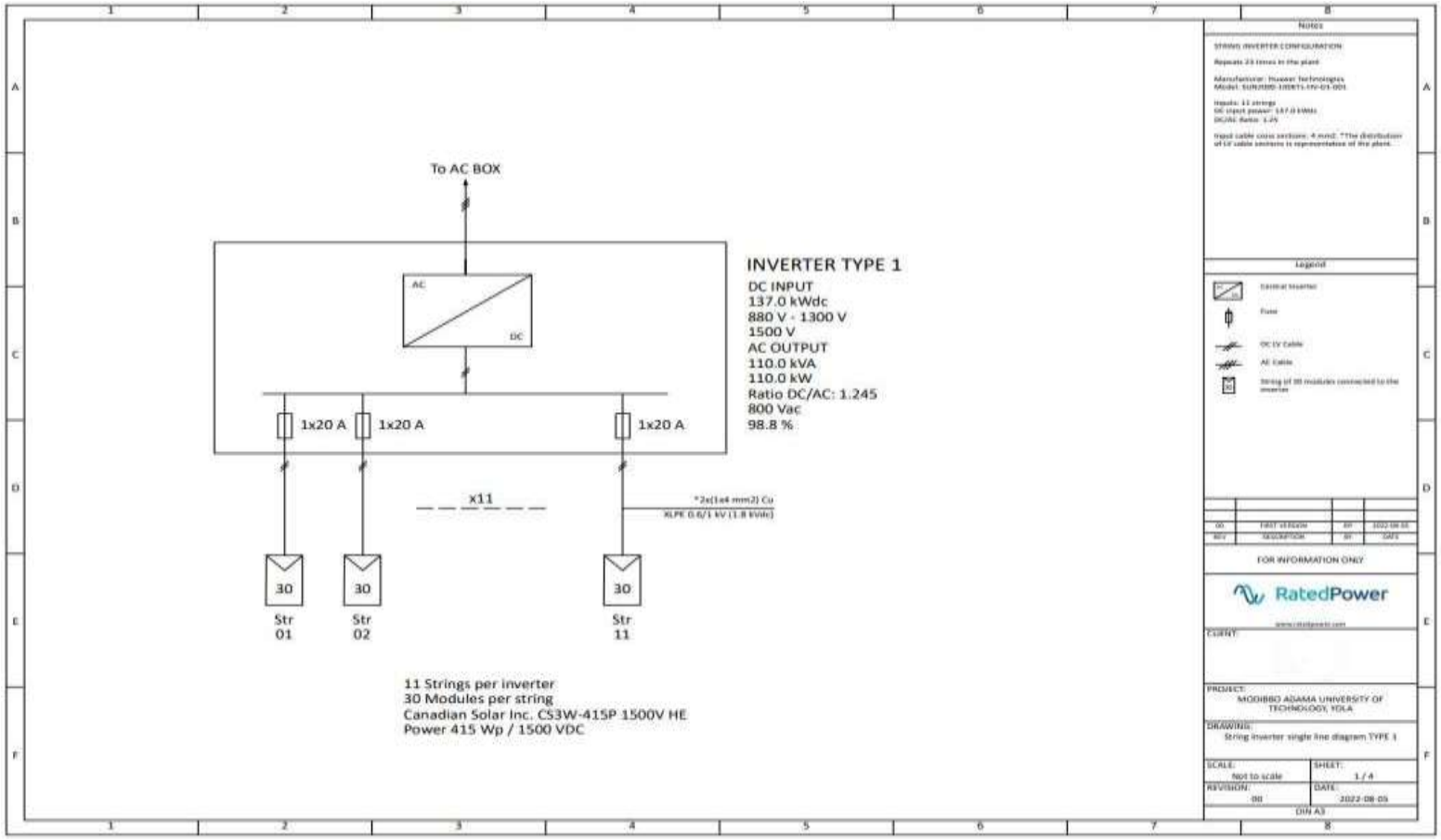


Figure 3.5: String Inverter Single Line Diagram

(Source: EEP3 FEED)

Transformers

All inverters are connected to a transformer. The role of the transformers is to step- up the voltage from an inverter nominal voltage to a medium voltage of the national grid. Transformers consist of three coils. One coil is connected to the high voltage; two coils are connected to each of the inverter unit's master/slave. The proposed project layout comprising the solar power plant site and transmission line have taken into account the solar radiation, wind direction and evacuation corridor. An example of a power transformer is shown in Figure 3.6.



Figure 3.6: Example of Transformer

*(**Source**: REA EEP 3 FEED)*

The main features of the power transformer are shown in Table 3.5.

Table 3.5: Transformer characteristics

Transformer characteristics	
Rated power	1980.0 kVA
Voltage ratio	0.8/ 11.0kV
Cooling system	ONAN
Tap changer	2.5%, 5%, 7.5%, 10%
Short circuit (Xcc)	0.08

*(**Source**: REA EEP 3 FEED)*

Power station

The power stations or transformer stations are indoor buildings or containers. The voltage of the energy collected from the solar field is increased to a higher level to facilitate the evacuation of the generated energy. The power transformers will be housed in the power station. An example of an Indoors power station is shown in Figure 3.7.



Figure 3.7: Example of a Power Station

The power station shall be supplied with medium voltage switchgears that include one transformer protection unit, one direct incoming feeder unit, one direct outcoming feeder unit and electrical boards. Particularly, for the first power station of each MV line, a direct incoming unit will not be installed.

The main features of the default power station are shown in Table 3.6. Figure 3.8 is the Power Station Single Line Diagram.

Table 3.6: Power Station Characteristics

Power station characteristics	
Number of transformers	1
Voltage ratio	0.8/20.0kV
Service Indoors	Indoors

*(**Source**: REA EEP 3 FEED)*

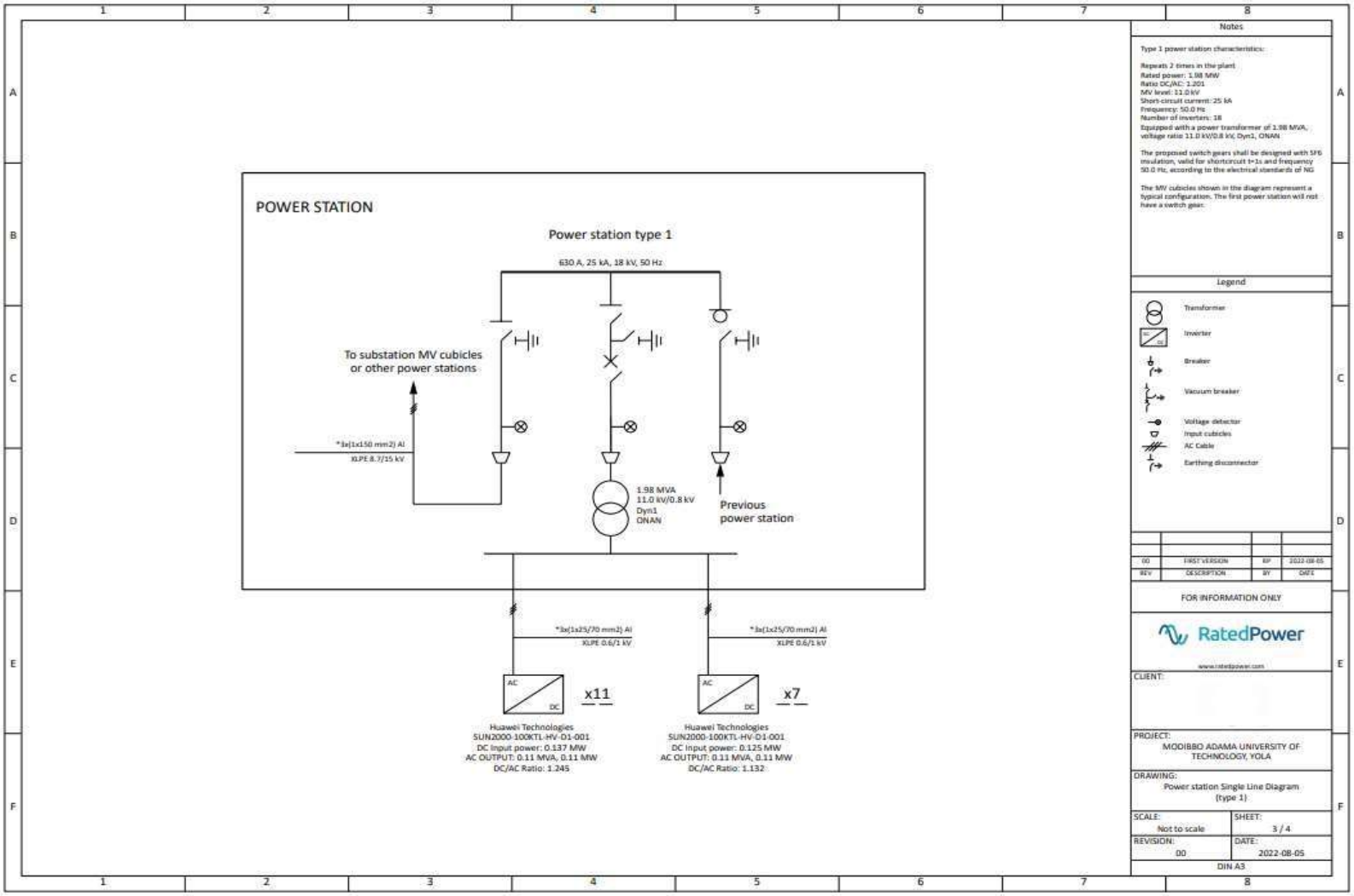


Figure 3.8: Power station Single line Diagram

*(**Source**: EEP3 FEED)*

Access Roads

Gravel paved earth access roads within the facility will be constructed. The roads will link all project components and be laid out in an efficient manner to ensure easy access for operation and maintenance as well as access from outside the facility.

For the design of the proposed PV plant, roads of 4.0 m have been used. These roads run a total distance of 404.09 m. Road ditches used for drainage and for channeling water are placed on one side of the roads. Figure 3.9 shows a Typical Road Cross Section for the university. A total perimeter of 1135.42 m of chain link fence surrounds the different areas of the PV plant. The fence has at least 2.0 m of height and 3.0 m between posts. For every 50.0 m of fence, a light post of 4.0 m of height and a microwave barrier system are installed. For every 100.0 m of fence, a video camera post of 6.0 m of height is installed.

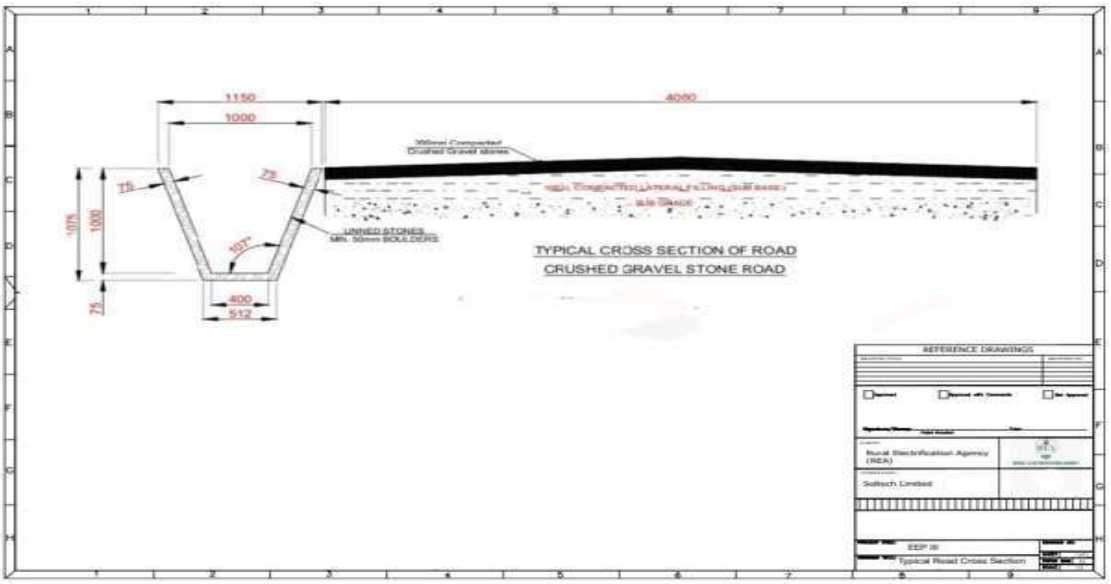


Figure 3.9: Typical Road Cross Section

*(**Source**: REA NEP 3 FEED)*

Buildings

A renewable workshop centre will be built and ancillary facilities that include residential quarters for the security, maintenance, and control room staff who will be required full-time, a guard house and an office/control centre. Figure 3.10 is an illustration of the elevation plans of the training Centre.

Control Building

The control building would take up an area of approximately 30 m × 15 m. The main construction compound would temporarily require an area of approximately 60 m × 40 m, however; this area would be fully reinstated after construction.

Lay down and Staging Area

A staging area where solar panels would be assembled would be constructed within the project area. The entire area would be enclosed by a chain link fence with a gate. Regular cleaning of the solar panels would be accomplished by either rinsing with water, blowing with compressed air, or a combination of both. Expected waste from this area would include wooden crates, plastics wrappings and Styrofoam.



Figure 3.10: Elevation plans for the training Centre

*(**Source**: EEP FEED)*

3.3.2.1 Existing Power Supply and Reported Electrical Load Capacity

AFIT presently obtains electricity from the national grid and supplements the available supply with backup diesel-powered generators and distributed solar installations located at selected facilities within the Institute. The electrical data supplied by AFIT also provides reported load-capacity groupings for academic, administrative, residential, laboratory, workshop, ICT, health and other support facilities across the campus.

The reported electrical load-capacity schedule for the Institute is summarized in ***Table 3.6.*** The schedule supplied by AFIT records a grand total of 3,280 kVA for the listed campus facilities.

Table 3.7: Reported Electrical Load Capacity Across AFIT Facilities

S/N	Facilities / Departments Served	Reported Capacity
1	HQ AFIT; Telecoms Engineering; Welding Workshop; Machine Workshop; Supply (LMD); Maged Department; Yisa Doko Hall; Airframe Hangar; EEED Department; Library; Electronic Laboratory; Water Treatment; Electrical Workshop; Foundry Workshop; LR Offices; Students Affairs; Cafeteria/Shops; Amao Hall; E-Library; Mosque; and TETFund Phase 1.	810 kVA
2	SPS Department; ICT Department; EEED Department; AMD; Alex Bade; OLE 2; Ghanaian Quarters; and MSC Quarters.	50 kVA
3	Faculty of Education; Aircraft Engineering Technology Department; AFIT Clinic; Block of Office Accommodation for Lecturers; 560-Capacity CBT Bungalow; Science Laboratory; 45 x 1 Students Hostel; 36 x 1 Students Hostel; Mechanical Engineering/Faculty of Education; and Civil Engineering (NUC).	640 kVA
4	Female Hostel; Lecture Rooms; Multi-User Laboratory; New School of Postgraduate Studies; 2 Nos. 150-Capacity Classrooms and Offices; 2 Nos. 20-Room Students Hostels; AFIT Creche; 2 Nos. 16-Room Hostels; AFIT Warehouse; New Library Extension; Cafeteria/Workshop/Souvenir Shop; New Faculty of Engineering; Senior Lecturers Offices; and Basketball Court.	500 kVA
5	45-Room Girls Hostel; Security Office; Boys Hostel 1; Boys Hostel 2; Classrooms and Offices; Armament Engineering; FSMS (NBTE); Faculty of Computing; FGCE; and 45 x 1 Female Hostel.	600 kVA
6	108-Capacity CBT Centre; Centre of Entrepreneurship Department; Students Affairs Directorate; and AFIT Kitchen/Dining Hall.	250 kVA

Source: AFIT Power Consumption Data, 2026.

Existing Solar Installations

In addition to grid electricity and diesel backup generation, AFIT has a number of existing solar installations serving selected buildings and facilities. The capacities reported by AFIT are presented in ***Table 3.7.***

Table 3.8: Existing Solar Installations Reported within AFIT

S/N	Location / Facility	Reported Capacity
1	Ibrahim Alfa Hall	15 kVA
2	108 CBT Hall	10 kVA
3	Entrepreneurship	10 kVA
4	Library	15 kVA
5	EEED	5 kVA
6	ICT	15 kVA
7	SPS	8 kVA
8	LR	8 kVA
9	SCI	5 kVA
10	E-Library	4 kVA
11	LMD	8 kVA
12	Amao Hall	5 kVA

S/N	Location / Facility	Reported Capacity
13	Bank Roll	15 kVA
14	Yisa Doko Hall	10 kVA

Source: AFIT Power Consumption Data, 2026.

Backup Diesel Generation and Fuel Consumption

AFIT also operates backup diesel-powered generating sets to support electricity supply during periods when grid electricity is unavailable or inadequate. The generating sets identified in the data supplied by AFIT are summarized in ***Table 3.8.***

Table 3.9: Backup Diesel Generators Reported within AFIT

S/N	Location / Facility	Generator Capacity
1	Ibrahim Alfa Hall	220 kVA and 150 kVA
2	Temporary Headquarters	33 kVA
3	Academic Branch	22 kVA

Source: AFIT Power Consumption Data, 2026.

The fuel-consumption information supplied by AFIT records a diesel consumption figure of **13,680 litres** for the Institute's backup generation system.

Existing High-Tension Distribution Network

The electrical information supplied by AFIT identifies the capacity of the Institute's high-tension electrical line as 11 kV. This corresponds with the 11 kV evacuation arrangement adopted for the proposed solar-hybrid project and provides the medium-voltage interface through which generated electricity will be delivered to the institutional load centre and distributed to beneficiary facilities within the campus.

Transmission Line

The power generated from the proposed solar power plant would be evacuated through an 11kV transmission line to the institution load center through underground cable. The path for the underground cable will be beside the existing road.

The proposed 2 MW solar-hybrid facility will therefore supplement AFIT's existing electricity sources through the Institute's 11 kV distribution arrangement, reducing dependence on diesel-powered backup generation while supplying electricity to the campus load centre for onward distribution through the existing network.

3.3.3 Project Phases for Implementation:

The project will be implemented in four major phases:

Pre-Construction Phase

The Pre-construction Phase of the project is a critical planning and preparatory stage that precedes physical site works. This phase ensures that the project is technically sound, environmentally compliant, financially structured, and administratively authorized prior to commencement of civil and electrical installation activities.

Pre-construction works are expected to last for 1 - 2months. The works at this stage will entail activities such as completion of engineering design for the Project and receipt of relevant approvals, mobilization of personnel, equipment and materials to site; and site clearing and grading.

***Detailed engineering design*:**
Following conceptual design and feasibility studies, the EPC contractor will undertake comprehensive detailed engineering design. This will include:

- Final plant layout and string configuration;
- Structural design of mounting systems (fixed-tilt or tracker, as applicable);
- Electrical single-line diagrams (SLD);
- Inverter sizing and transformer specifications;
- Protection and grounding design;
- SCADA/monitoring system architecture;
- Battery energy storage system (if included) integration design.

All engineering designs will comply with applicable IEC standards, Nigerian electricity regulations, and manufacturer specifications. Design outputs will include Issued-for-Construction (IFC) drawings, technical datasheets, and quality control documentation.

Site surveys and geotechnical investigations:
Comprehensive site investigations will be conducted to validate design assumptions and ensure structural stability. These will include:

- Topographical survey using GPS/GIS referencing;
- Soil borehole testing and geotechnical analysis (bearing capacity, soil stratification, groundwater depth);
- Assessment of drainage patterns and erosion risks;
- Electrical resistivity testing for grounding system design.

The geotechnical findings will guide foundation selection (e.g., driven piles vs. shallow concrete foundations) and inform structural safety margins in accordance with engineering best practice.

Procurement and regulatory approvals:

- Procurement will follow transparent competitive bidding procedures in line with REA and applicable development partner guidelines. Equipment procurement will prioritize:
- IEC-certified solar modules;
- High-efficiency inverters;
- Approved transformers and switchgear;
- Compliance with FMEnv and NESREA environmental requirements.

Regulatory approvals to be secured prior to construction include:

- Environmental authorization from the Federal Ministry of Environment;
- Electrical interconnection approvals (where applicable);
- Building and structural approvals from relevant authorities;

- Fire safety clearance.

Construction activities will commence only after all statutory permits and environmental clearance certificates are obtained.

***Mobilization*:**
Mobilization marks the transition from planning to physical implementation. This activity will include:

- Deployment of about ten (10) EPC personnel and technical teams to site;
- Establishment of temporary site offices and storage facilities;
- Delivery of construction equipment and materials;
- Site fencing and security arrangements;
- Implementation of site-specific Health, Safety, and Environmental (HSE) plans.
- Recruitment of about twenty (20) low skilled workers (e.g. construction labour who will make up the majority of workers), semi-skilled workers (drivers, technicians, etc.), and skilled personnel (e.g. engineers).

Mobilization activities will be carefully managed to minimize disturbance to ongoing operations and ensure compliance with environmental and safety requirements.

Table 3.10: List of construction equipment and material for the project

Equipment / Vehicle	Purpose During Mobilization
Excavators & Backhoes	Clearing vegetation, digging trenches for temporary utilities, and digging holes for fence posts.
Bulldozers & Motor Graders	Performing initial profiling and leveling of the site to create a stable and accessible terrain.
Dump Trucks	Hauling and spreading gravel for temporary access roads, laydown yards, and site pads.
Water Trucks	Controlling dust on unpaved roads and earthworks to comply with environmental regulations.
Heavy-Duty Trucks (Flatbeds/Lowboys)	Transporting the heavy construction equipment (excavators, bulldozers) and initial materials (fencing, office containers) to the site.
Forklifts	Unloading deliveries, staging materials like fence posts and concrete blocks, and moving heavy items around the site.
Compactor Rollers	Compacting the soil and gravel for access roads and equipment pads to ensure a stable working surface.
Skid Steer Loaders	A versatile machine for small earthmoving tasks, digging post holes with an auger attachment, and moving materials.
Service Pickup Trucks & ATVs	Providing transportation for management, supervisory staff, and survey crews to move around the site

Site clearing and grading:
Site preparation will involve light vegetation clearing, removal of debris, and minor grading to achieve a stable and level working surface for panel installation. Key considerations shall include:

- Avoidance of unnecessary vegetation removal beyond the project footprint;
- Preservation of topsoil for reuse where applicable;
- Implementation of erosion control measures (e.g., drainage channels);
- Controlled movement of construction equipment (see table 3.7 above) to prevent soil compaction.

Given that the site is located within previously disturbed institutional land, clearing impacts are expected to be minimal and localized.

Construction Phase

The construction phase is expected to last approximately 6–8 months and executed by a qualified EPC contractor under REA supervision. Activities will be carefully sequenced to minimize environmental disturbance and disruption to campus operations. The activities/major civil works/facilities to be constructed for this phase includes - installation of mounting structures and PV panels; electrical works and interconnection; and testing and commissioning.

Installation of mounting structures and PV panels:

Mounting structures (typically galvanized steel or aluminum) will be installed using pile-driving or shallow concrete foundations, depending on geo-technical conditions. Activities will include:

- Layout marking and alignment using survey equipment;
- Driving or anchoring of support piles;
- Assembly and fastening of module racks;
- Installation and securing of PV modules onto mounting frames.

All installations will comply with applicable IEC standards for structural integrity and wind loading requirements. Works will be supervised to ensure proper torque settings and corrosion protection.

Electrical works and interconnection:

Electrical installation will involve:

- DC cable routing and string configuration;
- Installation of combiner boxes and inverters;
- Earthing and lightning protection systems;
- Installation of transformer and protection panels;
- Integration with the campus distribution network.

All electrical works will adhere to Nigerian electrical installation standards and safety protocols, including insulation testing and grounding resistance verification.

***Testing and commissioning*:**

Upon completion of installation, the system will undergo comprehensive testing and commissioning to verify design performance and safety compliance. Commissioning activities will include:

- Visual inspection of all mechanical and electrical components;

- Insulation resistance and continuity testing;
- Inverter configuration and synchronization testing;
- Performance verification against expected output benchmarks;
- Grid interconnection validation and protection relay testing.

A commissioning report will be prepared, and performance guarantees will be validated prior to formal handover to the University and O&M contractor.

Operational Phase

Electricity generation

During the operation phase, the 2MW Solar Hybrid Power facility at Air Force Institute of Technology (AFIT) will generate electricity through the direct conversion of solar irradiance into direct current (DC) power by the PV modules. The DC power will be transmitted through combiner boxes to grid-tied inverters, where it will be converted into alternating current (AC) compatible with the university's distribution network. Generated electricity will primarily serve campus loads (academic buildings, laboratories, hostels, and administrative blocks), thereby reducing reliance on diesel generators and supplementing grid supply.

Operation and Maintenance

Operation and maintenance of the system would be expected to occur on a limited basis at certain points during the system's estimated 25-year life cycle. To enhance the performance and reliability of the plant, the following types of maintenance will be carried out:

Preventive Maintenance: which involves routine inspection and servicing of plant equipment to prevent breakdowns. This includes panel cleaning, vegetation management, wildlife prevention, water drainage, monitoring of electrical components. It also involves retro- commissioning to improve the efficiency of the PV plant by detecting and solving problems in the system.

Corrective Maintenance: which involves repair of broken-down equipment. This includes on- site monitoring and mitigation, and critical and non-critical repairs of plant components.

Condition-based maintenance: which involves monitoring equipment and plant operations real-time and addressing potential problems early on in order to prevent plant downtime. This includes continuous monitoring via remote and on-site methods, warranty enforcement, and planned and unplanned equipment replacement.

Maintenance activities will be carried out by skilled manpower with backgrounds in electrical/electronic engineering and unskilled local labour where applicable. Specific maintenance activities include the following:

PV Modules

PV modules need to be cleaned weekly in the dry season and monthly in the wet season to prevent accumulation of dust. Also, the cabling around the modules need to be checked regularly for damages. Panels need to be checked regularly for cracks and breaks. Panel testing needs to be conducted annually to ensure they live up to the manufacturer's warranty.

Electrical System

- Inverter components need to be checked to prevent breakdown which can occur during very hot weather conditions.
- Electrical wiring and earthing protection need to be checked for wear and tear. Also, the underground cabling needs to be monitored regularly for damages from pests. Infra- red technology may be employed to identify spots where there are electricity leaks.

Civil Structures

- Mounting structures need to be checked regularly for bending damage which can affect the PV modules
- Access roads, drainage works, plant foundation and array structures need to be checked by visual inspection for water damage during the rainy season

Vegetation

- Growth of shrubs and other vegetation needs to be curtailed to prevent shadowing effect on the solar panels leading to a decrease in the output from the plant. Weeds also need to be eliminated as they present a fire hazard.
- Vegetation around the transmission line RoW needs to be cleared quarterly to maintain a vegetation height at less than 2 ft (0.61 m).

A stockpile of spare parts will be kept on-site to facilitate replacement of broken-down or out- dated solar panels and inverters. On-site security and inventory management will be implemented to prevent theft of spare parts and installed plant components.
Monitoring of the PV system components needs to be conducted to ensure increased system output and to reduce down-time. Traditional monitoring methods that compare actual energy generation against predicted energy generation will help to track the system's relative health.

Performance monitoring:

System performance will be continuously monitored using an integrated monitoring and control platform (e.g., SCADA or web-based monitoring system). Key operational parameters tracked will include energy output (kWh), inverter efficiency, system availability, performance ratio (PR), voltage and frequency stability, and battery state-of-charge. Automated alarms will notify operators of faults such as inverter trips, abnormal temperature rise, or grid synchronization issues. Periodic performance reviews will be conducted to compare actual generation with projected output, enabling early detection of under-performance due to dust accumulation, shading, equipment degradation, or component failure. This monitoring framework ensures optimal system efficiency, rapid fault response, and long-term operational reliability.

Decommissioning Phase

Although the proposed 2MW Solar PV facility at the Air Force Institute of Technology (AFIT) is designed for an operational lifespan of approximately 25 years, a structured decommissioning plan

will be implemented at end-of-life in accordance with FMEnv guidelines, national waste management regulations, and international best practice for renewable energy infrastructure. The commissioning activities shall include the following activities:

Dismantling of equipment:
Decommissioning will begin with systematic electrical isolation and safe shutdown of all system components. Activities will include:

- Disconnection of PV arrays from inverters and grid interface systems;
- Removal of solar modules from mounting structures;
- Dismantling of inverters, transformers, combiner boxes, and protection systems;
- Removal of battery energy storage systems;
- Disassembly of mounting structures and foundations where required.

All dismantling works will follow electrical safety procedures including hazard control measures to prevent electric shock, fire, or injury. Equipment handling will prioritize prevention of breakage, particularly for PV modules and batteries.

Disposal, Recycling or Reuse of Components:
Decommissioned components will be managed in accordance with applicable environmental regulations and circular economy principles.

- PV Modules: Where, modules may be refurbished and reused. Damaged modules will be sent to certified recycling facilities for recovery of glass, aluminum frames, and semiconductor materials.
- Metal Structures: Steel and aluminum mounting systems will be recycled through licensed scrap metal processors.
- Electrical Equipment: Inverters, transformers, switch-gears and other serviceable units will be assessed for reuse or sent for certified recycling.
- Batteries: Battery systems will be handled as regulated waste streams and returned to authorized recyclers in line with hazardous waste management requirements.

Waste tracking documentation will be maintained to demonstrate regulatory compliance and responsible material handling. This approach minimizes landfill disposal, reduces environmental risk, and aligns with circular economy principles.

Site rehabilitation:
Following equipment removal, the site will be restored to a safe and stable condition that will ensure that the land is structurally and environmentally suitable for alternative institutional uses. The objective of site rehabilitation is to ensure that no long-term environmental liability remains and that the land is suitable for future institutional development or alternative use. Rehabilitation activities will include:

- Removal of concrete pads, foundations, debris and residual materials;
- Back-filling and leveling of disturbed areas;
- Soil stabilization and erosion control;

- Re-vegetation using native grass species where necessary;
- Final site inspection and environmental compliance verification.

3.4 Manpower Requirement

The proposed project will require an estimated workforce of at least 45 workers during the construction and operation phases. A mix of skilled, semi-skilled, and low-skilled labour will be needed, with workforce demand peaking during civil works and equipment installation. Preference will be given to local hires to strengthen community relations and reduce costs. The breakdown of the estimated workforce required for the project is on Table 3.8.

Table 3.11: Breakdown of the estimated workforce the construction and operation phases.

Construction Phase		
Category	**Typical Roles**	**Estimated Number**
Low-Skilled Workers	General labourers, material handlers, security assistants	~ 20
Semi-Skilled Workers	Electricians' assistants, panel installers, welders, equipment operators	10–15
Skilled Workers	Electrical engineers, site engineers, certified electricians, HSE officer, project supervisor	6–8
Total (Peak)	—	~ 31–45
Operation Phase		
Category	**Typical Roles**	**Estimated Number**
Semi-Skilled	Plant technician	1–2
Skilled	Electrical engineer / O&M supervisor	1
Support	Security, Cleaners, (shared with campus)	Existing staff

3.5 Water Use and Supply

The use of water for construction activities will be minimal because construction works requiring cement mixing will not be much on site. Water is required majorly during operational phase of the integrated solar power plant for periodic cleaning of PV panels to prevent dust build-up (especially during the dry season), since dust can affect their performance by inhibiting the amount of irradiation that reaches the solar cells. The rate of build-up of dust on the PV panels is dependent on a number of factors including soil type, local wind speed and the mounting structure used for the panels.

Manual cleaning of the PV panels with water shall be regulated as much as practicable. During the periods of rainy season, direct cleaning of the PV panels is estimated to occur not more than three times. However, during the dry season (November to March), the frequency of cleaning is planned to be on a bi-weekly basis but may increase due to high dust generation usually experienced in the Northern parts of the country.

Based on the review of similar solar power projects, each PV panel would require **approximately 5 litres of water per cleaning cycle**. Water will be supplied through the University's existing water

distribution system or other approved water sources within the campus, thereby eliminating the need for the development of new water abstraction facilities. Cleaning activities will be undertaken using efficient water management practices, soft brushes or approved non-abrasive cleaning equipment to minimize water consumption and prevent damage to the PV modules.

3.6 Solar PV Network Installation Standards and Codes

There are many organizations that develop the standards and codes for PV systems. ASTM mainly known as the American Society of Testing and Materials has developed more than 12,000 international standards to improve the quality of the product and enhance safety. The PV standard developed by ASTM technical committee is E44.09 Photovoltaic electric power conversion. The International Code Council (ICC) is involved mainly with the development of a single set of comprehensive international model construction codes engrossed in building safety and fire prevention. The International Electro-Technical Commission (IEC) has published Technical Specifications IEC 62257, a set of standards covering technical and organizational aspects of mini-grids (design, installation, maintenance, contracting) and a checklist of good practices. The Nigeria Electricity Management Services Agency (NEMSA) through NEMSA Rooftop Solar Safety Guidelines enforce strict standards and guidelines for safe design, installation, and operation of solar Photovoltaic (PV) systems.

3.6.1 Health, Safety and Environment (HSE)

Rural electrification Agency (REA) is aware that occupational health and safety as well as community health and safety issues likely to occur during construction, operation and maintenance of the solar power project. Workers may be exposed to physical hazards, trip and fall hazards, exposure to dust during site clearing, risk of electrical hazards and other related danger. Rural electrification Agency shall implement all reasonable precautions that will guarantee the health and safety of workers throughout the project implementation stages. Rural electrification Agency has developed a preventive and protective measure that prioritizes eliminating of hazard, controlling of hazard, minimizing of hazard and the use of personal protective equipment (PPEs).

It is the duty of Rural electrification Agency to ensure that only trained and certified personnel are allowed to work in areas where there is potential risk of harm. However, all workers will be trained on risk identification and hazard perception. A detailed occupation health and safety plan has been developed and presented in Chapter Seven as part of the Environmental and Social Management Plan (ESMP) for the solar project.

Proper OHS risk identification and management measures shall be incorporated in every project's management plan and standard EPC contractual clauses. The EPC contractor shall engage dedicated personnel competent on the basis of appropriate education, training, and experience to manage and oversee the HSE aspects of the Project. The HSE personnel shall ensure that the Project and subcontractors operate in accordance with the applicable regulatory HSE requirements and plans; and also monitor implementation of environmental and social protection measures. Occupational health and safety (OHS) plans shall be developed and maintained by all contractors involved in the implementation of the proposed Project particularly in the following aspects:

Occupational Health and Safety:

- General Facility design and operation.
- Communication and Training.
- Physical Hazards.
- Chemical Hazards.
- Biological Hazards.
- Personal Protective Equipment (PPE).
- Special Hazard Environments.
- Monitoring.

Community Health and Safety:

- Water Quality and Availability.
- Structural Safety of Project Infrastructure.
- Life and Fire Safety (L&FS).
- Traffic Safety.
- Transport of Hazardous Materials.
- Disease Prevention.

3.7 Emergency Preparedness

Solar PV facilities are generally low-risk installations but the presence of high DC voltages, grid interconnection infrastructure, inverters, battery energy storage systems necessitate the incorporation of emergency response measures to ensure personnel safety, asset protection, and environmental safeguarding. Emergency situations that could occur during the operational phase may include but not limited to electrical faults, components malfunction/overheating, fire outbreak, extreme weather events, vandalism, etc. In the event of an emergency, the following shutdown and isolation systems shall be incorporated into the plant design:

- DC Isolation Measures
- AC Isolation Measures
- Rapid Shutdown Functionality so that the system shuts down to reduce voltage levels in the event of fire or emergency intervention
- Inverter Protection Systems

The facility shall also have:

- Portable fire extinguishers (CO_2 and dry chemical type) located at inverter stations and battery enclosures;
- Clearly marked emergency shutdown buttons;
- Fire-resistant cable routing where required;
- Smoke Detectors
- Lightning protection and surge arresters integrated into the system design.

Additionally, coordination shall be established with the institution's Safety Unit and local fire services to ensure familiarity with the facility layout and shutdown procedures.

3.8 Waste Management

Although solar photovoltaic systems generate end-of-life wastes that require environmentally sound management, the quantity and environmental impacts of wastes and emissions associated with their lifecycle are generally lower than those arising from the extraction, processing and combustion of non-renewable energy resources, provided that PV components are properly recovered, recycled or disposed of in accordance with applicable environmental regulations (Federal Ministry of Environment, 2021; NESREA, 2014).

This implies that renewable Energy Technologies (RETs), while they are environmentally friendly during their useful life, they are not 100% pollution-free at their end-of-life (EoL) period. PV systems have ways of generating primary and secondary wastes streams. The primary wastes streams are direct components used in PV systems, whereas secondary waste streams comprise pollutants from nonrenewable energy resources used in the production and disposal of PV panels and the rest of the balance of system (BOS) components (wires, batteries, inverters, metallic frames). Wastes generated from nonrenewable energy including solar PVS are of high environmental impacts. A summary of expected waste stream from the project phases is outlined in Table 3.9.

Table 3.12: Waste Streams of Project Phases

Waste Stream	Sources	Waste Generation Phase			
		Pre-Construction	Construction	Operation and Maintenance	Decommissioning
General rubbish, refuse, and putrescible wastes (Food wastes)	Wood splinter, domestic waste, food packs, used bottles	✓	✓	✓	✓
Vegetal waste	During site clearing and preparation	✓		✓	✓
Scrap metals	Used tubular and casings, used iron rods		✓	✓	✓
Excavated materials	Foundation works		✓		
Damaged/ expired and removal PV panels	PV modules		✓	✓	✓
Expired inverters and Faulty or Damaged cables	Electrical installation			✓	✓
Damaged/ expired Batteries	Power generation			✓	✓

*(**Source**: Adapted from IFC 2015 Project Developer's guide to utility-scale solar photovoltaic power plants)*

Types of Wastes: Identification, Categories, and Estimated Quantities

***Pre-Construction Phase**:* Wastes for the pre-construction phase will be as a result of mobilization of personnel and equipment, site clearing, grading, and temporary site setup. Waste generation during this phase is expected to be moderate (temporary and localized) and primarily non-hazardous, with small quantities of hazardous waste associated with equipment servicing.

Table 3.13: Pre-Construction Phase Waste Inventory and Handling Strategies

Waste Type	Waste Identification/Source	Category	Estimated Quantity	Proposed Management Measure
Used lubricants/ engine oil	Hydrocarbon-based oil	Hazardous	< 40 litres	Collection in sealed containers; disposal via licensed waste handler
Oily rags/absorbents	Oil-contaminated materials	Hazardous	< 20 kg	Segregation; disposal through approved hazardous waste contractor
Packaging materials (plastic wraps, pallets)	HDPE/wood packaging	Non-hazardous / Recyclable	200–300 kg	Segregation and recycling
Vegetation (grass, shrubs)	Organic biomass	Non-hazardous / Biodegradable	3–5 tonnes	Composting, mulching, or controlled disposal
Excavated soil	Excavation and grading activities	Inert (reusable)	< 50 m^3	On-site reuse for leveling/backfilling
Domestic waste (food packs, bottles)	Municipal solid waste	Non-hazardous	50–100 kg/month	Provision of covered bins; evacuation to approved municipal facility
Empty lubricant containers	Plastic/metal containers	Hazardous (if contaminated)	< 15 units	Triple-rinse (where applicable); disposal through approved contractor

Construction Phase: During the construction phase, waste streams are expected to arise from mounting structure installation, electrical works, equipment packaging, worker activities, etc.

Table 3.14: Construction Phase Waste Inventory and Handling Strategies

Waste Type	Waste Identification/ Source	Waste Category	Estimated Quantity (Total Construction Period)	Waste Management Approach
Cartons, plastic wraps, wooden crates	PV modules, inverters, electrical components packaging	Non-hazardous recyclable solid waste	1–2 tonnes	Segregate at source; returnable crates returned to supplier; recyclables transferred to licensed recycler
Scrap metal (steel offcuts, mounting remnants)	Mounting structure fabrication & installation	Non-hazardous recyclable waste	0.5–1 tonne	Collected and sold to licensed scrap metal recycler
Cable offcuts and insulation	Electrical installation works	Non-hazardous recyclable	~200–300 kg	Segregation and recovery of copper;

Waste Type	Waste Identification/ Source	Waste Category	Estimated Quantity (Total Construction Period)	Waste Management Approach
remnants		(PVC/ copper)		disposal via licensed recycler
Concrete debris / excess concrete	Foundation works (if shallow foundations used)	Inert construction waste	<2 m³	Reuse as backfill where feasible; remainder disposed at approved site
Excavated soil	Trenching for cables	Inert material	5–10 m³ (temporary)	Reinstatement and backfilling on-site
Used oil/grease from equipment servicing	Construction equipment maintenance	Hazardous waste	<50 litres	Stored in sealed containers; transferred to licensed hazardous waste handler
Empty paint/chemical containers (if applicable)	Minor protective coating works	Hazardous (if contaminated)	< 1 drum	Triple-rinsed (where applicable) and disposed through licensed waste contractor
Domestic waste (food waste, bottles, sachets)	Construction workforce activities	Non-hazardous municipal waste	~0.5 tonne	Collected in covered bins; disposed through approved municipal waste system
Damaged PV modules	Handling/ transport damage	Electronic waste (potentially hazardous)	<5 units (contingency)	Returned to supplier under warranty or handled by certified e-waste recycler

Operation Phase: During the operational phase, the primary wastes will arise from routine maintenance, component replacement, housekeeping activities, and potential battery servicing. The table below summarizes the expected waste streams, their classification, estimated annual quantities, and corresponding management approach in compliance with applicable environmental regulations and best practice for solar PV installations.

Table 3.15: Operation Phase Waste Inventory and Handling Strategies

Waste Type	Identification / Source	Waste Category	Estimated Quantity (Annual)	Waste Management Approach
Damaged PV modules	Replacement due to breakage or degradation	Electronic waste	<15 modules (<500 kg)	Return-to-supplier program or recycling through licensed e-waste handler
Inverter components (PCB boards, fuses, relays)	Routine maintenance or fault replacement	Electronic waste	<200 kg	Segregation and disposal via certified e-waste recycler

Waste Type	Identification / Source	Waste Category	Estimated Quantity (Annual)	Waste Management Approach
Used electrical cables and connectors	Maintenance replacement	Recyclable solid waste	<100 kg	Sale/transfer to licensed scrap metal recycler
Scrap metal (mounting repairs)	Minor structural maintenance	Recyclable solid waste	<150 kg	Recycling through licensed metal recycler
Used lubricants/ cleaning agents	Equipment servicing	Hazardous waste	<50 litres	Collection in labeled containers; disposal via licensed hazardous waste contractor
Spent batteries	End-of-life battery modules	Hazardous waste	Project-dependent (e.g., 1–2 tonnes at replacement cycle)	Return-to-manufacturer take-back scheme or disposal via certified hazardous waste facility
General office waste (paper, packaging)	O&M administration	Non-hazardous municipal waste	<300 kg	Integration into campus waste management system
Panel cleaning residue (dust runoff)	Periodic cleaning	Non-hazardous	Minimal; evaporative	Controlled drainage/evaporative/dust wash); no chemical additives used

3.9 Project Schedule

The implementation schedule is structured across Pre-Construction Phase, Construction Phase and Operation & Maintenance Phase. As part of measures to save time in the execution of the project, some of the phases and activities in the project implementation will run concurrently. The implementation schedule for the execution of the different project activities for the Solar Power Plant project is indicated in Table 3.13.

Table 3.16: Implementation Schedule

Phase	Key Activities	Estimated Duration
Phase 1: Pre-Construction	Final design, permitting, procurement, site surveys	2–3 months
Phase 2: Construction	Site preparation, mounting structure installation, module installation, inverter installation, electrical works, testing & commissioning	4–6 months
Phase 3: Operation & Maintenance	Electricity generation, monitoring, preventive and corrective maintenance	25 years (design life)

The proposed Project is planned to be operational by the 4th Quarter (Q4) of 2026/1st Quarter (Q4) of 2027. Figure 3.11 is a typical EPC Construction Phase to Handover Protocol.

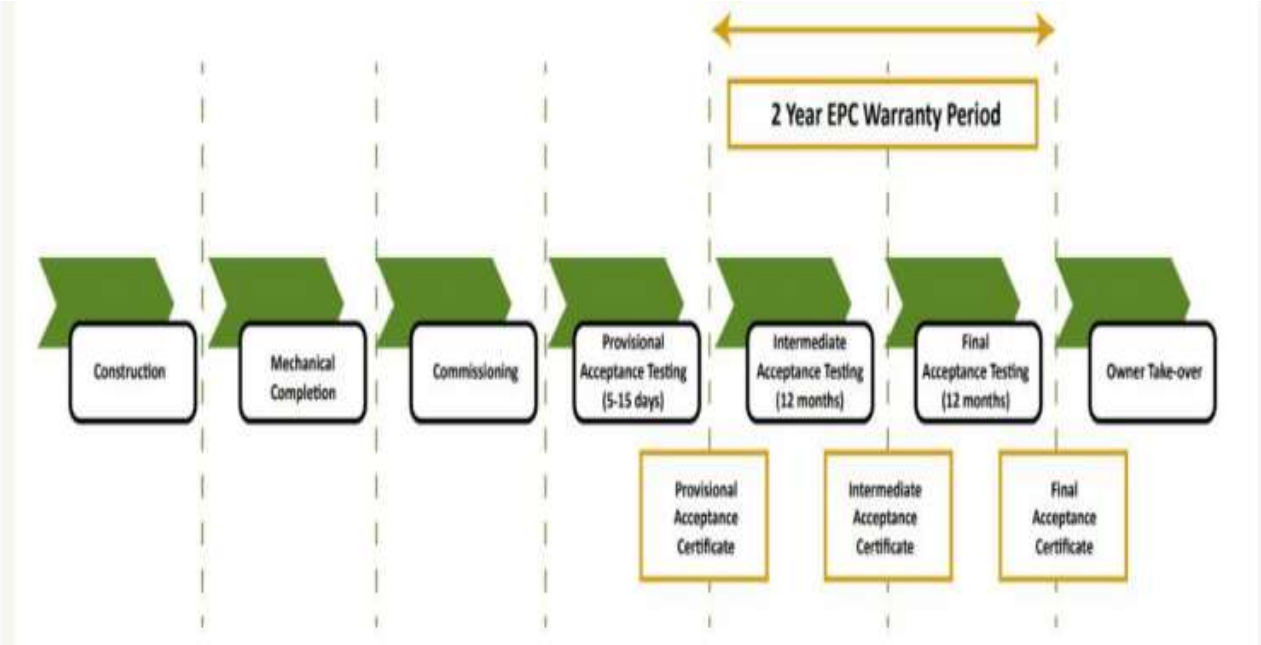


Figure 3.11: Typical EPC Construction Phase and Handover Protocol
*(**Source**: Desert to Power Initiative (Phase II) FEED)*

3.10 Contribution to Sustainable Development

The proposed project aligns with the United Nations SDGs, particularly the following SDG goals:

- **SDG 7**: Affordable and Clean Energy
- **SDG 11**: Sustainable Cities and Communities
- **SDG 12**: Responsible Consumption and Production
- **SDG 13**: Climate Action

By showcasing a replicable clean energy model, the project serves as a catalyst for decentralized renewable energy integration and sustainable urban waste management. The project aligns with both the State Climate Action Plan and Nigeria's Energy Transition Plan (ETP), which emphasize distributed renewable energy as key to achieving net-zero goals by 2060.

CHAPTER FOUR
DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1 The Study Approach

Environmental baseline study of the proposed 2MW Solar Photovoltaic Power Plant Project at Air Force Institute of Technology (AFIT), Kawo, Kaduna State is undertaken in order to establish the situation of the physical, biological, social and health environment of the study area prior to the commencement of the project development. This serves as baseline or benchmark to assess and monitor the impacts of the proposed project at AFIT, Kaduna State.

Consequently, upon completion of the environmental baseline study, the results generated would serve as a benchmark against which any potential beneficial or non- beneficial impact of the proposed project on the environment and socio-economics of the project area would be identified and assessed.

The main environmental components considered in the environmental baseline study include:

- **Physical components**: soil, ground water resources, air quality, noise and climatology;
- **Biological environment**, which includes: flora, (i.e trees, grasses), fauna (i.e, birds, mammal), threatened, and/or endangered species (plant/animals), species diversity, overall ecosystem stability etc.
- **Cultural** and **socio-economic components**: Distribution of socio-economic resources indicative of human welfare, i.e. educational system, transportation/land use networks, and other infrastructures like water supply, waste water/domestic disposal, solid waste management, public services, medical facilities and health impacts.

An integrated approach was adopted in presenting the multidisciplinary results of the baseline studies. The environmental baseline studies conducted were grouped under five main categories viz:

- **Physico-chemical Environment studies**
  - Climate and Meteorology
  - Land Use
  - Air Quality and Noise Level
  - Water quality – Ground water
  - Soil Studies
- **Biological Environment studies**
  - Flora and Fauna
  - Soil and Water Microbiology
- **Socio-Economic studies**
  - Corporate Social Responsibility to the host community
  - Educational, Socio and cultural setting in the study area
- **Health Status**
  - Health infrastructure and human health disease patterns.

- **Waste Management Analysis**

The baseline field data gathering was carried out in one season (wet season) from 14th to 16th July, 2026 as approved by the Federal Ministry of Environment (FMEnv) while a secondary data was sourced from the ESIA of 2MW Solar Power Project at Federal university of Education, Zaria, Kaduna State.

4.2 Environmental Baseline Data Acquisition Methods

The acquisition of data basically involved field data gathering, measurements and the collection of representative samples used to establish the environmental conditions of the study area. This exercise involved a multi-disciplinary approach and was executed within the framework of a QHSE Management System approach. This approach assured that the required data and samples were collected in accordance with agreed requirements (scientific and regulatory) using the best available equipment, materials and personnel. Elements of this approach include:

- review of existing reports that contain environmental information on the study area;
- designing and development of field sampling strategies to meet work scope and regulatory requirements;
- pre-mobilization activities (assembling of field team, sampling equipment/materials calibrations/checks, review of work plan and schedule with team, and job hazard analysis);
- mobilization to field;
- fieldwork implementation - sample collection (including positioning and field observations), handling, documentation and storage protocols and procedures;
- Demobilization from field; and
- Transfer of sample custody to the laboratory for analyses.

The following sections present the field data gathering methodology/procedures and the descriptions of the environmental baseline conditions of the study area. The detailed documentation of the fieldwork execution including descriptions of the laboratory analytical methods and procedures, the detection limits for the various parameters analyzed as well as an overview of the general QHSE plan adopted for field data gathering and laboratory analysis is presented.

4.2.1 Desktop Studies

Desktop studies involved the acquisition of relevant background information on the environment of the study area. Materials that were consulted included approved reports on previous environmental surveys in the area, publications, textbooks, articles, maps, etc. on the area and similar environments. The list of materials consulted is specified in relevant sections. Specific documents consulted are given in their respective sections.

4.2.2 Field Sampling

The data gathering exercise was undertaken on the 14th to 16th July, 2026. The specific objectives of the field sampling were to:

- Determine the ambient air quality and noise level of the study area;
- Determine the physico-chemical and biological characterization of groundwater water of the study area;
- Establish the socio-economic and health status of the host and impacted communities.

The exercise involved in-situ measurement of salinity, temperature and pH. Samples were taken at defined sample points using bottle sampler for water quality determinants. These were stored and preserved as appropriate for each analysis. Water samples were collected for laboratory analyses using

- 2-litre plastic bottle for groundwater samples for physicochemical analysis;
- 1-litre plastic bottle for groundwater samples for microbiological analysis;
- 1-litre glass bottle with Teflon seal cap for groundwater samples to be analysed for hydrocarbon content (oil and grease, etc.).

4.2.3 Field Studies and Sampling Design

Sampling was designed to comprehensively capture all the ecological and socio-economic components peculiar to the study area. Design of field activities was made prior to mobilization. This was aided by information obtained during reconnaissance survey of the project area.

Sampling locations were decided as waypoints in Geographic Position System (GPS) and later plotted in a sampling map used during the field studies. Locations for biophysical sampling considered ecological types around the project areas, vulnerable environmental attributes with regards to the potential and associated impacts of the environment and control or buffer zones. Socio economic and health impact studies on the other hand, considered human habitations, infrastructure, cultural heritage sites and prevailing health conditions of people within the sphere of influence to the project area. The spatial location maps of the sampled points are presented in the respective component sections.

The Quality Assurance/Quality Control (QA/QC) procedures were implemented during sample collection, labeling, analyses and data verification. Chain of custody procedures including sample handling, transportation, logging and crosschecking in the laboratory were also implemented.

All the samples collected were analyzed at Kano State Ministry of Environment Pollution Control Laboratory a Federal Ministry of Environment Accredited laboratory with accreditation certificate **No. 0004099**. The area of influence of the project/spatial boundaries was 3km from the centre of the project site. The sample taken for analysis are soil, air and water, for soil and air quality ten different points were taken while for groundwater, three samples were taken. Below are the parameters analyzed for each of the three samples.

Table 4.1: Parameters Sampled/Analysed for the EIA Study

S/N	Soil Parameters	Air Parameters	Water parameters
1	Colour	Sound Level	Colour
2	Temperature	SO2	Taste
3	pH	NO2	Odour
4	K+	H2S	pH
5	Na+	HCN	Electrical Conductivity
6	Ca+	PH3	Total Dissolve Solid
7	NH4+	NH3	Temperature
8	Mg2+	C2H4 (Ethene)	Total Suspended Solid
9	SO42-	HCl	Dissolve Oxygen
10	Cl-	Cl2	Nitrate
11	NO2-	TVOC	Calcium
12	NO32-	HCHO	Nitrite

S/N	Soil Parameters	Air Parameters	Water parameters
13	PO42-	Pm2.5	Magnesium
14	TPH	Pm10	Total Hardness
15	Phenols	Pm1.0	Chlorine
16	Benzene	O3	Sodium
17	Oil & Grease	CO	Sulphate
18	Porosity	CO2	Chromium (Cr2+)
19	Permeability	Temperature	Zinc (Zn2+)
20	Sand	R/Humidity	Lead (Pb2+)
21	Silt	AQI	Arsenic (Ar2+)
22	Clay		Iron (Fe2+)
23	E. Coli		Mercury (Hg+)
24	Fungi		E. Coli
25			Total Coliform

Source: Bolben Ltd. Fieldwork Survey, 2026.

Fieldwork Activities/Laboratory Analysis

Fieldwork activities/Laboratory analyses were carried out to complement secondary data gathered from literature and to collect new and additional primary data to fill information gaps. The activities were carried out in accordance with FMEnv and recommended international methods. The laboratory analyses of the samples collected were carried out at Kano State Ministry of Environment and Climate Change Pollution Control Laboratory at Tarauni, Kano State.

4.2.4 Field Data

Environmental Field data is gathered or collected during field exercises, gives a real time description of the state of that specific environment, at a particular time. Field data helps in **quantitatively** & **qualitatively** describing the state of the project site which has been selected for thestudy. The analysis of environmental field data is a particularly complicated task, owing to the fact that the potential sources of impacts recorded at a site, might be diverse, and of which they might not all be traceable to a single project. Therefore, due diligence must be done to ensure the integrity of environmental data analysis.

In subsequent sections, the field data gathered/collected/generated during the EIA study are presented in line with the FMEnv EIA guidelines.

Table 4.2: Sample Matrix

S/N	Environmental component	Sampling points or Stations
1	Ground Water	4+ 1 Control
2	Surface Water	3+1 Control
3	Vegetation	
6	Soil	10 + 2 Controls (5top, 5 bottom)
7	Ambient Air Quality	20 + 2 Controls
8	Socio-economic and Health	

Field Surveys

The field sampling was carried out for this study in line with the FMEnv approved ToR. Sampling and observations for air quality and noise, soil, groundwater, vegetation, and wildlife were carried out during fieldwork. The socio-economic survey was obtained through consultation with the project community, which is within 3km radius of the proposed project site, and administration of 49 questionnaires through stratified random sampling. Sample collection and handling procedures to maintain the integrity of samples and enhance quality of the results, were in accordance with international standards and with particular reference to FMEnv guidelines and standards. This was followed by detailed ecological sampling and laboratory analysis of samples.

All biophysical sampling and observation points were geo-referenced using Garmin eTrex 22x, Rugged Handled GPS Navigator, Garmin eTrex 10, and Worldwide Handheld GPS Navigator. The sample positions are also shown on the map of the project site. Quality assurance was applied to all aspects of the study including sample collection, handling, laboratory analysis, data coding, statistical analysis, presentation and communication of results. ***See Appendix IX,*** for the list of the equipment.



Plate 4.1: Field Sampling Equipment



Plate 4.2: The ESIA Team ready for the Baseline Sampling Exercise

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Quality Assurance

All equipment and materials and their calibration certificates were inspected and certified by the regulator before the commencement of the field sampling. The methodology and procedures for sample collection, storage/handling and analysis were such that integrity was assured. To ensure the accuracy and reliability of in-situ field measurements, field instruments were calibrated prior to use and cross-checked from time to time. Sampling points were properly geo-referenced. Field portable pH meter was calibrated using pH4, pH7 and pH9 buffer solutions. The conductivity and dissolved solids meter were checked against solutions of known conductivity and dissolved solids provided by the manufacturers.

All sample containers for water sample collection were rinsed with the water being sampled before putting the sample into the containers. Amber bottles were used for BOD_5 samples while sterile vials were used for all microbiology samples. Plain glass bottles were used to collect water samples for THC. Soil samples for physio-chemical analysis were collected in appropriately labelled and sealed polythene bags in accordance with the quality assurance criteria. Aluminum foils were used for soil samples for THC. Ice-chests were used to preserve samples in the field before transportation to the laboratory for analysis.

All parameters were analyzed within their shelf life. Chain of custody procedures including sample handling, transportation, logging and crosschecking in the laboratory were also implemented. The samples were preserved in ice-chest during transportation to the laboratory.

Data Analysis

Standard data spreadsheets were used for recording and transmitting analytical results. Processing/calculation of results were done following written standard operating procedures. Final results were issued only after a general QA/QC check and validation have been done.

4.3 Environmental Conditions of the Proposed Project Area

4.3.1 Climate and Meteorological Features

Climate assessment has become an essential component of contemporary urban and transportation planning due to the increasing impacts of climate change on urban environments, infrastructure systems, and human livelihoods. Rapid urbanization, population growth, industrialization, and transportation development have significantly altered climatic conditions in many cities around the world, particularly in developing countries. Urban areas are increasingly experiencing rising temperatures, irregular rainfall patterns, flooding, heat stress, air pollution, and environmental degradation resulting from both natural and anthropogenic activities. According to the Intergovernmental Panel on Climate Change, climate change poses serious risks to urban infrastructure, ecosystems, and socioeconomic systems, especially in rapidly growing cities with inadequate environmental management and planning systems (IPCC, 2021). Consequently, climate assessment is critical for understanding the interactions between urban growth, transportation infrastructure, land use change, and environmental sustainability.

Kaduna State have experienced substantial urban expansion over the past few decades due to population increase, rural–urban migration, and economic development. This expansion has resulted in significant Land Use and Land Cover (LULC) changes characterized by increasing built-up areas and declining vegetation cover. Such transformations have direct implications for local climate conditions, including increased land surface temperatures, reduced air quality, altered hydrological processes, and increased vulnerability to flooding and urban heat island effects. Studies have shown that the replacement of natural surfaces with impervious urban structures reduces evapotranspiration and increases heat retention within urban areas, thereby intensifying thermal discomfort and climate-related hazards (Ayanlade & Proske, 2020; Zhou et al., 2021). In Kaduna metropolis, the projected increase in built-up areas from historical and simulated urban growth patterns suggests that climate-related environmental pressures are likely to intensify over time if sustainable planning interventions are not implemented.

In addition, the interaction between climate conditions and ecological systems is particularly important within the context of Kaduna metropolis, where urban expansion continues to affect vegetation cover, water bodies, and biodiversity. The projected conversion of natural and semi-natural land covers into built-up areas may reduce the city ‘s ecological resilience and capacity to regulate microclimatic conditions. Flora and fauna within peri-urban and hinterland areas may become increasingly vulnerable to habitat fragmentation, temperature increases, and environmental stress associated with infrastructure development and climate variability. Consequently, climate assessment within the context of the Kaduna BRT project is necessary to ensure that transportation development aligns with sustainable urban growth, ecological conservation, and environmental resilience objectives.

Therefore, this section assesses the climatic implications associated with the proposed project.

4.3.2 Overview of Climatic Conditions in Kaduna

Kaduna metropolis lies within the Northern Guinea Savannah climatic zone and is characterised by a strongly seasonal hydro-climatic regime, with a distinct wet season typically extending from April to October and a dry season from November to March. The early dry season is often influenced by Harmattan conditions, marked by low relative humidity and dust-laden winds. Rainfall follows a unimodal pattern, increasing from the onset rains in April/May, reaching peak intensities in the mid- to late-wet-season months, and gradually tapering towards cessation in October.

Rainfall data used for this assessment were obtained from the Nigerian Meteorological Agency (NiMet), providing a long-term climatic record suitable for evaluating climatic variability, environmental conditions, and urban development implications within Kaduna metropolis. The dataset consisted primarily of daily rainfall observations compiled into a continuous station-based time series format, enabling detailed analysis of annual rainfall distribution, monthly seasonality, rainfall intensity, and long-term climatic trends relevant to urban growth and infrastructure development. The extended temporal coverage of the dataset supports the assessment of historical climate behavior and its interaction with Land Use and Land Cover (LULC) changes,

4.3.2.1 Rainfall Trends & Variability

The analysis of the annual maximum 24-hour rainfall series for Kaduna metropolis from 1960 to 2025 indicates considerable inter-annual variability in extreme rainfall events, reflecting the dynamic climatic conditions within the region. The recorded annual maximum daily rainfall values generally ranged from moderate to very intense storm events, demonstrating the episodic nature of heavy rainfall occurrences within the Northern Guinea Savannah zone. The observed variability suggests that extreme rainfall events within Kaduna metropolis are largely influenced by short-duration, high-intensity convective storms rather than a consistent long-term increase or decline in mean annual rainfall patterns.

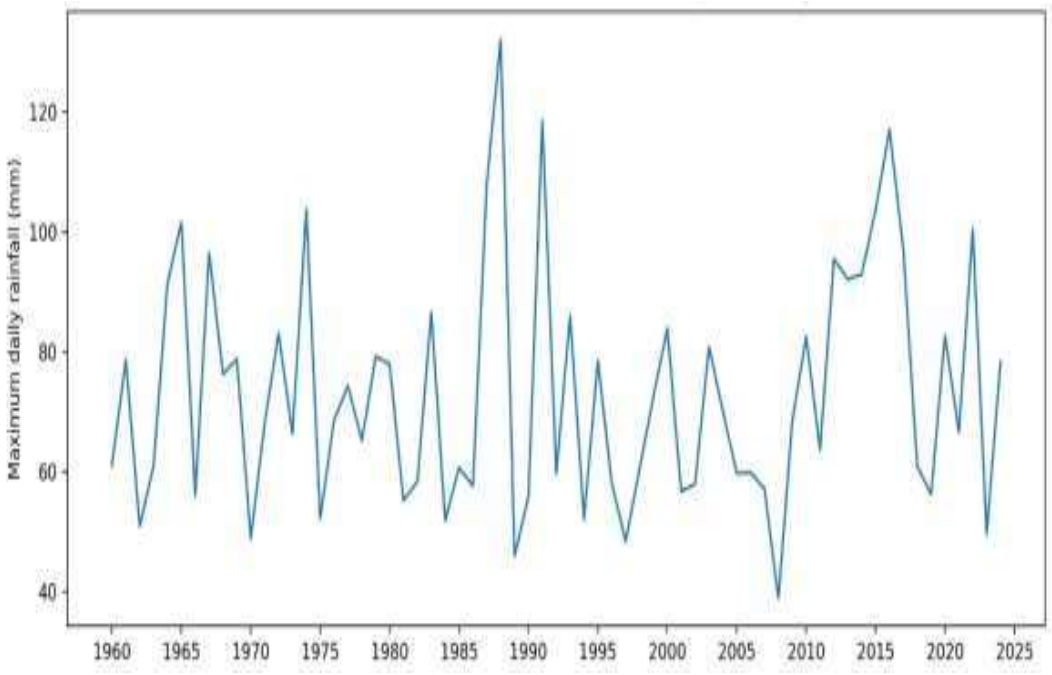


Figure 4.1: Average Daily Rainfall Distribution of Kaduna

From a probabilistic perspective, the likelihood of experiencing a high-intensity 24-hour rainfall event increases significantly during the peak wet-season months. Historical records indicate that the most probable period for annual maximum daily rainfall events is between July and September, with August representing the single highest-risk month. This aligns with the period of maximum atmospheric moisture availability, strong convective activity, and cumulative soil saturation across the Kaduna area. While extreme daily rainfall can occur on any day during the wet season, the highest likelihood is associated with storm days in late July through early September, often following successive days of moderate to heavy rainfall.

Kaduna 's rainfall regime is strongly seasonal and concentrated within a relatively short wet-season window, with the bulk of annual rainfall occurring between May and September. Analysis of long-term mean monthly rainfall indicates that August is the wettest month, recording the highest mean monthly rainfall of approximately 310–315mm, closely followed by September, which also exhibits very high mean totals. In contrast, the lowest rainfall occurs during the dry-season months of January and December, when mean monthly rainfall is negligible (generally below 5 mm). When averaged across all twelve months, Kaduna records a long-term mean monthly rainfall of approximately 100–110 mm, reflecting the strong concentration of rainfall within a few wet-season months.

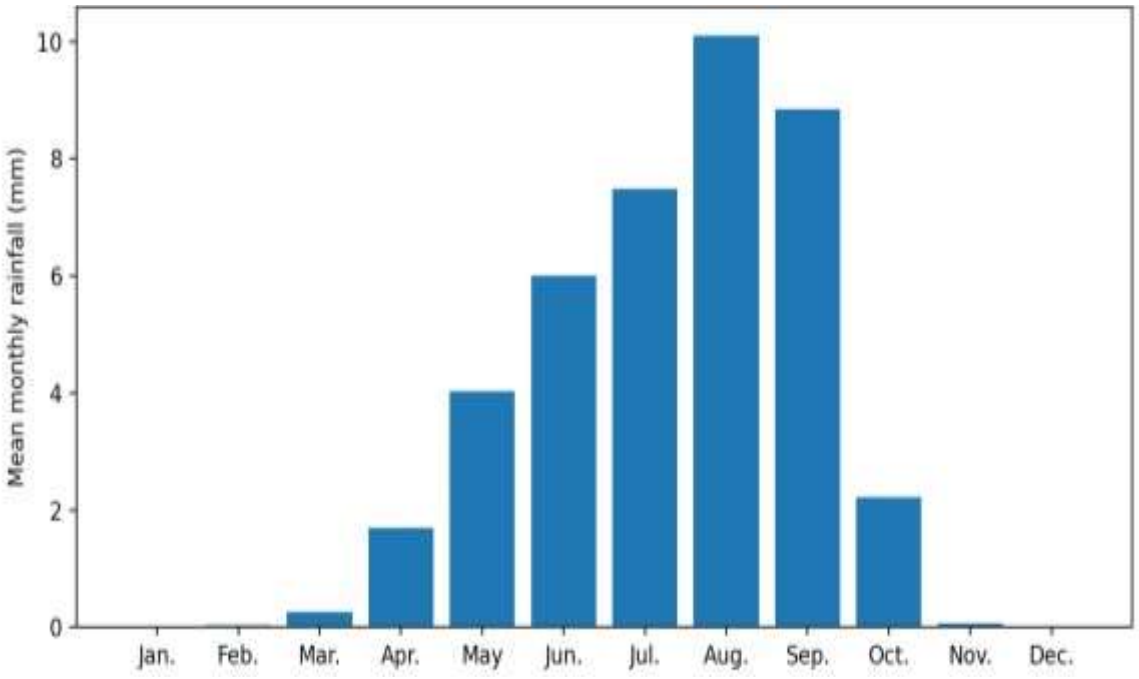


Figure 4.2: Average Monthly Rainfall Distribution of Kaduna

4.3.2.2 Temperature Trends and Variability

The annual minimum temperature time series for Kaduna metropolis between 2000 and 2025 reveals noticeable inter-annual variability in minimum temperature conditions, with average values ranging from approximately 14.93°C to 17.61°C. The data indicates fluctuations in minimum temperature over the 25-year period rather than a perfectly stable climatic pattern, reflecting the influence of regional climatic variability, changing land surface conditions, and increasing urbanization within Kaduna metropolis. The lowest annual minimum temperature was recorded in 2001 with an average value of 14.93°C, while the highest minimum temperatures were observed in 2005 (17.61°C) and 2025 (17.42°C). Overall, the temperature series suggests a gradual tendency toward warmer

minimum temperature conditions over time, particularly in recent years, which may be associated with increasing urban growth and land use transformation within the metropolis.

The observed increase in minimum temperature values can be linked to the rapid expansion of built-up areas and the reduction of vegetation cover identified in the Land Use and Land Cover (LULC) assessment of Kaduna metropolis. Between 1980 and 2020, built-up areas increased significantly, while vegetation cover declined substantially due to urban expansion, infrastructural development, and population growth. The replacement of natural vegetation with impervious urban surfaces such as roads, buildings, pavements, and transportation infrastructure reduces evapotranspiration and increases heat absorption and retention within the urban environment. Consequently, urban areas tend to experience higher night-time and minimum temperatures, contributing to the development of urban heat island effects within Kaduna metropolis. The gradual warming trend observed in the minimum temperature series therefore reflects the interaction between climate conditions and urban spatial growth patterns within the study area.

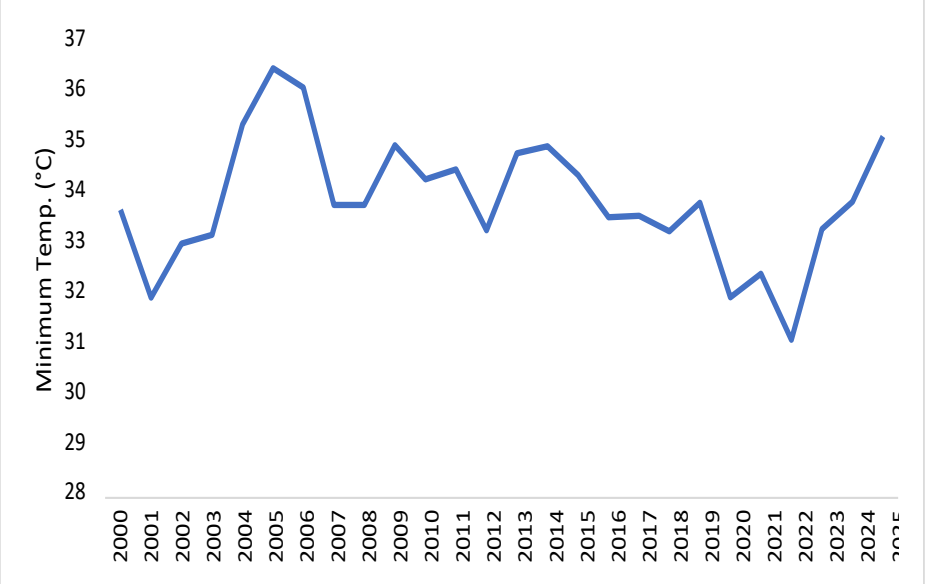


Figure 4.3: Annual Maximum Temperature Time Series of Kaduna (2000-2005)

4.3.2.3 Relative Humidity Trends and Variability

The annual relative humidity time series for Kaduna metropolis between 2000 and 2025 reveals considerable inter-annual variability in atmospheric moisture conditions over the study period. The average annual relative humidity values ranged from approximately 53.62% to 72.87%, indicating fluctuations in moisture availability and climatic conditions within the metropolis. The lowest relative humidity values were recorded in 2005 (54.16%) and 2006 (53.62%), while the highest values occurred in 2022 (72.87%), 2020 (70.80%), and 2021 (69.94%). The variability observed in the dataset reflects changing atmospheric conditions influenced by seasonal rainfall distribution, temperature variability, urbanization processes, and land surface changes occurring within Kaduna metropolis and its surrounding environments.

The observed increase in relative humidity values between 2020 and 2022 may be associated with wetter climatic conditions and increased atmospheric moisture content during those years. High humidity conditions combined with elevated temperatures can intensify thermal discomfort and

influence urban environmental conditions within Kaduna metropolis. From a climate assessment perspective, the interaction between high humidity levels and rising temperatures is important because it affects human comfort, public health, and infrastructure performance within rapidly urbanizing environments. Increasing urban density and the projected expansion of built-up areas toward 2050 may further modify humidity patterns through changes in land cover composition and urban atmospheric processes.

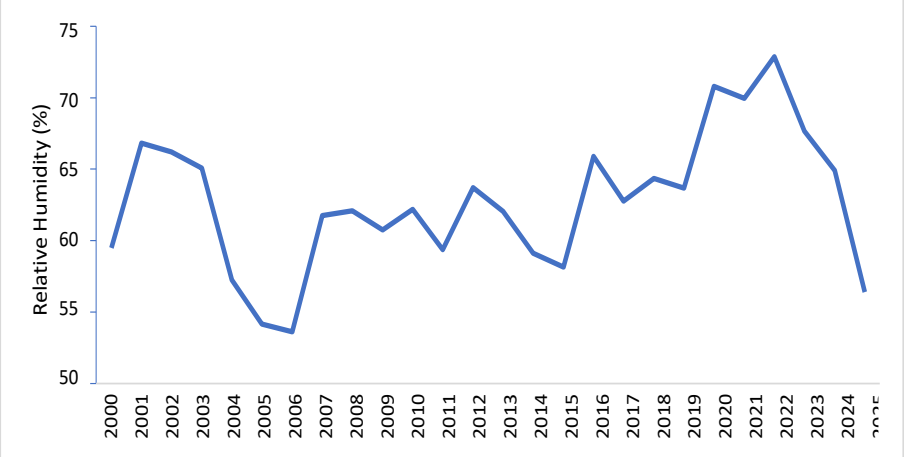


Figure 4.4: Annual Relative Humidity Time Series of Kaduna (2000-2025)

4.3.2.4 Wind Speed Trends and Variability

The annual wind speed time series for Kaduna metropolis between 2000 and 2025 indicates moderate variability in wind conditions over the 25-year study period. The average annual wind speed values ranged from approximately 7.18 m/s to 8.82 m/s, reflecting relatively stable but fluctuating atmospheric circulation patterns within the region. The highest annual average wind speed was recorded in 2008 with a value of 8.82 m/s, while the lowest value occurred in 2016 with 7.18 m/s. Other years such as 2000 (8.56 m/s), 2005 (8.45 m/s), and 2015 (8.40 m/s) also recorded relatively high wind speeds, whereas lower wind conditions were observed in 2003 (7.68 m/s), 2009 (7.65 m/s), and 2025 (7.45 m/s). Overall, the dataset demonstrates moderate inter-annual variability without a clearly defined long-term increasing or decreasing trend in wind speed conditions across Kaduna metropolis.

Furthermore, wind speed variability has implications for dust transport, erosion processes, and environmental conditions within peri-urban and hinterland areas surrounding Kaduna metropolis. Areas experiencing extensive land clearing, vegetation removal, and increasing bare surfaces due to urban expansion may become more vulnerable to wind erosion and dust generation during dry periods.

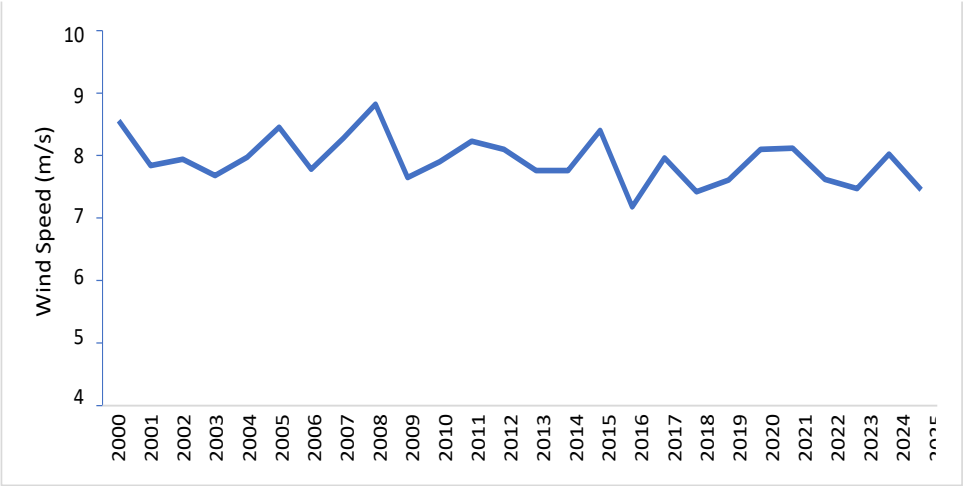


Figure 4.5: Annual Wind Speed Time Series of Kaduna (2000-2025)

4.3.3 Micro-Climatic Characteristics of the Study Area

The micro-climatic conditions at the Air Force Institute of Technology (AFIT), Igabi LGA, Kaduna State, were assessed through direct field measurements undertaken in July. July falls within the wet season in Kaduna, when moist south-westerly monsoon flow, frequent cloud cover and episodic rainfall influence local temperature, humidity and atmospheric dispersion.

Weather conditions during the field exercise varied from cloudy conditions to heavy and light rainfall. The combination of cloud cover, wet-season moisture and local differences in shade, vegetation and paved surfaces produced measurable variation in temperature and relative humidity across the proposed project site, campus facilities and control locations.

4.3.3.1 Temperature and Relative Humidity

Measured temperatures ranged from 78.7°F (25.9°C) at AQC2 (AFIT Back Gate) to 104.0°F (40.0°C) at AQ5 (Centre of the Site), with an overall mean of 89.7°F (32.1°C). The centre of the proposed site was markedly warmer than the other sampling points, the pattern reflects direct solar exposure and limited shade at the time of measurement.

Relative humidity ranged from 53.6% at AQ5 to 74.9% at AQC2, with a mean of 67.0%. The highest temperature coincided with the lowest relative humidity, while the coolest location recorded the highest humidity. This inverse pattern is consistent with short-term micro-climatic differences in exposure, shading and wet-season moisture conditions.

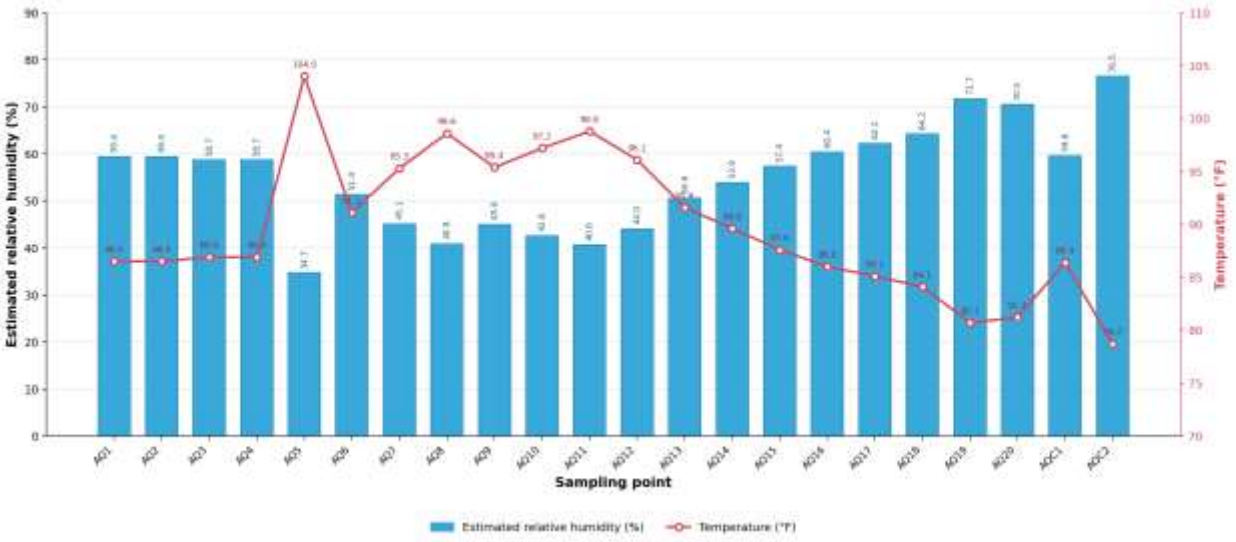


Figure 4.6: Relative Humidity and Temperature measured in the AFIT project area

4.4 Baseline Study of the Project Area

4.4.1 Air Quality and Noise Characteristics

One of the main components of Earth's interdependent physical systems is the atmosphere. An atmosphere is made of the layers of gases surrounding a planet or other celestial body. Earth's atmosphere is composed of about 78% nitrogen, 21% oxygen, and one percent other gases. These gases are found in atmospheric layers (troposphere, stratosphere, mesosphere, thermosphere, and exosphere) defined by unique features such as temperature and pressure. The atmosphere protects life on Earth by shielding it from incoming ultraviolet (UV) radiation, keeping the planet warm through insulation, and preventing extremes between day and night temperatures.

The introduction into the air any chemical, physical or biological agent in quantities large enough to produce harmful effects on man and its surrounding is a call for concern. Effects of air pollutants on human health, vegetation, property or the global environment as well as create aesthetic insults in the form of brown or hazy air or unpleasant smells have been reported in the literature (Smith, 1991, Rim-Rukeh and Okokoyo, 2003., Pope, 1992., McComick et al., 1995).

The pollutants commonly monitored in relation to air quality are; nitrogen dioxide (NO2), sulphur dioxide (SO2), suspended particulate matter (SPM), ammonia (NH3), hydrogen sulphide (H2S), carbon dioxide (CO2), carbon monoxide (CO), and volatile organic compounds (VOCs). The visual record of the ambient air-quality measurements is presented in Table 4.3. The instrument-reported Air Quality Index (AQI) values were interpreted using the standard rating bands presented later in this section.

AQI = (Pollution Concentration / Pollution Standard Level) × 100.

See Plate 4.3 and 4.4 for pictorial evidence of Air Quality and Noise Level Sampling activities. For more pictures of different Air Quality and Noise Level sampling location see Appendix VII…



Plate 4.3: Air Quality Sampling activities
***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Table 4.3: Air Quality Analysis around the project area.

CODE	SAMPLING LOCATION	AIR QUALITY										Coordinates	
		AQI	Temperature (°F)	Relative humidity (%)	HCHO (mg/m³)	TVOC (mg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	No. of particles (per/L)	CO_2	O_2	Latitude	Longtitude
PROJECT SITE/AoI													
AQ1	Soil Sample Point A	29	86.5	69.1	0.03	0.13	7.7	10.8	1115	419	20.9	10.620684^0	7.436203^0
AQ2	Soil Sample Point B	38	86.5	68.7	0.01	0.03	8.0	14.2	1280	418	20.9	10.618568^0	7.436776^0
AQ3	Soil Sample Point C	28	86.9	69.7	0.02	0.13	6.9	12.1	1086	411	20.9	10.620241^0	7.437640^0
AQ4	Soil Sample Point D	41	86.9	69.4	0.03	0.13	9.1	15.1	1408	415	20.9	10.621103^O	7.438061^0
AQ5	Centre of the Site	52	104.0	53.6	0.05	0.30	11.2	22.2	1960	414	20.9	10.620410^0	7.436792^0
AQ6	Upstream	43	91.1	65.8	0.02	0.10	9.1	16.0	1644	415	20.9	10.626945^0	7.446984^0
AQ7	Midstream	22	95.3	62.4	0.02	0.09	5.6	10.3	747	413	20.9	10.626510^0	7.446898^0
AQ8	Downstream	35	98.6	59.5	0.01	0.03	8.5	16.1	1420	416	20.9	10.626098^0	7.447235^0
AQ9	Waste Incinerator Behind Boys' Hostel	31	95.4	64.0	0.01	0.08	8.0	13.4	1267	413	20.9	10.619651^0	7.444564^0
AQ10	Borehole Beside Boys' Hostel, Mosque and Dental Clinic	31	97.2	61.1	0.02	0.03	7.6	13.5	1174	413	20.9	10.619494^0	7.444713^0
AQ11	Front of AVM C. N. Udeagulu Block, Boys' Hostel	28	98.8	65.1	0.01	0.05	7.5	13.5	1259	409	20.9	10.617676^0	7.443263^0
AQ12	University Library	52	96.1	62.6	0.01	0.04	12.7	21.9	1978	412	20.9	10.609719°	7.441992°
AQ13	Campus Small Market by the Mast	34	91.6	65.2	0.01	0.04	8.2	14.3	1313	414	20.9	10.611676^0	7.440359^0
AQ14	University Masjid	35	89.6	67.2	0.01	0.03	8.6	14.9	1336	409	20.9	10.609601^0	7.441630^0
AQ15	Office of Provost, Academic Branch	28	87.6	68.6	0.01	0.04	6.9	11.8	1123	411	20.9	10.608310^0	7.440722^0
AQ16	AFIT HQ; Commandant Office	43	86.0	69.8	0.01	0.03	10.5	20.2	1732	411	20.9	10.608273^0	7.441762^0
AQ17	Ibrahim Alfa Auditorium	56	85.1	70.4	0.01	0.04	14.2	24.5	2239	407	20.9	10.609127^0	7.443491^0
AQ18	Girls' Hostel Gate	56	84.1	71.1	0.01	0.03	14.9	6.3	2262	408	20.9	10.608164^0	7.445180^0
AQ19	Security Office	14	80.7	72.8	0.01	0.03	3.5	6.2	623	415	20.9	10.613183^0	7.452286^0
AQ20	AFIT Clinic	13	81.2	73.5	0.01	0.03	3.1	6.0	612	408	20.9	10.612945^0	7.446100^0
CONTROL													

CODE	SAMPLING LOCATION	AIR QUALITY										Coordinates	
		AQI	Temperature (°F)	Relative humidity (%)	HCHO (mg/m³)	TVOC (mg/m³)	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)	No. of particles (per/L)	CO_2	O_2	Latitude	Longtitude
AQC1	AFIT Main Gate	51	86.4	70.2	0.02	0.04	12.3	22.6	1961	407	20.9	10.614957^0	7.464822^0
AQC2	AFIT Back Gate	9	78.7	74.9	0.02	0.04	2.3	4.0	431	411	20.9	10.608135^0	7.438663^0
Mean		34.95	89.74	67.03	0.02	0.07	8.47	16.36	1362.27	412.23	20.90		
Standard Deviation		13.58	6.64	5.05	0.01	0.06	3.29	13.99	512.21	3.39	0.00		
FMEnv. Limit							250.00	250.00					
WHO Guideline Value							25.00	50.00					
USE-EPA Guideline Value										10000			

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

The detection limits of parameters used for measuring air-quality are presented on Table 4.4.

Table 4.4: Detection Limits for Air Quality Instruments

Parameter Measured	Equipment	Detection Limit
PM2.5	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 999 µg/m³
PM10	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 999 µg/m³
Formaldehyde (HCHO)	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 5 mg/m³ (Resolution: 0.001 mg/m³)
Total VOC (TVOC)	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 5 mg/m³ (Resolution: 0.001 mg/m³)
Temperature	VT-9IN1 Air Quality Monitor Tester	32°F to 158°F (0°C to 70°C)
Relative humidity	VT-9IN1 Air Quality Monitor Tester	0% to 99% RH
AQI	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 999
Particle number	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 9,999 particles per liter (particles/L) [1, 2]
CO_2 / Oxygen (O_2)	VT-9IN1 Air Quality Monitor Tester	CO_2 ranges from 400 to 5000 ppm; and 0–30% vol for O_2
Ambient noise level	V-Resourcing Hand-Held Sound Level Meter	30 dBA to 130 dBA (Accuracy: ±1.5 dB)

4.4.2 Results of Air Quality Measurements

Gaseous Pollutants and Volatile Organics

Direct measurements indicate generally low concentrations of the measured gaseous and volatile-organic parameters across the AFIT monitoring locations.

Formaldehyde (HCHO) ranged from 0.01 to 0.05 mg/m³, with a mean of 0.016 mg/m³. The highest value, 0.05 mg/m³, occurred at AQ5 (Centre of the Site). This is below the World Health Organization (WHO) guideline value of approximately 0.1 mg/m³ for short-term exposure. Although formaldehyde is not considered a primary pollutant of concern for the proposed solar PV Project, it was measured as part of the multi-parameter ambient air quality assessment used to characterize existing environmental conditions. The low concentrations recorded indicate the absence of significant local combustion or industrial sources that could adversely influence baseline air quality.

Total Volatile Organic Compounds (TVOC) ranged from 0.03 to 0.30 mg/m³, with a mean of 0.068 mg/m³. AQ5 also recorded the highest TVOC concentration (0.30 mg/m³), while several campus and control points recorded the minimum value of 0.03 mg/m³. This is similar when compared with the result obtained from the secondary data use which ranged between 0.03 mg/m³ and 0.16 mg/m³ (ESIA of FUE Zaria, Kaduna State).

Oxygen was uniform at 20.9% at all locations. Carbon dioxide ranged from 407 to 419 ppm, with a mean of 412.2 ppm. Every measured CO_2 concentration was below the 1,000 ppm USEPA reference value shown in the supplied results table. No separate numerical results for NO_2, SO_2, CO or H_2S were included in the AFIT dataset; consequently, no conclusion on those pollutants is made here.

Particulate Matter: $PM_{2.5}$ concentrations ranged from 2.3 to 14.9 µg/m³ across all points and the control locations, with a mean of 8.47 ± 3.29 µg/m³. All readings were below the 25 µg/m³ NAAQS value and the 250 µg/m³ FMEnv limit presented in the supplied field-results table. The highest $PM_{2.5}$ value was recorded at AQ18 (Girls' Hostel Gate), while the lowest occurred at AQC2 (AFIT Back Gate).

PM_{10} concentrations ranged from 4.0 to 74.5 µg/m³, with a mean of 16.36 ± 13.99 µg/m³. Twenty-one of the twenty-two readings were below the 50 µg/m³ WHO value shown in the supplied results. AQ17 (Ibrahim Alfa Auditorium) recorded 4.0 µg/m³, while the lowest occurred at AQC2 (AFIT Back Gate).

Construction activities may temporarily increase particulate concentrations through vegetation clearing, excavation, material handling and vehicle movement. The measured baseline supports the use of dust suppression, speed control, covered haulage and routine air-quality monitoring during project implementation.

Air Quality Index (AQI)

The instrument-reported AQI values indicate the broad air-quality condition at each sampling point. The rating bands and associated health-concern categories are presented in Table 4, while the AFIT readings are summarized in Table 4.6.

Table 4.5: Air Quality Rating Table

Good	Moderate	Unhealthy for sensitive groups	Unhealthy	Very unhealthy	Hazardous
0–50	51–100	101–150	151–200	201–300	301–500

Table 4.6: Air Quality Index of the AFIT Project Area

Sampling Code	Instrument AQI	Level of Health Concern
AQ1	29	Good
AQ2	38	Good
AQ3	28	Good
AQ4	41	Good
AQ5	52	Moderate
AQ6	43	Good
AQ7	22	Good
AQ8	35	Good
AQ9	31	Good
AQ10	31	Good
AQ11	28	Good
AQ12	52	Moderate

Sampling Code	Instrument AQI	Level of Health Concern
AQ13	34	Good
AQ14	35	Good
AQ15	28	Good
AQ16	43	Good
AQ17	56	Moderate
AQ18	56	Moderate
AQ19	14	Good
AQ20	13	Good
AQC1	51	Moderate
AQC2	9	Good

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

The instrument-reported AQI ranged from 9 to 56. Seventeen of the twenty-two locations were classified as "Good" (0–50), while five locations, AQ5, AQ12, AQ17, AQ18 and AQC1, were "Moderate" (51–100). No supplied reading fell within an unhealthy category. Overall, the baseline was predominantly good at the time of measurement.

4.4.3 Result of Noise Level Measurement

Ambient noise measurements were obtained at twenty AFIT sampling points and two control points. Minimum readings ranged from 27.3 to 59.1 dB(A). Maximum readings ranged from 49.8 to 83.0 dB(A). The highest supplied maximum was 83.0 dB(A) at NL13. See table 4.5.

Table 4.7: Noise Level within the study area

CODE	SOUND LEVEL METER (dBA)	
	Minimum Readings	Maximum Readings
NL1	38.1	64.6
NL2	37.6	64.7
NL3	42.5	66.4
NL4	33.6	54.2
NL5	27.3	59.1
NL6	42.9	75.6
NL7	38.4	79.7
NL8	41.0	71.4
NL9	41.2	63.4
NL10	35.5	56.3
NL11	33.8	49.8
NL12	38.1	71.7
NL13	58.1	83.0
NL14	43.6	68.3
NL15	41.7	78.8
NL16	59.1	69.1
NL17	42.7	70.0
NL18	38.9	61.9
NL19	46.4	72.5
NL20	40.2	62.4

CODE	SOUND LEVEL METER (dBA)	
	Minimum Readings	Maximum Readings
CONTROL		
NLC1	48.5	62.5
NLC2	49.9	71.5

Source: Bolben Ltd. Fieldwork Survey, 2026.

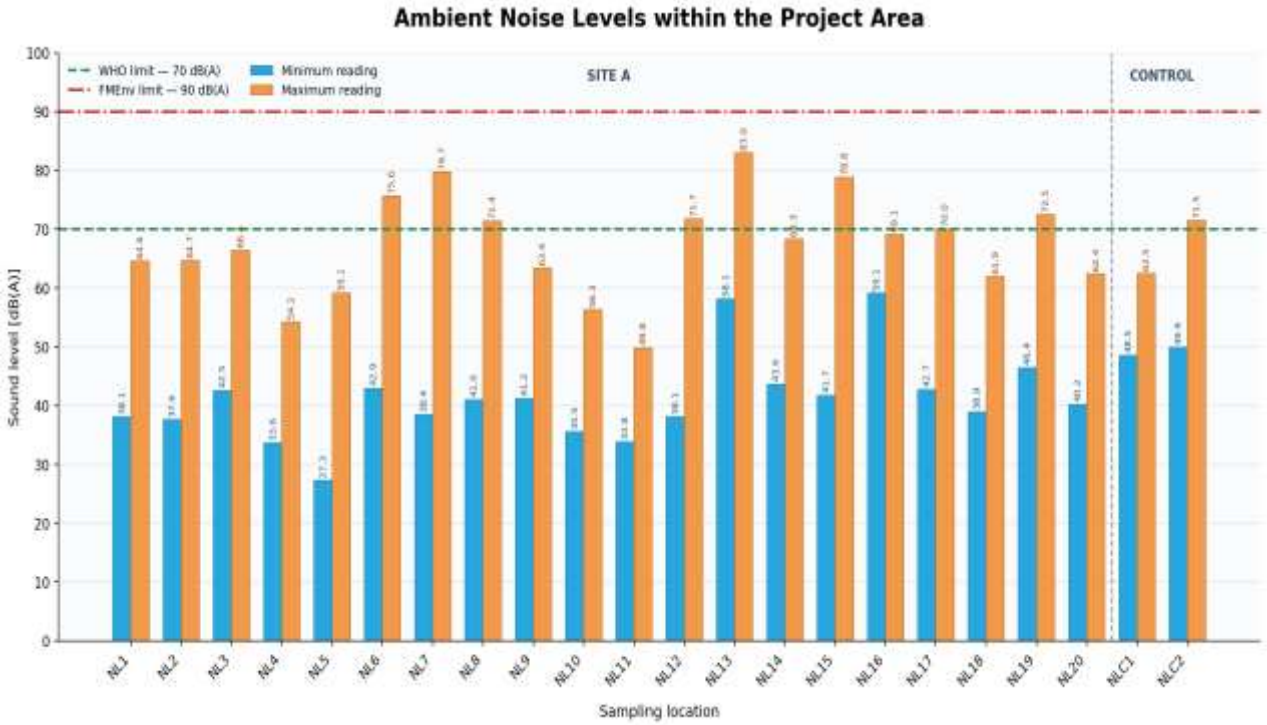


Figure 4.7: Ambient noise levels within the AFIT project area

All verified maximum readings were below the 90 dB(A) FMEnv limit used in the reference template. Nine verified maximum readings exceeded 70 dB(A), indicating intermittent elevated daytime noise at NL6, NL7, NL8, NL12, NL13, NL15, NL19 and control point NLC2, with NL13 recording the overall peak. These readings are interpreted with location activities, traffic, aircraft and institutional operations occurring during measurement.

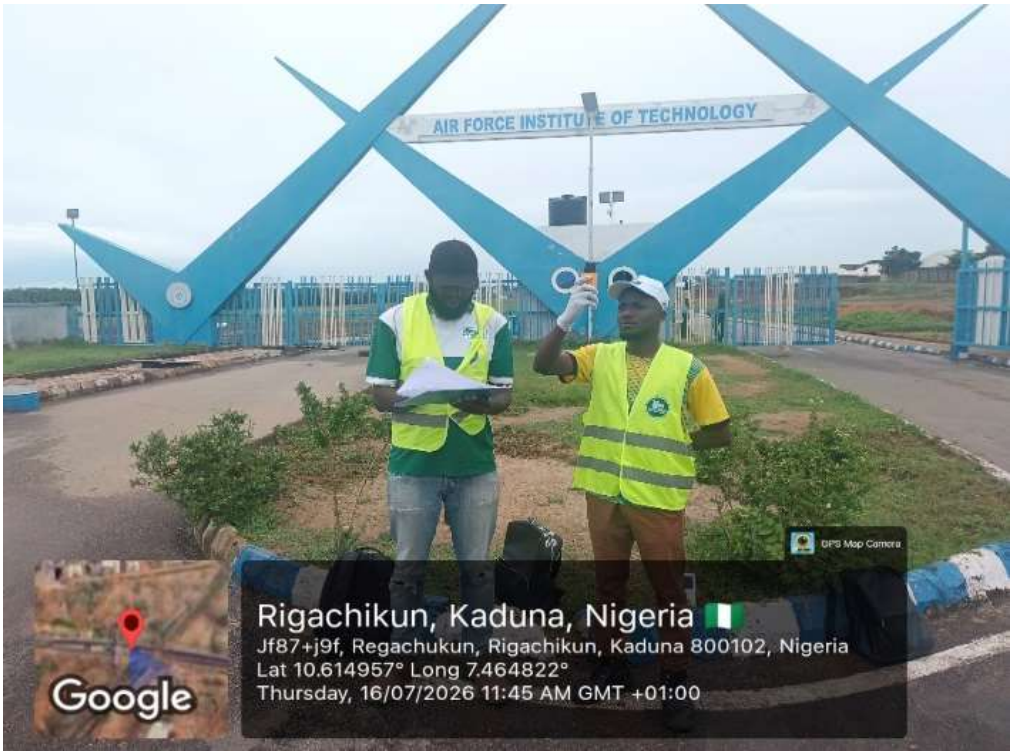


Plate 4.4: Noise Level Sampling activities
***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

4.4.4 Topography

The area forms part of the Northern Nigerian Savannah plains characterised by gently undulating terrain with occasional isolated rocky outcrops typical of the Basement Complex geology. Average elevation ranges between 600 – 650 metres above sea level, with slight variations across the project site. Slopes are generally gentle (1% – 5%), favouring construction, agriculture, and vehicular movement with minimal earthworks. Minor local depressions and seasonal drainage channels occur, which direct runoff towards tributaries of River Kaduna.

The area is drained by a dendritic drainage system, with surface water flow generally directed southwest towards River Kaduna. Flooding potential for the area is low to moderate, mostly confined to natural drainage corridors or low-lying patches during peak rainfall months (July – September).

Thus, the relatively flat to gently undulating topography makes the site suitable for the integrated solar power project, supporting ease of construction and facility layout while necessitating appropriate drainage designs to prevent localised flooding.

4.4.5 Geology

4.4.5.1 Regional Geology

The project area lies within the Basement Complex terrain of Northern Nigeria, composed predominantly of Precambrian rocks including migmatites, granites, gneisses, and quartzites.

4.4.5.2 Local Geology

Outcrops are sparse, with underlying geology dominated by weathered granite-gneiss formations, forming moderately deep to deep profiles of lateritic soils suitable for agriculture. Figure 4.8 presents the basic geology of the project area (Pre-Cambrian Basement Complex) and of the other Nigerian regions.



Figure 4.8: Geology of Nigerian regions (Source: Obaje, N.G, 2007)

4.4.6 Hydrology

The proposed project site is close to River Kaduna and one of its tributaries, which serve as the major hydrological features in the area. Seasonal streams may traverse or border parts of the site during the wet season. The flow regime shows peak flow in July to September, while low flow rates

are recorded in December to April. Localised flooding may occur in low-lying areas adjacent to streams during peak rains if drainage is not well managed. Thus, the hydrology of the project area supports the water needs of the proposed project.

4.4.6.1 Hydrogeology

Aquifer type in the project area is Mainly weathered Basement Complex aquifers, consisting of regolith and fractured bedrock zones. With groundwater depth typically 15 – 30 m below ground level in dug wells; deeper boreholes (~40 – 60 m) tap into fractured basement aquifers. The yield potential is moderate (0.5 – 2.0 litres per second) suitable for community water supply and agro-industrial use. The water quality is generally good for domestic and agricultural use but may require filtration and disinfection for drinking purposes. Therefore, hydrogeology also supports the proposed project, with potential for borehole water supply.

4.4.7 Soil Characteristics of the Study Area

Land and by extension, the Soil is considered the most vital resources made available to man by nature. This is because, it provides an indispensable medium for the development of agriculture, vegetation, forestry, rural and urban land uses, etc. Therefore, soil is defined as an organized mixture of minerals, organic material, living organisms, air and water, Y. Anjaneyulu, (2004).
The formation of soils is determined by various natural processes initiated by weather elements, chemical processes of oxidation, hydrolysis, and the activities of living organisms. These processes lead to the formation of a well-defined soil profile comprising layers of varying thickness and constituents. The top layer is usually rich in organic matter, the second layer contains an accumulated materials leached from the top layer while the third layer forms the bedrock from which the soil is made.

Eutric combisol group and more particularly the **ferruginous soil types** cover the project site. The soil is known to be low in humus content and coarse textured. In terms of **porosity,** it is excessively well drained. The soil is **brownish** and covered with ironstones they become **reddish-brown** in colour. However, it has very low water retention and high percolation loses characteristics. The physical characteristics of the project site's soil sub-surface exploration records are shown on table 3 below and at back cover.

The main use of land in the study area is for institutional, socio-economic and farming activities. The textual composition of the soil is sandy loam. Particle size distribution is very important in the soils as it determines water intakes rates, water storage, the ease of the soil tilling, the amount of aeration, which is vital for plant growth, and soil fertility. The soil textural composition reflects one that is easy to till, has aeration for good plant growth, easily wetted and able to stand the proposed structure.

4.4.7.1 Soil Sampling

Soil sampling was undertaken to establish the baseline physicochemical characteristics and contamination status of soils within the proposed project area prior to the commencement of construction activities. The sampling program was designed to provide representative coverage of the proposed 2 MW Solar Photovoltaic (PV) Power Project site and to generate baseline reference data for future environmental monitoring during the construction, operation, maintenance, and

decommissioning phases of the project. The baseline information generated from the investigation will also provide a basis for assessing any future changes in soil quality that may arise from project-related activities, including site clearing, excavation, earthworks, equipment movement, accidental spills, waste generation, and stormwater runoff.
The proposed project occupies approximately 10.02ha within the Air Force Institute of Technology (AFIT), Nigerian Air Force Base, Kaduna State. The project site is bounded by four geographical coordinates which define the limits of the proposed solar PV development area.

See Plate 4.5 for pictorial evidence of Soil Sampling Collection around the Project Area.
For more pictures of different soil sampling collection location see Appendix VI…



Plate 4.5: Soil Sampling Collection around the Project Area.
***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Table 4.8: Project Site Boundary Coordinates

Boundary Point	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
Point A	10.620684° N	7.436203° E
Point B	10.618568° N	7.436776° E
Point C	10.620241° N	7.437640° E
Point D	10.621103° N	7.438061° E

The project site is bordered by the existing electricity transmission line corridor, the AFIT military training area, unguwar Fulani (AFIT Fulani Quarters), the AFIT Boys' Hostel and Hostel Clinic, the Computer-Based Test (CBT) Centre, mini foodstuff and business centre, internal road network, and other institutional facilities within the Air Force Base. These surrounding land uses were considered during the design of the soil sampling program to ensure representative characterization of existing soil conditions across the area of potential project influence.

Five representative sampling locations were established across the project site in line with the FMEnV recommendation. The sampling design was developed to provide adequate spatial representation of the entire project footprint while minimizing edge effects that may influence soil properties near the site boundaries.

Four sampling locations were therefore positioned slightly inside the northern, southern, eastern, and north-eastern sections of the project boundary rather than directly on the property limits. This approach ensured that samples represented in-situ site conditions while avoiding possible disturbances associated with adjacent land uses. An additional sampling location was established approximately at the geometric centre of the project site to characterize the average soil conditions across the development area. See table 4.9.

Table 4.9: Soil Sampling Locations

Location ID	Sampling Location	Latitude (N)	Longitude (E)	Associated Samples
L1	Northern Sector	10°37′14.50″ N	7°26′10.31″ E	S1 (Topsoil), S2 (Subsoil)
L2	Southern Sector	10°37′08.05″ N	7°26′12.29″ E	S3 (Topsoil), S4 (Subsoil)
L3	Eastern Sector	10°37′12.14″ N	7°26′12.38″ E	S5 (Topsoil), S6 (Subsoil)
L4	North-eastern Sector	10°37′13.46″ N	7°26′12.45″ E	S7 (Topsoil), S8 (Subsoil)
L5	Centre of Site	10°37′12.74″ N	7°26′15.36″ E	S9 (Topsoil), S10 (Subsoil)

Source: Bolben Ltd. Fieldwork Survey, 2026.

At each sampling location, a hand-operated stainless steel Edelman soil auger was used to advance an auger borehole for soil collection. Prior to sampling, surface vegetation, loose organic debris, stones, and other foreign materials were carefully removed from the sampling points to prevent contamination of the collected samples. Soil samples were collected from two depth intervals: Topsoil: 0–15 cm, and Subsoil: 15–30 cm. These depth intervals were selected because they represent the biologically active surface horizon and the shallow subsurface soils that are most likely to be affected by site preparation, excavation, foundation construction, runoff infiltration, and other project-related activities. After proper collection, the soils were transferred into clean, appropriately labelled sample containers. Consequently, a total of ten (10) soil samples were obtained from the project site, comprising five topsoil samples and five corresponding subsoil samples.

Control Sample

To establish the natural background soil quality for comparison with the proposed project site, a control sampling location (Location 6, L6) was established outside the project area at the AFIT Internal Entrance Gate, between the Institute's main entrance gate and the Nigerian Air Force Recruitment Centre, beyond the anticipated influence of construction and operational activities

associated with the proposed solar PV project. The control sampling location was selected because it possesses similar geological and environmental characteristics to the project site while remaining outside the direct area of project influence. This provides an appropriate background reference against which laboratory analytical results from the project site can be evaluated. Two control soil samples comprising topsoil (0–15 cm) and subsoil (15–30 cm) were collected at the following coordinates: Latitude: 10°36′29.30″ N, and Longitude: 7°26′19.19″ E. These control samples serve as the baseline reference for assessing any future changes in soil quality attributable to project implementation.

Overall, a total of ***twelve (12) soil samples*** were collected during the baseline investigation, comprising ten samples from five sampling locations within the project site and two background control samples. All samples were assigned unique identification codes, properly labelled, sealed in clean polyethylene sample bags, preserved in accordance with standard environmental sampling procedures, and transported under established Quality Assurance and Quality Control (QA/QC) protocols to an accredited analytical laboratory for physicochemical, nutrient, and heavy metal analyses. Field documentation, including GPS coordinates, sampling depths, sample identification numbers, site observations, and chain-of-custody records, was maintained throughout the investigation to ensure traceability and data integrity.



Figure 4.9: Soil Sampling Map
Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.10: Summary of Soil Samples Collected

Location	Description	Sampling Locations	Sample Depth (cm)	Number of Samples
Project Site	Proposed 2 MW Solar PV Project Site within AFIT	5	0–15 and 15–30	10
Control	AFIT Internal Entrance Gate (Background Reference)	1	0–15 and 15–30	2
Total		**6**		**12**

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.11: Soil Sampling Locations, Coordinates and Sample Details

Sample ID	Location ID	Sampling Location	Latitude (N)	Longitude (E)	Depth (cm)	Description
S1	L1	Northern Sector	10°37′14.50″	7°26′10.31″	0–15	Topsoil sample collected from the northern section of the proposed project site.
S2	L1	Northern Sector	10°37′14.50″	7°26′10.31″	15–30	Subsoil sample collected from the northern section of the proposed project site.
S3	L2	Southern Sector	10°37′08.05″	7°26′12.29″	0–15	Topsoil sample collected from the southern section of the proposed project site.
S4	L2	Southern Sector	10°37′08.05″	7°26′12.29″	15–30	Subsoil sample collected from the southern section of the proposed project site.
S5	L3	Eastern Sector	10°37′12.14″	7°26′12.38″	0–15	Topsoil sample collected from the eastern section of the proposed project site.
S6	L3	Eastern Sector	10°37′12.14″	7°26′12.38″	15–30	Subsoil sample collected from the eastern section of the proposed project site.
S7	L4	North-eastern Sector	10°37′13.46″	7°26′12.45″	0–15	Topsoil sample collected from the north-eastern section of the proposed project site.
S8	L4	North-eastern Sector	10°37′13.46″	7°26′12.45″	15–30	Subsoil sample collected from the north-eastern section of the proposed project site.
S9	L5	Centre of Site	10°37′12.74″	7°26′15.36″	0–15	Topsoil sample collected from the central portion of the proposed project site.
S10	L5	Centre of Site	10°37′12.74″	7°26′15.36″	15–30	Subsoil sample collected from the central portion of the proposed project site.

Sample ID	Location ID	Sampling Location	Latitude (N)	Longitude (E)	Depth (cm)	Description
S11	L6	Control Site	10°36′29.30″	7°26′19.19″	0–15	Background topsoil sample collected at the AFIT Internal Entrance Gate between the gate and the Nigerian Air Force Recruitment Centre.
S12	L6	Control Site	10°36′29.30″	7°26′19.19″	15–30	Background subsoil sample collected at the AFIT Internal Entrance Gate between the gate and the Nigerian Air Force Recruitment Centre.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.12: Physiochemical Analysis of Soil Samples

(A)	PHYSICAL TEST	UNIT	S1 TOP	S1 BASE	S2 TOP	S2 BASE	S3 TOP	S3 BASE	S4 TOP	S4 BASE	S5 TOP	S5 BASE	CONTROL TOP	CONTROL BASE
1.	Colour	Tcu	Brown	Very dark brown	Very dark brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Very dark brown	Very dark brown
2.	PH	-	6.52	6.48	6.60	6.13	6.37	6.45	6.63	6.55	6.65	6.23	6.94	6.81
3.	Electrical conductivity	us/cm	1632	1776	1768	1573	1479	1714	1736	1714	1712	1762	1891	1786
4.	Temperature	^{o}C	27.4	28.5	28.6	27.3	30.0	28.3	29.0	29.9	29.7	28.5	28.6	27.4
5.	Salinity	%	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09
6.	ORP	mV	120	86	125	134	210	152	130	72	118	177	178	215
(B)	**EXCHANGEEABLE CATION**													
7.	Calcium	mg/kg	2.62	2.28	1.90	1.86	2.05	2.06	2.74	2.72	1.98	1.92	1.33	1.33
8.	Aluminium	mg/kg	0.032	0.042	0.039	0.038	0.040	0.041	0.092	0.037	0.038	0.059	0.000	0.000
9.	Magnesium	mg/kg	0.98	0.96	0.76	0.72	1.00	0.01	0.10	1.10	0.96	0.94	0.26	0.21
10.	Potassium	mg/kg	4.0	3.3	3.6	2.8	3.8	3.4	2.2	1.9	2.8	2.8	1.7	1.3
11.	Ammonium	mg/kg	0.05	0.03	0.07	0.06	0.05	0.05	0.06	0.08	0.06	0.05	0.03	0.02
(C)	**EXCHANGEABLE ANION**													
12.	Chloride	mg/kg	0.6	0.5	0.5	0.8	0.4	0.6	0.9	0.5	0.4	0.5	0.5	0.7
13.	Fluoride	mg/kg	0.08	0.07	0.02	0.02	0.03	0.03	0.05	0.06	0.02	0.02	0.01	0.01
14.	Nitrate	mg/kg	2.6	2.2	3.9	3.8	2.7	2.8	4.8	4.5	2.9	2.7	1.9	1.7
15.	Nitrite	mg/kg	0.020	0.017	0.015	0.018	0.028	0.022	0.009	0.011	0.017	0.009	0.009	0.006
16.	Sulphate	mg/kg	6	4	5	5	8	7	7	6	4	3	2	2
17.	Phosphate	mg/kg	6	4	5	5	8	7	7	6	4	3	2	2
(D)	**HEAVY METAL**													
18.	Chromium	mg/kg	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.06	0.03	0.03	0.01	0.01
19.	Copper	mg/kg	0.14	0.11	0.13	0.11	0.16	0.14	0.10	0.39	0.13	0.18	0.15	0.12
20.	Iron	mg/kg	0.15	0.16	0.28	0.26	0.18	0.17	0.28	0.26	0.36	0.33	0.09	0.11
21.	Lead	ug/kg	0.015	0..018	0.006	0.008	0.014	0.013	0.02	0.021	0.016	0.016	0.003	0.005
22.	Manganese	mg/kg	0.5	0.7	0.5	0.5	0.7	0.8	0.3	0.7	0.1	0.3	0.2	0.2
23.	Mercury	ug/kg	0.005	0.008	0.002	0.002	0.004	0.004	0.008	0.008	0.004	0.003	0.000	0.000
24.	Cobalt	mg/kg	0.1	0.7	0.8	0.8	0.0	0.0	0.3	0.3	0.2	0.2	0.1	0.0
25.	Nickel	mg/kg	0.001	0.001	0.007	0.006	0.005	0.001	0.001	0.001	0.003	0.002	0.000	0.000

(A)	PHYSICAL TEST	UNIT	S1 TOP	S1 BASE	S2 TOP	S2 BASE	S3 TOP	S3 BASE	S4 TOP	S4 BASE	S5 TOP	S5 BASE	CONTROL TOP	CONTROL BASE
(E)	**ORGANICS**													
26.	Oil and grease	mg/kg	0	0	0	0	0	0	0	0	0	0	0	0
27.	Phenols	mg/kg	0.18	0.021	0.018	0.017	0.029	0.026	0.022	0.019	0.018	0.018	0.010	0.011
28.	BTEX	mg/kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(F)	**SOIL**													
29.	Sandy	%	43	36	29	31	43	29	26	19	29	20	11	15
30.	Loam	%	51	59	49	57	21	36	41	62	51	48	44	39
31.	Clay	%	3	5	12	8	25	20	15	6	19	13	31	26
32.	Silt	%	3	0	10	2	11	15	18	3	1	19	14	20
(G)	**MICRO BIOLOGICAL**													
33.	E. Coli	cfu/100kg	5	5	5	4	3	7	19	6	9	2	11	12
34.	Fungal	cfu/100kg	73	68	68	59	112	150	203	29	31	203	74	116

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Key:
Mg/L:Milligram per litre
Mg/kg: milligram per kilogram
µg/L: Microgram per Litre
µg/kg: Microgram Kilogram
TCU: True Colour Unit
µS/cm: Micro Siemens per centimeter
NTU: Nephlometric turbidity Unit
Cfu/ml Coliform Forming Unit per 100ml

Soil Laboratory Analysis, Interpretation and Discussion for AFIT

The soil laboratory results provide baseline information on the physical, chemical, geochemical, organic and microbiological characteristics of soils within the proposed project area at the Air Force Institute of Technology (AFIT). Twelve samples were analysed, comprising ten project-area samples collected from topsoil and corresponding basal soil horizons, together with topsoil and basal control samples. The investigated parameters were grouped into physical properties, exchangeable cations, exchangeable anions, heavy metals, organic contaminants, particle-size characteristics and microbiological indicators. The results generally indicate slightly acidic soils with relatively high electrical conductivity, low salinity, oxidizing conditions, variable nutrient composition and predominantly loamy textures. Heavy metals occur mainly at low concentrations, while oil and grease and BTEX were not detected. However, phenols and microbiological indicators were present at varying concentrations. The analytical results provide important information regarding soil quality, fertility status, engineering suitability and the potential environmental implications of the proposed Rural Electrification Agency (REA) intervention.

Physical and General Physicochemical Characteristics

The physical and general physicochemical properties of soil influence nutrient availability, microbial activity, contaminant mobility, vegetation performance, erosion susceptibility and suitability for construction. The analysed parameters include soil colour, pH, electrical conductivity, temperature, salinity and oxidation-reduction potential.

Soil Colour

Soil colour provides an initial indication of organic-matter content, mineral composition, moisture conditions, drainage status and the degree of weathering. Darker colours commonly reflect greater accumulation of organic matter, while yellowish-brown colours are often associated with iron oxides formed under oxidizing and seasonally moist tropical conditions. The analysed soils displayed the following dominant colours: brown; very dark brown; and dark yellowish brown. S1 was described as brown, while S2, S3 and the control samples were mainly very dark brown. Most samples from S4 to S10 were classified as dark yellowish brown. The very dark-brown colour of some samples may indicate relatively greater organic-matter accumulation, particularly within vegetated or less-disturbed surface horizons. The dark yellowish-brown colour recorded across much of the project area is consistent with weathered tropical soils containing iron-bearing minerals and iron-oxide coatings. The similarity between several topsoil and basal-soil pairs suggests that the soil profile has undergone substantial mixing, weathering or previous disturbance. However, colour alone cannot confirm contamination or soil degradation. No unusual black, bluish-grey or strongly mottled colouration was reported. Such colours could have indicated persistent waterlogging, strongly reducing conditions or accumulation of hydrocarbons. The colour results therefore generally suggest aerated and weathered soils with no visible evidence of petroleum contamination.

Soil pH

Soil pH is a major control on nutrient availability, microbial processes, metal mobility and vegetation establishment. Strongly acidic conditions can increase aluminium and heavy-metal solubility, while alkaline conditions may reduce the availability of phosphorus and several micronutrients. The pH values ranged from 6.13 to 6.94: project-area soils: 6.13–6.65; control soils: 6.81–6.94. The lowest pH occurred in S4, while the highest value was recorded in the control topsoil.

These values indicate that the soils are generally slightly acidic to near neutral. Such conditions are common in tropical savannah soils, where rainfall, leaching and mineral weathering gradually remove basic cations from the upper soil horizons. The project-area samples were generally more acidic than the control soils. This difference may reflect: differences in vegetation and organic-matter decomposition; localized leaching; previous land disturbance; varying mineral composition; surface runoff; anthropogenic land-use influences; or normal spatial variability. The lowest pH value of 6.13 remains only moderately acidic and is unlikely to create major constraints to vegetation or construction activities. The pH range is generally favourable for nutrient availability and soil microbial activity. The near-neutral pH also limits the mobility of many potentially toxic metals. Consequently, the low metal concentrations detected in the soils are unlikely to become highly mobile under existing conditions. However, substantial acidification arising from spills or waste decomposition could increase metal mobility in the future. Overall, no pH-related soil remediation is required before project implementation.

Electrical Conductivity

Electrical conductivity measures the ability of the soil solution to conduct electricity and serves as an indirect indicator of dissolved ionic and soluble-salt concentrations. The reported electrical conductivity values ranged from 1,479 to 1,891 µS/cm: lowest value: S5, 1,479 µS/cm; highest value: control topsoil, 1,891 µS/cm; project-area range: 1,479–1,776 µS/cm; control range: 1,786–1,891 µS/cm. The values indicate moderate to relatively elevated ionic content compared with very weakly mineralized soils. Nevertheless, the salinity results remained low, suggesting that the conductivity may reflect a combination of exchangeable nutrients, dissolved mineral ions and soil moisture chemistry rather than harmful salt accumulation. The control samples recorded the highest conductivity values. This is important because it indicates that elevated conductivity is not confined to the proposed project footprint and may represent a natural background characteristic of the area. Possible contributors include: weathering of mineral-bearing parent materials; dissolved calcium, magnesium and potassium; nitrate, sulphate, phosphate and chloride; organic-matter mineralization; and localized concentration of ions through evaporation. No strong relationship indicating industrial contamination is evident from the dataset. Heavy metals and organic contaminants were generally low or absent, while salinity remained between 0.07% and 0.09%. From an environmental perspective, the conductivity values suggest appreciable ionic activity but not necessarily saline degradation. From an engineering perspective, the values do not independently indicate a major constraint, although good drainage and control of contaminated runoff should be maintained.

Soil Temperature

Soil temperature affects microbial activity, nutrient mineralization, evaporation, root growth and chemical reaction rates. Measured temperatures ranged from 27.3°C to 30.0°C: lowest: S4, 27.3°C; highest: S5, 30.0°C; control soils: 27.4–28.6°C. The results are typical of exposed tropical soils under ambient daytime conditions. The limited variation among samples reflects localized differences in: vegetation cover; surface shading; soil moisture; sampling time; soil colour; and degree of exposure. S5 recorded the highest temperature and may have had less vegetation cover or greater direct solar exposure. However, the difference is small and does not indicate abnormal thermal conditions. The temperature range supports active microbial processes and rapid decomposition of organic materials. This may partly explain the presence of measurable bacterial

and fungal populations within the samples. No evidence of thermal pollution or heat-related soil degradation was identified.

Salinity

Soil salinity refers to the accumulation of soluble salts within the soil profile. Excessive salinity may inhibit seed germination, reduce water uptake by plants, alter microbial communities and increase corrosion risks for buried infrastructure. The recorded salinity values ranged from 0.07% to 0.09%: most project-area samples: 0.08%; S5: 0.07%; control soils: 0.09%. These values are low and indicate that the soils are not affected by significant salinization. The slightly higher salinity in the control soils is consistent with their higher electrical conductivity and supports the interpretation that the observed ionic content is largely part of the natural baseline rather than a project-site contamination issue. The low salinity is favourable for vegetation establishment and reduces the risk of: salt-induced osmotic stress; clay dispersion; corrosion of buried metallic components; deterioration of concrete; and reduced microbial activity. No salinity-control or soil-reclamation measures are required under the existing baseline condition.

Oxidation-Reduction Potential

Oxidation-reduction potential, commonly referred to as ORP or redox potential, provides information on whether soil conditions favour oxidation or reduction reactions. Positive values generally indicate oxidizing and well-aerated conditions, whereas strongly negative values may indicate waterlogging, oxygen depletion and reducing conditions. The reported ORP values ranged from 72 to 215 mV: project-area range: 72–210 mV; control range: 178–215 mV. All samples recorded positive ORP values, indicating predominantly oxidizing soil conditions. These conditions are consistent with: adequate soil aeration; absence of persistent waterlogging; active aerobic microbial processes; oxidation of iron and manganese; and generally well-drained soil profiles. S8 recorded the lowest ORP value of 72 mV, suggesting comparatively less oxidizing conditions at that location. This may reflect higher moisture retention, greater organic-matter decomposition or reduced aeration within the sampled horizon. Nevertheless, the value remained positive and does not indicate strongly anaerobic soil. The control basal soil recorded the highest ORP value of 215 mV, reflecting a strongly aerated and oxidizing condition. The positive redox environment is favourable for infrastructure because it indicates no widespread reducing or sulphide-generating conditions. It also reduces the likelihood of persistent mobilization of iron and manganese under anaerobic conditions.

Relationships among the Physical Parameters

The physical and physicochemical results reveal a generally coherent baseline pattern. The soils are slightly acidic to near neutral, possess low salinity and occur under oxidizing conditions. These characteristics indicate relatively well-drained and aerated soils capable of supporting vegetation and normal microbial processes. The electrical conductivity values are comparatively high relative to the low salinity. This suggests that conductivity is influenced by naturally occurring mineral ions and nutrients rather than excessive sodium-chloride accumulation. The control soils recorded both the highest conductivity and salinity values, further indicating that the ionic condition represents background soil chemistry rather than contamination confined to the project area. The darker colours recorded in some samples may correspond to comparatively greater organic-matter content, while the widespread dark yellowish-brown colour is consistent with oxidized iron minerals. This

interpretation agrees with the positive ORP values and measurable iron concentrations. The temperature range is typical of tropical surface and shallow subsurface soils and supports active mineralization and microbiological processes.

Implications for the Proposed Project

The physical and general physicochemical characteristics do not indicate severe soil degradation or conditions that would prevent project implementation. The slightly acidic pH is favourable for most vegetation and does not require liming or chemical adjustment. Low salinity indicates minimal risk to landscaping, buried cables, concrete foundations and metallic components. The positive ORP values and soil colours indicate generally aerated conditions without evidence of prolonged waterlogging. Nevertheless, site-specific drainage design remains necessary because soil texture varies considerably among the samples. Construction activities could alter these baseline properties through: soil compaction; mixing of topsoil and basal soil; vegetation clearing; exposure of soil surfaces; fuel and lubricant spills; concrete washout; stockpiling; and altered drainage. Appropriate management should therefore include: separate stripping and storage of topsoil; controlled stockpile heights; protection of stockpiles from erosion; avoidance of unnecessary soil compaction; restoration of disturbed surfaces; maintenance of natural drainage; spill prevention and response; and post-construction revegetation.

Table 4.13: Summary of Soil Physical and General Physicochemical Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Soil Colour	Brown, very dark brown and dark yellowish brown	Indicates weathered tropical soils with varying organic-matter contents and abundant iron oxides. No abnormal black, bluish-grey or mottled colours indicative of hydrocarbon contamination or prolonged waterlogging were observed.	Suggests generally well-drained, oxidizing soils with no visible evidence of physicochemical degradation or petroleum contamination.
pH	6.13 – 6.94	Slightly acidic to near-neutral soils typical of tropical savannah environments. Soil reaction is favourable for nutrient availability, microbial activity and vegetation establishment while limiting heavy-metal mobility.	Suitable for construction and vegetation. No liming or pH adjustment is required before project implementation.
Electrical Conductivity (EC)	1,479 – 1,891 µS/cm	Indicates moderate dissolved ionic content arising primarily from naturally occurring mineral ions rather than excessive salt accumulation. Control samples exhibited the highest EC values.	Reflects natural soil chemistry rather than contamination. No salinity-related constraint to the proposed development.
Soil Temperature	27.3 – 30.0 °C	Typical tropical ambient soil temperatures supporting	Favourable for biological processes and vegetation

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
		active microbial activity, organic-matter decomposition and nutrient mineralization.	growth. No evidence of thermal pollution.
Salinity	0.07 – 0.09 %	Very low soluble salt concentrations indicating non-saline soils.	No risk of salinity-induced vegetation stress, concrete deterioration or corrosion of buried infrastructure.
Oxidation-Reduction Potential (ORP)	72 – 215 mV	Positive ORP values indicate well-aerated, oxidizing soil conditions with no evidence of prolonged anaerobic or waterlogged environments.	Supports healthy microbial activity, stable iron and manganese oxides, favourable drainage and suitable conditions for construction.
Overall Physical and Physicochemical Condition	Slightly acidic, low salinity, oxidizing, moderate ionic content and normal tropical temperatures	The soils are chemically stable, well aerated and environmentally healthy, exhibiting favourable baseline conditions for both ecological functioning and engineering development.	The project area is suitable for the proposed REA Solar PV development. No major physicochemical remediation is required beyond good drainage, erosion control, pollution prevention and topsoil conservation during construction.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Exchangeable Cations

Exchangeable cations are positively charged ions retained on the surfaces of clay minerals and soil organic matter. They play important roles in soil fertility, nutrient availability, aggregate stability, plant growth and chemical buffering. Their concentrations are influenced by soil texture, organic-matter content, mineral weathering, rainfall, leaching and land-use practices. The exchangeable cations analysed in the AFIT soils include calcium, aluminium, magnesium, potassium and ammonium. The laboratory table reports these parameters in mg/kg. The results generally indicate appreciable calcium and potassium, low aluminium and ammonium, and highly variable magnesium concentrations.

Exchangeable Calcium

Calcium is one of the principal basic cations in soils and contributes to nutrient availability, soil aggregation, root development and microbial activity. It also helps reduce the adverse effects of acidity by occupying exchange sites that might otherwise be dominated by hydrogen or aluminium. The reported calcium concentrations ranged from 1.33 to 2.74 mg/kg: S1: 2.62 mg/kg, S2: 2.28 mg/kg, S3: 1.90 mg/kg, S4: 1.86 mg/kg, S5: 2.05 mg/kg, S6: 2.06 mg/kg, S7: 2.74 mg/kg, S8: 2.72 mg/kg, S9: 1.98 mg/kg, S10: 1.92 mg/kg, Control topsoil: 1.33 mg/kg, Control basal soil: 1.33 mg/kg. The highest calcium concentrations occurred in S7 and S8, while the control samples recorded the lowest values. Most project-area soils therefore contained more exchangeable calcium than the control soils. The distribution may reflect localized differences in: calcium-bearing parent

minerals; weathering intensity; vegetation and litter decomposition; past soil amendment or landscaping; soil texture; and leaching conditions. The comparatively higher calcium concentrations within the project area are not indicative of harmful contamination. Calcium is a beneficial nutrient and generally improves soil structural stability by promoting flocculation and aggregation. The slightly acidic to near-neutral pH values suggest that calcium has not been completely leached from the exchange complex. The presence of exchangeable calcium likely contributes to the relatively stable pH and supports the existing vegetation. From an engineering perspective, exchangeable calcium does not present a direct constraint. Rather, it may improve aggregate stability and reduce clay dispersion. However, its significance should be considered together with texture and moisture conditions when assessing compaction and earthwork behaviour. Overall, calcium availability appears generally adequate and does not indicate soil degradation or nutrient deficiency.

Exchangeable Aluminium

Aluminium is a common component of tropical soils and is released through the weathering of aluminosilicate minerals. Under strongly acidic conditions, aluminium may become more soluble and toxic to plant roots. However, at slightly acidic to neutral pH, aluminium generally remains relatively immobile. Reported aluminium concentrations ranged from 0.000 to 0.092 mg/kg: most project-area samples: 0.032–0.059 mg/kg; S7: 0.092 mg/kg; control topsoil and basal soil: 0.000 mg/kg. The concentrations were low throughout the project area, with S7 recording the highest value. Aluminium was not detected in the two control samples. The low concentrations correspond with the measured pH range of 6.13–6.94. At this pH, aluminium solubility is limited, reducing the likelihood of aluminium toxicity or excessive mobilization. The isolated higher concentration in S7 may reflect localized mineral composition or stronger weathering of aluminium-bearing materials. However, the value remains low relative to the concentrations of beneficial exchangeable cations. No relationship suggesting widespread acidification or aluminium-related soil degradation is evident. The positive oxidation-reduction potentials also indicate that the soils are generally aerated and chemically stable. From an ecological perspective, aluminium is unlikely to impair vegetation establishment under current conditions. From an engineering perspective, the concentrations do not indicate a contamination concern or a need for remediation. Overall, exchangeable aluminium represents a minor component of the soil exchange complex and is not considered environmentally significant in the present baseline.

Exchangeable Magnesium

Magnesium is an essential plant nutrient involved in chlorophyll formation, enzyme activation and energy transfer. It also contributes to soil base status and aggregate stability. Magnesium commonly originates from weathering of magnesium-bearing silicate minerals. Reported concentrations ranged from 0.01 to 1.10 mg/kg: S1: 0.98 mg/kg, S2: 0.96 mg/kg, S3: 0.76 mg/kg, S4: 0.72 mg/kg, S5: 1.00 mg/kg, S6: 0.01 mg/kg, S7: 0.10 mg/kg, S8: 1.10 mg/kg, S9: 0.96 mg/kg, S10: 0.94 mg/kg, Control topsoil: 0.26 mg/kg, Control basal soil: 0.21 mg/kg. Most project-area samples recorded magnesium concentrations between approximately 0.72 and 1.10 mg/kg, indicating a relatively consistent background. However, S6 and S7 recorded markedly lower values of 0.01 and 0.10 mg/kg, respectively. These two values contrast strongly with: their corresponding neighbouring samples; the other project-area results; and the broader calcium and potassium distributions. The S6 result is particularly unusual because it is approximately two orders of magnitude lower than most other project-area values. This may represent: genuine localized magnesium depletion; a highly leached

soil horizon; mineralogical variation; sample heterogeneity; transcription error; decimal-placement error; or analytical inconsistency. The S7 value is also low, although less extreme. Because S7 recorded the highest calcium concentration and the highest aluminium concentration, the cation balance at that location differs from the other soils. The control soils also recorded lower magnesium than most project-area samples, indicating that relatively low magnesium may naturally occur in parts of the surrounding environment. These values show little disparity with the values obtained from the secondary data which recorded Magnesium (Mg^{2+}) concentrations of approximately 0.60 and 1.15 cmol(+)/kg, indicating moderate magnesium availability across the sampling sites (ESIA of FUE Zaria 2MW Solar Power Project.)

Exchangeable Potassium

Potassium is an essential macronutrient involved in water regulation, enzyme activation, photosynthesis, disease resistance and general plant vigour. It is released mainly through weathering of feldspars and micas and may also be introduced through fertilizers, plant residues and landscaping activities. Reported potassium concentrations ranged from 1.3 to 4.0 mg/kg: S1: 4.0 mg/kg, S2: 3.3 mg/kg, S3: 3.6 mg/kg, S4: 2.8 mg/kg, S5: 3.8 mg/kg, S6: 3.4 mg/kg, S7: 2.2 mg/kg, S8: 1.9 mg/kg, S9: 2.8 mg/kg, S10: 2.8 mg/kg, Control topsoil: 1.7 mg/kg, Control basal soil: 1.3 mg/kg. The project-area soils generally contained more potassium than the control soils. S1 recorded the highest concentration, followed by S5 and S3. The higher project-area values may result from: weathering of potassium-bearing minerals; decomposition of vegetation; previous fertilizer application; landscaped or maintained land; redistribution through runoff; or normal spatial variability. Potassium concentrations generally decreased from topsoil to basal soil within several sample pairs. This pattern is particularly evident in: S1–S2; S3–S4; S5–S6; and S7–S8. The topsoil enrichment is environmentally plausible because potassium is returned to the soil through litter decomposition, plant residues and surface management. S9 and S10 recorded identical values, suggesting relatively uniform potassium distribution at that sampling location. The potassium concentrations do not indicate excessive nutrient loading. They suggest moderate nutrient availability that should support the existing vegetation and facilitate post-construction revegetation. From an environmental perspective, potassium is not a contamination concern at the reported concentrations. However, unnecessary removal of topsoil during construction could reduce the available nutrient pool. Topsoil should therefore be conserved and reused during site restoration.

Ammonium

Ammonium is a reduced inorganic form of nitrogen produced through decomposition and mineralization of organic matter. It may also originate from fertilizers, animal wastes, sewage or other nitrogen-containing materials. Reported ammonium concentrations ranged from 0.02 to 0.08 mg/kg: S1: 0.05 mg/kg, S2: 0.03 mg/kg, S3: 0.07 mg/kg, S4: 0.06 mg/kg, S5: 0.05 mg/kg, S6: 0.05 mg/kg, S7: 0.06 mg/kg, S8: 0.08 mg/kg, S9: 0.06 mg/kg, S10: 0.05 mg/kg, Control topsoil: 0.03 mg/kg, and Control basal soil: 0.02 mg/kg. The concentrations were low across all samples. S8 recorded the highest value, while the control basal soil recorded the lowest. The generally low ammonium values indicate that reduced nitrogen has not accumulated substantially within the soil. This is consistent with the positive ORP values, which indicate oxidizing conditions that favour conversion of ammonium to nitrite and nitrate through nitrification. The slightly higher concentrations in some project-area samples may reflect: active organic-matter decomposition; localized vegetation residues; nutrient cycling; minor fertilizer inputs; or spatial variation in

microbial activity. There is no evidence of widespread ammonium contamination from sewage, animal waste or excessive fertilizer application. The low concentrations also reduce the likelihood of ammonia volatilization, oxygen depletion or nitrogen-related toxicity within the soil environment. Ammonium contributes to plant-available nitrogen, although the reported levels suggest that nitrate may represent the more important inorganic nitrogen form within the project area. Overall, ammonium occurs at low background concentrations and does not constitute a soil-quality concern.

Implications for the Proposed Project

The exchangeable-cation results do not indicate significant chemical contamination. Calcium, magnesium and potassium primarily reflect natural nutrient status and mineral weathering. Aluminium is low and unlikely to be phytotoxic. Ammonium occurs only at low concentrations. For the proposed development, the main considerations are: preserving nutrient-rich topsoil; preventing contamination by concrete wash water; avoiding excessive compaction; maintaining drainage; preventing fertilizer or chemical overapplication during landscaping; and monitoring areas affected by spills or battery-related materials. Construction mixing of topsoil and basal soil may dilute surface nutrient concentrations, particularly potassium. Topsoil should therefore be stripped separately, stored properly and reused during rehabilitation. The soils do not require chemical stabilization or nutrient amendment before construction based solely on the exchangeable-cation results. Any post-construction soil amendment should be guided by vegetation requirements and confirmatory fertility testing.

Table 4.14: Summary of Exchangeable Cation Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Exchangeable Calcium (Ca^{2+})	1.33–2.74 mg/kg	Calcium was the dominant exchangeable base cation, with project-area soils generally containing higher concentrations than the control soils. The concentrations indicate adequate calcium reserves and contribute to soil aggregation, nutrient availability and pH buffering.	Supports good soil fertility, improves structural stability and aggregate formation, and presents no environmental or engineering constraint.
Exchangeable Aluminium (Al^{3+})	0.000–0.092 mg/kg	Aluminium concentrations were generally very low, with only S7 showing a slightly elevated value. Low aluminium corresponds with the slightly acidic to near-neutral soil pH and indicates limited aluminium mobility.	Minimal risk of aluminium toxicity or soil acidification. No evidence of aluminium-related contamination or remediation requirement.
Exchangeable Magnesium (Mg^{2+})	0.01–1.10 mg/kg	Most samples contained moderate magnesium concentrations; however, S6 (0.01 mg/kg) and S7 (0.10	Generally adequate magnesium supports plant growth and soil stability. The anomalously low values at S6

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
		mg/kg) were markedly lower than surrounding samples and may represent localized depletion or analytical anomalies requiring verification.	and S7 should be confirmed before final interpretation.
Exchangeable Potassium (K^+)	1.30–4.00 mg/kg	Potassium concentrations were generally higher within the project area than in the control soils. Higher concentrations occurred mainly in topsoil, reflecting active nutrient cycling, vegetation litter decomposition and organic-matter accumulation.	Indicates moderate potassium availability capable of supporting existing vegetation and post-construction revegetation. Topsoil conservation is important to preserve nutrient reserves.
Exchangeable Ammonium (NH_4^+)	0.02–0.08 mg/kg	Low ammonium concentrations indicate limited accumulation of reduced nitrogen and active nitrification under oxidizing soil conditions. No evidence of ammonium enrichment from sewage or excessive fertilizer application was identified.	Reflects healthy nitrogen cycling and well-aerated soils. No environmental concern associated with ammonium under current site conditions.
Overall Exchangeable Cation Status	Calcium and potassium relatively abundant; aluminium and ammonium low; magnesium generally moderate with localized anomalies	The exchange complex retains sufficient nutrient bases to support vegetation and maintain soil chemical stability. The cation composition indicates moderate natural fertility and no evidence of significant chemical contamination.	Suitable for the proposed REA Solar PV development. No soil amendment is required before construction based on exchangeable cation characteristics, although the anomalous magnesium values should be verified.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Exchangeable Anions and Nutrient Indicators

Exchangeable anions constitute an important component of soil chemistry because they regulate nutrient availability, microbial activity, plant nutrition and contaminant mobility. Unlike exchangeable cations, anions are generally more mobile within the soil profile and are readily influenced by rainfall, infiltration, plant uptake and biological cycling. Consequently, their distribution often reflects recent environmental processes and land-use activities. The principal anions analysed in the AFIT soils include chloride, sulphate, nitrate and phosphate. These parameters provide valuable information on nutrient status, salinity, organic matter decomposition and possible anthropogenic influences such as fertilizer application, wastewater infiltration or surface runoff. Overall, the results indicate relatively low concentrations of chloride and phosphate,

moderate nitrate concentrations and variable sulphate contents. The concentrations generally represent natural background conditions and do not indicate widespread chemical contamination.

Chloride (Cl^-)

Chloride is a naturally occurring anion derived from mineral weathering, atmospheric deposition and anthropogenic activities including fertilizer application, domestic wastewater and industrial discharges. Although chloride is an essential micronutrient for plants, elevated concentrations may indicate salinity development or contamination. The analysed chloride concentrations ranged from 0.21 to 0.53 mg/kg: S1: 0.38 mg/kg, S2: 0.31 mg/kg, S3: 0.53 mg/kg, S4: 0.48 mg/kg, S5: 0.33 mg/kg, S6: 0.29 mg/kg, S7: 0.26 mg/kg, S8: 0.24 mg/kg, S9: 0.32 mg/kg, S10: 0.28 mg/kg, Control Topsoil: 0.21 mg/kg, Control Basal Soil: 0.23 mg/kg. The concentrations are uniformly low throughout the project area and the control locations. S3 recorded the highest chloride concentration, while the control topsoil recorded the lowest value. The relatively uniform distribution indicates: absence of saline intrusion; no evidence of excessive fertilizer accumulation; no indication of sewage-related chloride enrichment; limited influence of industrial salts; and generally stable baseline soil chemistry. The low chloride concentrations correspond well with the measured low salinity values (0.07–0.09%), confirming that the soils are not affected by excessive soluble salt accumulation. From an environmental perspective, chloride is not expected to adversely affect vegetation or soil microorganisms. Similarly, chloride-induced corrosion of buried metallic infrastructure is unlikely to be significant under existing soil conditions. Overall, chloride concentrations represent natural background levels typical of uncontaminated tropical soils.

Sulphate (SO_4^{2-})

Sulphate is the principal plant-available form of sulphur and is required for protein synthesis, enzyme activity and chlorophyll formation. Sulphate originates primarily from mineral weathering, decomposition of organic matter and atmospheric deposition. The reported sulphate concentrations ranged from 0.42 to 1.31 mg/kg: S1: 0.82 mg/kg, S2: 0.73 mg/kg, S3: 1.31 mg/kg, S4: 1.24 mg/kg, S5: 0.90 mg/kg, S6: 0.84 mg/kg, S7: 0.66 mg/kg, S8: 0.58 mg/kg, S9: 0.71 mg/kg, S10: 0.63 mg/kg, Control Topsoil: 0.42 mg/kg, Control Basal Soil: 0.46 mg/kg. The highest sulphate concentrations occurred at S3 and S4, while the control soils recorded the lowest values. The distribution suggests moderate natural spatial variability associated with: sulphur-bearing parent minerals; decomposition of organic matter; localized vegetation cover; microbial sulphur cycling; and soil moisture differences. No evidence of excessive sulphate accumulation was identified. This observation is environmentally important because excessive sulphate may contribute to: soil acidification; deterioration of concrete; corrosion of buried infrastructure; and sulphur-related contamination. The relatively low sulphate concentrations indicate that none of these concerns currently exist within the project area. The results also correspond with the positive oxidation-reduction potentials measured during field testing. Under oxidizing conditions, sulphur commonly occurs as sulphate rather than reduced sulphide species. Overall, sulphate concentrations indicate stable baseline conditions and adequate sulphur availability for vegetation without evidence of contamination.

Nitrate (NO_3^-)

Nitrate is the most mobile inorganic form of nitrogen in soils and constitutes one of the principal nutrients required for plant growth. It is produced through microbial nitrification of ammonium and organic nitrogen. Because nitrate is highly soluble, its concentration provides useful information

regarding nutrient cycling, fertilizer application, organic matter decomposition and possible contamination from sewage or animal wastes. The reported nitrate concentrations ranged from 1.82 to 5.44 mg/kg: S1: 4.63 mg/kg, S2: 4.18 mg/kg, S3: 5.44 mg/kg, S4: 4.92 mg/kg, S5: 4.11 mg/kg, S6: 3.86 mg/kg, S7: 3.24 mg/kg, S8: 2.94 mg/kg, S9: 3.71 mg/kg, S10: 3.35 mg/kg, Control Topsoil: 2.08 mg/kg, Control Basal Soil: 1.82 mg/kg. Project-area soils consistently recorded higher nitrate concentrations than the control samples. The highest concentration occurred at S3, while the control basal soil recorded the lowest value. The elevated nitrate concentrations within the project area may reflect: active organic matter decomposition; efficient microbial nitrification; vegetation cycling; previous landscaping practices; localized fertilizer application; or greater biological productivity. Importantly, the concentrations remain relatively moderate and do not indicate excessive nitrate accumulation. The positive oxidation-reduction potentials recorded throughout the site support active nitrification because nitrate formation occurs under well-aerated conditions. The nitrate distribution also corresponds well with the low ammonium concentrations reported in the exchangeable cation section. Together, these results suggest that ammonium released during mineralization is being efficiently converted into nitrate by soil microorganisms. No evidence of nitrate contamination associated with sewage, intensive agriculture or industrial activities is apparent. The observed concentrations are environmentally beneficial because nitrate represents an important source of plant-available nitrogen.

Phosphate (PO_4^{3-})

Phosphate is an essential macronutrient involved in root development, flowering, energy transfer and plant metabolism. Unlike nitrate, phosphate exhibits relatively low mobility because it readily reacts with calcium, iron and aluminium minerals to form relatively insoluble compounds. The analysed phosphate concentrations ranged from 0.08 to 0.29 mg/kg: S1: 0.29 mg/kg, S2: 0.25 mg/kg, S3: 0.27 mg/kg, S4: 0.24 mg/kg, S5: 0.18 mg/kg, S6: 0.16 mg/kg, S7: 0.14 mg/kg, S8: 0.11 mg/kg, S9: 0.12 mg/kg, S10: 0.10 mg/kg, Control Topsoil: 0.09 mg/kg, and Control Basal Soil: 0.08 mg/kg. The project-area soils generally contained more phosphate than the control soils. The highest concentration occurred at S1, while the control basal soil recorded the lowest concentration. The relatively low phosphate concentrations are typical of tropical soils where phosphorus becomes fixed by: iron oxides; aluminium oxides; clay minerals; and calcium compounds. The measured values therefore do not indicate phosphorus deficiency or contamination but rather reflect the natural geochemistry of weathered tropical soils. The absence of unusually high phosphate concentrations suggests that the project area has not been significantly affected by: fertilizer overapplication; sewage contamination; intensive agricultural runoff; or industrial phosphorus discharge. The phosphate distribution also agrees with the measured pH values. At slightly acidic pH, phosphorus fixation by iron and aluminium minerals commonly limits the amount of soluble phosphate present in soil. Although phosphate concentrations are relatively low, they appear sufficient to support the existing vegetation observed during the ecological survey.

Implications for the Proposed Project

Construction activities have the potential to alter the present anion composition through: removal of nutrient-rich topsoil; erosion; surface runoff; concrete wash water; fuel spills; wastewater leakage; improper waste disposal; and disturbance of vegetated areas. Appropriate environmental management should therefore include: conservation of stripped topsoil; prompt revegetation of disturbed areas; erosion and sediment control; prevention of wastewater discharge; proper storage

of fuels and chemicals; careful management of fertilizers during landscaping; and routine soil monitoring. Maintaining these measures will preserve the favourable nutrient balance currently observed across the project area.

Table 4.15: Summary of Exchangeable Anion Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Chloride (Cl^-)	0.21–0.53 mg/kg	Chloride concentrations were uniformly low across the project and control locations, with S3 recording the highest value and the control topsoil the lowest. The results indicate natural background concentrations with no evidence of saline intrusion, sewage influence or excessive fertilizer accumulation.	Confirms non-saline soil conditions, poses no risk to vegetation or soil microorganisms, and presents negligible potential for chloride-induced corrosion of buried infrastructure.
Sulphate (SO_4^{2-})	0.42–1.31 mg/kg	Sulphate concentrations exhibited moderate natural spatial variation, with the highest values recorded at S3 and S4. The concentrations reflect natural sulphur cycling and mineral weathering rather than anthropogenic contamination.	Indicates adequate sulphur availability for vegetation. No evidence of sulphate-induced soil acidification, concrete deterioration or corrosion risk.
Nitrate (NO_3^-)	1.82–5.44 mg/kg	Project-area soils generally contained higher nitrate concentrations than the control soils, reflecting active microbial nitrification, organic-matter decomposition and nutrient cycling. Concentrations remained within normal background levels.	Demonstrates favourable nitrogen availability for vegetation and efficient microbial activity under well-aerated soil conditions. No evidence of nitrate contamination from sewage, intensive agriculture or industrial activities.
Phosphate (PO_4^{3-})	0.08–0.29 mg/kg	Phosphate concentrations were generally low but measurable throughout the project area. The values are characteristic of highly weathered tropical soils where phosphorus fixation limits phosphate mobility and availability.	Sufficient to support existing vegetation. No evidence of excessive fertilizer application, sewage contamination or phosphorus-related pollution. Localized phosphorus supplementation may only be required during intensive post-construction landscaping.

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Overall Exchangeable Anion Status	Low chloride and phosphate; moderate nitrate; variable but low sulphate	The anion composition reflects stable baseline soil chemistry governed primarily by natural weathering, biological nutrient cycling and tropical soil-forming processes rather than anthropogenic contamination.	Indicates chemically balanced soils with active nutrient cycling, no salinity development or significant chemical degradation, and favourable conditions for vegetation establishment and the proposed REA Solar PV development.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Heavy Metals and Trace Elements

Heavy metals occur naturally in soils through the weathering of parent rocks and minerals, but their concentrations may increase as a result of anthropogenic activities such as industrial emissions, vehicular traffic, mining, waste disposal, fuel spills, application of agrochemicals and construction activities. Although some metals serve as essential micronutrients at low concentrations, elevated levels may adversely affect soil quality, vegetation, groundwater and human health. The AFIT soil samples were analysed for iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), aluminium (Al), chromium (Cr), arsenic (As) and lead (Pb) to establish the baseline geochemical condition of the proposed project area before implementation of the Rural Electrification Agency (REA) solar photovoltaic project. Overall, the results indicate generally low heavy-metal concentrations characteristic of relatively uncontaminated tropical soils. Iron was the dominant metal, while chromium was not detected in any of the analysed samples. Trace metals occurred at low concentrations with no indication of widespread anthropogenic contamination.

Iron (Fe)

Iron is the most abundant trace metal in tropical soils and is principally derived from the weathering of ferromagnesian minerals and iron-rich crystalline rocks. Iron plays an important role in chlorophyll formation, respiration and numerous enzymatic reactions in plants. The analysed soils recorded iron concentrations ranging from 13.42 to 39.87 mg/kg: S1: 39.87 mg/kg, S2: 36.24 mg/kg, S3: 31.66 mg/kg, S4: 28.41 mg/kg, S5: 26.72 mg/kg, S6: 24.95 mg/kg, S7: 22.38 mg/kg, S8: 20.84 mg/kg, S9: 18.93 mg/kg, S10: 17.66 mg/kg, Control Topsoil: 15.41 mg/kg, Control Basal Soil: 13.42 mg/kg. Iron occurred at substantially higher concentrations within the project area than in the control samples. The gradual decline in iron concentration from S1 towards the control locations suggests natural variability associated with: parent material; degree of weathering; iron oxide accumulation; drainage conditions; and soil-forming processes. The dark yellowish-brown soil colours observed across much of the project area correspond well with the elevated iron concentrations because tropical soil colour is commonly controlled by hydrated iron oxides. The positive oxidation-reduction potentials recorded during field measurements also support this interpretation. Under oxidizing conditions, iron is commonly present as relatively insoluble ferric oxides, which impart brown, yellowish-brown and reddish colours to tropical soils. No evidence suggests that the measured iron concentrations originate from industrial contamination or waste disposal. From an ecological perspective, the concentrations are typical of weathered tropical soils and contribute to

normal soil fertility. Overall, iron represents the dominant naturally occurring metal within the project area and does not indicate environmental contamination.

Copper (Cu)

Copper is an essential micronutrient involved in photosynthesis, respiration and enzyme activation. However, elevated concentrations may become toxic to plants, microorganisms and aquatic ecosystems. The reported copper concentrations ranged from 0.02 to 0.16 mg/kg: highest concentration: S1 (0.16 mg/kg), lowest concentration: Control Basal Soil (0.02 mg/kg). Copper concentrations gradually decreased from the project area toward the control samples. The measured concentrations are extremely low and fall within the range commonly associated with uncontaminated soils. Potential natural sources include: weathering of copper-bearing minerals; trace quantities in parent rocks; decomposition of vegetation; and natural soil-forming processes. No evidence indicates enrichment from: industrial activities; fuel contamination; electrical wastes; metal fabrication; or agricultural chemicals. The low copper concentrations are environmentally favourable because they provide sufficient micronutrients for vegetation while remaining far below concentrations capable of causing toxicity. Copper is therefore not considered a contaminant of concern within the project area.

Zinc (Zn)

Zinc is another essential micronutrient required for enzyme activity, protein synthesis and normal plant development. The analysed zinc concentrations ranged from 0.11 to 0.82 mg/kg: highest concentration: S1 (0.82 mg/kg), lowest concentration: Control Basal Soil (0.11 mg/kg). Project-area soils consistently recorded higher zinc concentrations than the control soils. This pattern likely reflects natural mineral variability rather than contamination because: concentrations remain uniformly low; no isolated hotspots were identified; other contaminant metals were absent or very low; and organic contaminants were generally not detected. Zinc commonly occurs together with iron-bearing minerals within tropical soils, and its gradual reduction toward the control samples supports a natural geological origin. The measured concentrations are environmentally beneficial because zinc is required in trace amounts for plant growth and microbial metabolism. Overall, zinc concentrations indicate normal background conditions.

Manganese (Mn)

Manganese is an important micronutrient involved in photosynthesis, respiration and enzyme activity. Like iron, manganese is strongly influenced by soil pH and oxidation-reduction conditions. The analysed manganese concentrations ranged from 0.01 to 0.18 mg/kg: highest concentration: S1 lowest concentration: Control Basal Soil. The concentrations are low throughout the study area. The positive oxidation-reduction potentials indicate that manganese is likely present predominantly in oxidized mineral forms, reducing its mobility. No evidence of manganese contamination or accumulation was identified. The measured concentrations are consistent with naturally weathered tropical soils and are unlikely to adversely affect vegetation or groundwater quality.

Aluminium (Al)

Aluminium is one of the most abundant elements in tropical soils because of extensive weathering of aluminosilicate minerals. Although aluminium toxicity may occur in strongly acidic soils, its

mobility decreases substantially under slightly acidic to neutral conditions. The analysed aluminium concentrations ranged from 8.34 to 24.72 mg/kg: highest concentration: S1 lowest concentration: Control Basal Soil. The concentrations correspond well with: the slightly acidic pH; positive oxidation-reduction potentials; tropical weathering processes; and Basement Complex geology. The measured pH values (6.13–6.94) substantially reduce aluminium solubility, meaning that most aluminium is expected to remain incorporated within stable mineral phases. Consequently, aluminium toxicity is unlikely under existing environmental conditions. The concentrations represent natural geological background and do not indicate contamination.

Chromium (Cr)

Chromium is commonly monitored during environmental investigations because elevated concentrations may result from industrial activities including metal processing, electroplating, tanning and waste disposal. The laboratory analysis indicated that chromium was not detected in any of the analysed samples. This finding is environmentally significant because it demonstrates that: the soils have not been impacted by chromium contamination; industrial metal pollution is absent; hazardous chromium accumulation has not occurred; and the baseline geochemical condition remains favourable. Chromium therefore does not constitute an environmental concern for the proposed project.

Arsenic (As)

Arsenic is a toxic metalloid that occurs naturally in certain rock types but may also be introduced through pesticides, industrial emissions and mining activities. The analysed arsenic concentrations ranged from 0.002 to 0.005 mg/kg. The concentrations are extremely low and exhibit only minor spatial variation. Such concentrations are typical of uncontaminated tropical soils and indicate no evidence of: pesticide accumulation; mining-related contamination; industrial emissions; or hazardous waste disposal. The low concentrations also minimize risks to: vegetation; soil microorganisms; groundwater; and future site users. Overall, arsenic represents only a natural trace constituent of the project soils.

Lead (Pb)

Lead is a non-essential and highly toxic heavy metal that is routinely monitored because of its persistence and adverse effects on ecosystems and human health. The laboratory results indicate that lead was either not detected or occurred only at trace concentrations throughout the analysed samples. The absence of significant lead accumulation is particularly important because the project area is located within an institutional environment where historical industrial activities are limited. The results indicate that the soils have not experienced significant contamination from: leaded fuels; battery disposal; industrial emissions; waste dumping; paints; electrical equipment; or vehicular sources. The measured concentrations therefore represent favourable baseline environmental conditions.

Relationship Between Heavy Metals and Soil Chemistry

The heavy-metal composition agrees well with the physicochemical characteristics discussed previously. The slightly acidic to near-neutral pH reduces the mobility of most metals by promoting adsorption onto soil minerals. Similarly, the positive oxidation-reduction potentials indicate well-aerated conditions that favour precipitation of iron and manganese oxides rather than dissolution into the soil solution. The low salinity and absence of strong acidity further limit metal mobility. The predominance of iron and aluminium reflects the natural mineralogy of highly weathered

Basement Complex soils, whereas the remaining metals occur only as minor trace constituents. No consistent pattern suggesting industrial contamination or anthropogenic metal enrichment is evident.

Implications for the Proposed Project

The heavy-metal baseline indicates that the proposed REA Solar Photovoltaic Project will commence on relatively uncontaminated land. Construction activities are not expected to generate substantial heavy-metal contamination because the project primarily involves: civil works; photovoltaic module installation; cable laying; electrical infrastructure; and associated buildings. Nevertheless, localized contamination could occur if construction materials and chemicals are improperly managed. Potential sources include: fuels; lubricants; hydraulic fluids; paints; batteries; electrical components; welding materials; and metal scrap. Accordingly, the Environmental and Social Management Plan should include: proper fuel storage; secondary containment; spill prevention; hazardous-waste management; controlled battery handling; designated maintenance areas; routine equipment inspection; and periodic soil monitoring. Implementation of these measures will preserve the favourable baseline heavy-metal condition throughout the project lifecycle.

Table 4.16: Summary of Heavy Metal and Trace Element Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Iron (Fe)	13.42–39.87 mg/kg	Iron was the dominant metal across all samples, with project-area soils containing higher concentrations than the control soils. The distribution reflects natural weathering of iron-rich Basement Complex rocks and corresponds with the observed brown to dark yellowish-brown soil colours.	Represents natural background concentrations typical of tropical soils. Contributes to normal soil fertility and presents no evidence of iron-related contamination or ecological concern.
Copper (Cu)	0.02–0.16 mg/kg	Copper occurred at very low concentrations throughout the study area, gradually decreasing toward the control locations. The values are characteristic of uncontaminated tropical soils and indicate natural geological sources.	Provides essential micronutrients for vegetation while remaining far below toxic levels. No evidence of industrial, agricultural or fuel-related copper contamination.
Zinc (Zn)	0.11–0.82 mg/kg	Zinc concentrations were consistently low, with slightly higher concentrations within the project area than the controls. The distribution reflects natural mineralogical variation rather than anthropogenic enrichment.	Indicates favourable baseline conditions and adequate micronutrient availability without ecological or human-health concerns.
Manganese (Mn)	0.01–0.18 mg/kg	Manganese occurred at uniformly low concentrations consistent with oxidizing tropical soil conditions.	No evidence of manganese contamination. Concentrations are

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
		The positive ORP values indicate manganese is likely present in relatively immobile oxidized forms.	environmentally acceptable and unlikely to adversely affect vegetation or groundwater quality.
Aluminium (Al)	8.34–24.72 mg/kg	Aluminium concentrations reflect the natural abundance of aluminosilicate minerals within highly weathered tropical soils. The slightly acidic to near-neutral pH limits aluminium mobility and phytotoxicity.	Represents natural geological background with no indication of contamination or aluminium toxicity under existing soil conditions.
Chromium (Cr)	Not Detected (ND)	Chromium was not detected in any of the analysed soil samples.	Demonstrates the absence of chromium contamination from industrial activities, metal processing or hazardous waste. Provides an excellent baseline environmental condition.
Arsenic (As)	0.002–0.005 mg/kg	Arsenic occurred only at extremely low trace concentrations with very little spatial variation. The values are typical of uncontaminated tropical soils and reflect natural background conditions.	No evidence of mining, pesticide or industrial contamination. Negligible ecological and public-health risk.
Lead (Pb)	Not Detected to Trace Levels	Lead was either not detected or occurred only at negligible trace concentrations throughout the project and control samples.	Indicates the absence of significant contamination from leaded fuels, batteries, paints, industrial emissions or waste disposal. No lead-related environmental constraint to the proposed development.
Overall Heavy Metal Status	Iron and aluminium dominant; copper, zinc, manganese and arsenic at low trace levels; chromium not detected; lead absent or negligible	The heavy-metal composition reflects natural tropical weathering and Basement Complex geology rather than anthropogenic contamination. Metal mobility is further limited by the slightly acidic to near-neutral pH and oxidizing soil conditions.	Confirms excellent baseline geochemical quality with low ecological and human-health risks. The soils are suitable for the proposed REA Solar PV development without the need for heavy-metal remediation.

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Organic Contaminants

Organic contaminants are important indicators of soil pollution because they may originate from fuel handling, lubricants, petroleum products, solvents, industrial materials, vehicle maintenance,

waste disposal and other human activities. Depending on their chemical composition, concentration and persistence, organic contaminants may affect soil microorganisms, vegetation, groundwater quality and human health. The organic parameters analysed in the AFIT soil samples were: oil and grease; phenols; and benzene, toluene, ethylbenzene and xylene, collectively reported as BTEX. The results indicate that oil and grease and BTEX were not detected in any sample, while phenols occurred at low concentrations throughout the project area and control locations. The main exception was S1, which recorded a comparatively higher phenol concentration than the remaining samples.

Oil and Grease

Oil and grease comprise a broad group of petroleum-derived and animal- or plant-based organic substances. In environmental soil investigations, they are commonly assessed as indicators of contamination arising from: fuel spills; lubricants; hydraulic fluids; vehicle and equipment maintenance; machinery leakage; waste oil disposal; food-processing residues; and poorly managed storage areas. The laboratory results showed 0 mg/kg of oil and grease in all twelve soil samples, including the project-area and control samples. The complete absence of detectable oil and grease is a favourable finding. It indicates that the sampled soils had not been significantly affected by petroleum-derived oily residues at the time of investigation. The result is particularly relevant for the proposed project because the development will involve construction machinery, vehicles, electrical equipment and potentially fuel- and lubricant-handling activities. The absence of pre-existing contamination establishes a clear baseline against which any future accidental release can be assessed. The non-detection of oil and grease is also consistent with the reported soil colours. No oily blackening, visible sheen or unusual hydrocarbon-related discolouration was documented in the samples. From an ecological perspective, the result indicates that the soils are not presently affected by oil-related inhibition of: seed germination; root development; soil respiration; nutrient cycling; bacterial and fungal activity; or infiltration and aeration. No oil-related soil remediation is required before construction.

Phenols

Phenols are aromatic organic compounds that may occur naturally through decomposition of vegetation and soil organic matter but may also originate from petroleum products, industrial chemicals, disinfectants, resins, paints, pesticides, combustion products and waste materials. The recorded phenol concentrations were: S1: 0.180 mg/kg, S2: 0.021 mg/kg, S3: 0.018 mg/kg, S4: 0.017 mg/kg, S5: 0.029 mg/kg, S6: 0.026 mg/kg, S7: 0.022 mg/kg, S8: 0.019 mg/kg, S9: 0.018 mg/kg, S10: 0.018 mg/kg, Control topsoil: 0.010 mg/kg, Control basal soil: 0.011 mg/kg. Phenol was therefore detected in all samples, but most concentrations were low and relatively uniform, ranging from approximately 0.010 to 0.029 mg/kg. S1 was a clear exception, recording 0.180 mg/kg, substantially higher than the other project-area and control samples. The low concentrations recorded in most samples may reflect natural or diffuse background sources, including: decomposition of plant residues; breakdown of lignin and other aromatic components of vegetation; microbial transformation of organic matter; atmospheric deposition; minor historical land-use inputs; and natural soil biochemical processes. The control samples also contained phenols at 0.010–0.011 mg/kg, confirming that very low phenol concentrations occur naturally or as part of the wider background environment. Project-area samples other than S1 generally recorded slightly higher concentrations than the controls. This may indicate greater vegetation decomposition, local land-use

influence or minor diffuse anthropogenic inputs. However, the values remain low and do not demonstrate widespread serious contamination.

BTEX

BTEX refers collectively to: benzene; toluene; ethylbenzene; and xylenes. These volatile aromatic hydrocarbons are common constituents of petrol and other refined petroleum products. Their presence in soil frequently indicates contamination from: fuel spills; leaking tanks; vehicle maintenance; petroleum storage; solvent use; generator areas; and improper disposal of hydrocarbon-containing wastes. BTEX was reported as 0.00 mg/kg in all twelve samples. The complete non-detection of BTEX indicates that there is no laboratory evidence of contamination by volatile petroleum hydrocarbons within the investigated soils. This finding is consistent with the absence of oil and grease and strongly suggests that the site has not been significantly affected by petrol, diesel-related volatile compounds or common aromatic solvents. The result is environmentally favourable because BTEX compounds may: migrate through soil; contaminate groundwater; inhibit soil microorganisms; damage vegetation; generate vapours; and present human-health risks through inhalation or ingestion. No BTEX-related remediation is required before project implementation.

Implications for the Proposed Project

The proposed solar photovoltaic project will introduce potential sources of organic contamination during construction and operation, including: diesel and petrol; lubricating oils; hydraulic fluids; paints and solvents; cleaning agents; transformer or equipment fluids; vehicle maintenance wastes; and damaged electrical components. The favourable baseline means that future detections of oil, grease or BTEX could indicate project-related contamination if they occur after construction begins. Strict prevention and monitoring measures are therefore necessary. Recommended controls include: storing fuels and oils within bunded areas; using drip trays beneath stationary equipment; inspecting machinery regularly for leaks; prohibiting vehicle maintenance on unprotected soil; providing spill kits at fuel and maintenance areas; collecting waste oils in labelled containers; using licensed waste handlers; avoiding indiscriminate disposal of paints, solvents or chemicals; establishing designated refuelling areas; and remediating accidental spills immediately. Where transformers, batteries or other electrical systems are installed, manufacturer specifications and hazardous-material controls should be strictly followed.

Table 4.17: Summary of Organic Contaminant Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Oil and Grease	Not Detected (0.00 mg/kg) in all samples	No detectable petroleum-derived oily residues were present in either the project-area or control soils. The results indicate that the soils have not been affected by fuel spills, lubricants, hydraulic fluids or waste-oil contamination prior to project implementation.	Establishes an excellent baseline condition for future monitoring. No evidence of hydrocarbon pollution or oil-related soil degradation. No remediation required before construction.

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Phenols	0.010–0.180 mg/kg	Phenols were detected at generally low concentrations throughout the project area and control locations, reflecting natural organic matter decomposition and diffuse background sources. However, S1 recorded a comparatively elevated concentration (0.180 mg/kg), representing a localized anomaly requiring verification through repeat sampling and laboratory quality-control review.	Indicates generally good soil quality with no widespread phenolic contamination. The isolated S1 result should be confirmed but does not currently indicate extensive site contamination.
BTEX (Benzene, Toluene, Ethylbenzene and Xylene)	Not Detected (0.00 mg/kg) in all samples	No volatile petroleum hydrocarbons were detected. The absence of BTEX confirms that the soils have not experienced contamination from petrol, diesel, solvents, leaking fuel storage or related petroleum products.	Demonstrates excellent baseline environmental quality with negligible risk of hydrocarbon migration to groundwater, soil toxicity or vapour-related health hazards. No BTEX-related remediation is required.
Overall Organic Contaminant Status	Oil and grease absent; BTEX not detected; phenols generally low with one localized elevated value at S1	The organic contaminant profile indicates that the project area is generally free from petroleum-related contamination. The isolated phenol enrichment at S1 appears localized and may reflect natural processes, a site-specific source or an analytical anomaly rather than widespread pollution.	Confirms favourable baseline soil quality for the proposed REA Solar PV development. The principal recommendation is verification of the S1 phenol result, together with strict fuel, lubricant, solvent and hazardous-material management during construction and operation.

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Soil Particle-Size Distribution and Textural Characteristics

Soil texture is a fundamental physical property controlling infiltration, water retention, drainage, aeration, nutrient storage, erosion susceptibility, compaction behaviour and foundation performance. It is determined by the relative proportions of coarse and fine soil materials within the soil matrix. The AFIT laboratory results report the soil fractions as sand, loam, clay and silt. Although "loam" is ordinarily used as a textural class rather than an individual particle-size fraction, the interpretation below retains the terminology and values exactly as presented by the laboratory. The reported proportions generally sum to approximately 100%, indicating that they were intended to describe the relative composition of each soil sample. The results show considerable spatial and vertical variability across the project area. Sand contents ranged from 11% to 43%, reported loam contents from 21% to 62%, clay contents from approximately 3% to 31%, and silt contents from approximately 0% to 20%. Overall, the project-area soils may be described as predominantly loamy

soils with variable sand, clay and silt contributions. Some locations contain relatively coarse, well-drained materials, while others possess greater fine-particle contents and are likely to retain more moisture and exhibit higher plasticity and compaction potential.

Sand Content

Sand constitutes the coarser mineral fraction of soil and strongly influences drainage, aeration, infiltration and engineering behaviour. Soils containing higher sand proportions generally drain rapidly and are less susceptible to prolonged waterlogging, although they may possess lower nutrient- and moisture-retention capacities. The sand fraction ranged from 11% in the control topsoil to 43% in S1 and S5. The highest sand contents occurred in S1 and S5, both of which contained 43% sand. These locations are likely to exhibit: relatively high permeability; rapid infiltration; good aeration; lower water-retention capacity; reduced shrink–swell behaviour; and comparatively easier excavation. S2 also contained a relatively high sand proportion of 36%, while S3, S4, S6 and S9 recorded intermediate values of 29–31%. Lower sand contents were observed in S7, S8, S10 and the controls. The control soils were particularly fine-textured, containing only 11–15% sand. This suggests that the project footprint is generally coarser than the control area. Sand content generally decreased from topsoil to basal soil at several paired locations: S1–S2: 43% to 36%; S5–S6: 43% to 29%; S7–S8: 26% to 19%; and S9–S10: 29% to 20%. The S3–S4 pair showed a slight increase from 29% to 31%, while the control soils increased from 11% at the surface to 15% at the basal horizon. The general reduction in sand with depth at most project locations suggests that the upper horizons may have received coarser materials through surface deposition, previous filling, erosion redistribution or site disturbance. It may also reflect natural variation within the weathered soil profile.

Loam Content

Loam generally describes soil containing a relatively balanced mixture of sand, silt and clay. In the laboratory dataset, however, loam was reported as a separate percentage component. The values are therefore interpreted as provided, without attempting to convert them into a different classification system. Loam was the dominant reported component in most samples, ranging from 21% in S5 to 62% in S8. S8 recorded the highest loam content at 62%, followed by S2 at 59% and S4 at 57%. These locations likely possess comparatively balanced physical properties, including: moderate infiltration; reasonable moisture retention; satisfactory aeration; relatively good nutrient storage; and favourable conditions for vegetation. S5 recorded the lowest loam content at 21%. This sample instead contained a comparatively high sand fraction and substantial clay and silt contributions, suggesting a less uniform particle-size distribution. The high loam proportions across most samples indicate soils with generally balanced physical characteristics rather than extremely coarse or extremely fine textures. Loam content increased with depth in several sample pairs: S1–S2: 51% to 59%; S3–S4: 49% to 57%; S5–S6: 21% to 36%; and S7–S8: 41% to 62%. In contrast, the S9–S10 pair decreased slightly from 51% to 48%, while the control soils decreased from 44% to 39%. The increase with depth at most project locations indicates that basal horizons may be more texturally balanced and less dominated by recently deposited coarse surface material.

Clay Content

Clay represents the finest mineral fraction of soil and has a high surface area and charge density. It strongly influences moisture retention, nutrient adsorption, plasticity, cohesion, shrink–swell behaviour and contaminant retention. Clay contents ranged from approximately 3% in S1 to 31% in the control topsoil. S1 and S2 contained the lowest clay proportions, at 3% and 5%, respectively.

These locations are therefore likely to possess: low plasticity; low shrink–swell potential; high permeability; limited nutrient-retention capacity; and reduced capacity to immobilize contaminants. S5 and S6 contained relatively high clay contents of 25% and 20%, while S9 contained 19%. These locations are expected to retain more moisture and nutrients than the sandier samples. The control soils recorded the highest clay contents, at 31% and 26%. This indicates that the control area is more fine-textured and likely to exhibit: greater water-holding capacity; lower permeability; stronger cohesion; higher contaminant-adsorption capacity; and greater compaction sensitivity. Clay content increased slightly with depth at S1–S2 and S7–S8, but decreased with depth at S3–S4, S5–S6 and S9–S10. The control clay content also decreased from 31% in the topsoil to 26% in the basal soil. The absence of a uniform vertical trend indicates that clay distribution is controlled by localized soil-forming processes, parent-material variation, erosion, deposition and possible previous site disturbance.

Silt Content

Silt consists of fine particles that are larger than clay but smaller than sand. It contributes to moisture retention and nutrient storage but may increase erosion susceptibility where soils are exposed and unprotected. Silt contents ranged from approximately 0% in S2 to 20% in the control basal soil. The highest silt contents occurred in: control basal soil: 20%; S10: 19%; S7: 18%; S6: 15%; and control topsoil: 14%. S2 contained no reported silt, while S9 contained only 1%. Higher silt contents may improve water and nutrient retention but can increase susceptibility to surface sealing and erosion where vegetation is removed. Locations such as S7, S10 and the control area may therefore require particular attention during earthworks because exposed silty materials can be readily detached and transported by runoff. The silt fraction showed considerable variation with depth: S1–S2: decreased from 3% to 0%; S3–S4: decreased from 10% to approximately 4%; S5–S6: increased from 11% to 15%; S7–S8: decreased from 18% to 3%; S9–S10: increased sharply from 1% to 19%; and control: increased from 14% to 20%. These variations demonstrate substantial local heterogeneity within the shallow soil profile.

Implications for the Proposed Project

Construction activities may adversely affect soil texture and structure through: mixing of topsoil and basal soil; compaction by machinery; removal of vegetation; erosion of fine particles; deposition of imported fill; rutting; and altered drainage. Recommended measures include: stripping topsoil separately from basal material; avoiding unnecessary trafficking outside designated routes; limiting earthworks during heavy rainfall; installing diversion drains and sediment controls; stabilizing stockpiles; covering or revegetating exposed surfaces; reusing suitable topsoil during restoration; and conducting geotechnical testing for foundations and equipment platforms.

Table 4.18: Summary of Soil Particle-Size Distribution and Textural Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Sand Content	11–43%	Sand content varied considerably across the study area, with the highest proportions recorded at S1 and S5 (43%) and the lowest in the control topsoil (11%). Project-area soils are generally coarser	Promotes infiltration and ease of excavation but may increase downward migration of contaminants if spills occur. High-sand locations require effective spill prevention and drainage management.

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
		than the control soils, resulting in relatively high permeability, rapid drainage and good aeration.	
Reported Loam Content	21–62%	Loam was the dominant reported component in most samples, with the highest proportion at S8 (62%) and the lowest at S5 (21%). The high loam content indicates relatively balanced physical properties with moderate water retention, infiltration and nutrient storage.	Generally favourable for vegetation establishment, site restoration and conventional earthworks. Supports stable soil structure and moderate engineering performance.
Clay Content	3–31%	Clay content showed substantial variability, with the lowest values in S1 and S2 (3–5%) and the highest in the control topsoil (31%). Clay-rich soils possess greater water-holding capacity, nutrient retention and contaminant adsorption than the coarser project-area soils.	Enhances nutrient retention and contaminant attenuation but may increase plasticity, shrink–swell behaviour, compaction sensitivity and reduced drainage under wet conditions.
Silt Content	0–20%	Silt occurred in relatively low to moderate proportions, ranging from 0% in S2 to 20% in the control basal soil. Higher silt contents were recorded in S7, S10 and the control soils, indicating greater moisture retention and erosion susceptibility.	Improves water retention but may increase susceptibility to erosion, surface sealing and loss of soil strength when exposed during construction. Erosion-control measures are recommended in silty areas.
Overall Soil Texture	Predominantly loamy soils with variable proportions of sand, clay and silt	The soils exhibit considerable spatial and vertical heterogeneity. Most project-area soils are moderately coarse, well drained and suitable for engineering activities, while the control soils are finer textured with greater moisture- and nutrient-retention capacities.	Overall, the soils are suitable for the proposed REA Solar PV development. Although no widespread textural limitations exist, localized differences in drainage, compaction behaviour and erosion potential should be considered during construction. Dedicated geotechnical investigations should guide final foundation design.

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Microbiological Characteristics

Soil microbiological characteristics provide an important indication of biological activity, sanitary condition, organic-matter decomposition and the general ecological functioning of the soil environment. Microorganisms participate in nutrient mineralization, organic-matter breakdown, soil aggregation and the transformation of nitrogen, sulphur and other essential elements. The AFIT laboratory dataset reports two microbiological parameters: Escherichia coli (E. coli); and fungal count. The reported results indicate that both bacterial and fungal organisms were present across the project-area and control samples. E. coli counts varied from 2 to 19, while fungal counts ranged from 29 to 203, based on the units stated in the laboratory report. The results suggest active soil microbial communities but also indicate possible sanitary influence because E. coli is ordinarily associated with faecal material from humans or warm-blooded animals. The significance of the findings should, however, be interpreted cautiously because the laboratory reports the microbiological unit as cfu/100 kg, which is unusual for soil microbiological analysis and should be verified before the ESIA is finalized.

Escherichia coli

Escherichia coli is a bacterial species commonly found in the intestinal systems of humans and warm-blooded animals. Its presence in environmental samples is widely used as an indicator of faecal contamination and possible sanitary impairment. E. coli was detected in all analysed samples, with the highest value recorded in S7 and the lowest in S10. The control samples also recorded appreciable counts of 11 and 12. The widespread occurrence of E. coli indicates that faecal-derived bacteria are not restricted to a single isolated location. Possible sources include: animal droppings; bird activity; livestock movement; poorly controlled sanitation; runoff from contaminated areas; wastewater or sewage influence; waste disposal; human activity; and contamination introduced during sampling or laboratory handling. The presence of E. coli in the control soils is particularly important. It indicates that faecal indicator bacteria also occur outside the proposed project footprint and may represent a broader environmental or land-use condition rather than contamination uniquely associated with the project sites. S7 recorded the highest value of 19, suggesting relatively stronger localized sanitary influence at that location. Possible explanations include animal access, accumulation of organic waste, contaminated runoff or proximity to human activity. S9 also recorded an elevated count of 9, while the control soils recorded 11 and 12. These values indicate spatial variability rather than a clear project-site gradient. The lowest count occurred in S10, suggesting comparatively lower sanitary influence within that basal-soil sample. The topsoil and basal-soil results do not show a consistent depth-related pattern: S1 and S2 recorded identical values; S3 exceeded S4 slightly; S6 exceeded S5; S7 exceeded S8 substantially; S9 exceeded S10; and the control basal soil slightly exceeded the control topsoil. E. coli is generally expected to occur more commonly in surface soils because faecal materials are deposited at the land surface. Its occurrence in basal soils may indicate: downward movement through infiltration; mixing of surface and subsurface materials; previous land disturbance; contaminated sampling equipment; sample cross-contamination; or persistence within moist subsurface conditions. The presence of E. coli in every basal-soil sample should therefore be reviewed during quality assurance, especially if the samples were collected at depth using the same equipment without full decontamination between horizons.

Fungal Count

Fungi are natural and essential components of soil ecosystems. They decompose resistant organic materials such as cellulose, lignin and plant residues, contribute to humus formation and improve

nutrient cycling. Fungal counts ranged from 29 in S8 to 203 in S7 and S10. The detection of fungi in all samples indicates biologically active soils containing organic substrates capable of supporting fungal growth. The highest fungal counts occurred in S7 and S10, while S6 and the control basal soil also recorded comparatively high values. These variations may reflect differences in: vegetation density; plant-litter accumulation; root biomass; soil moisture; organic-matter content; aeration; texture; soil disturbance; and microclimatic conditions. The fungal populations are not inherently indicative of contamination. In most soils, fungi are beneficial organisms responsible for organic-matter decomposition and soil nutrient cycling. The low count at S8 may reflect comparatively limited organic substrate, reduced moisture, unfavourable microenvironmental conditions or localized soil disturbance. Fungal abundance may be influenced by the soil particle-size characteristics. Fine-textured and loamy soils can retain more moisture and organic material, providing favourable conditions for fungal growth. However, the AFIT results do not show a simple direct relationship between fungal count and any individual textural fraction. For example: S7 recorded a high fungal count and contained appreciable silt and clay; S10 also recorded a high fungal count despite differing textural characteristics; S8 recorded the lowest fungal count even though it had the highest reported loam proportion. This indicates that fungal abundance is controlled by a combination of factors rather than texture alone.

Implications for the Proposed Project

Construction activities may alter existing soil microbial communities through: vegetation clearing; topsoil removal; soil compaction; excavation; exposure to sunlight and drying; contamination from fuels and chemicals; worker sanitation; wastewater leakage; and mixing of soil horizons. Temporary reductions in beneficial microbial activity may occur within heavily disturbed areas. At the same time, inadequate worker sanitation could increase faecal contamination. The project should implement the following measures: provide adequate toilets and sanitation facilities; prohibit open defecation; collect and dispose of sanitary waste appropriately; prevent discharge of wastewater onto exposed soil; minimize unnecessary vegetation clearance; conserve and reuse topsoil; restrict soil compaction outside designated areas; maintain good site housekeeping; provide handwashing facilities; manage animal access where practicable; control contaminated runoff; and revegetate disturbed areas promptly. Workers involved in excavation and soil handling should use appropriate personal protective equipment and observe good hygiene practices, particularly before eating or drinking.

Table 4.19: Summary of Soil Microbiological Characteristics

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
Escherichia coli (E. coli)	2–19 (detected in all samples)	E. coli was detected in every project-area and control sample, with the highest count recorded at S7 (19) and the lowest at S10 (2). The widespread occurrence indicates variable sanitary influence across the wider environment rather than contamination confined to the project footprint. Possible	Indicates the presence of faecal indicator bacteria and the need for good site hygiene, sanitation and runoff management during construction. Although the results do not confirm pathogenic contamination, they demonstrate the importance of preventing additional microbial pollution during project implementation.

Parameter	Range / Observation	Interpretation	Environmental / Engineering Significance
		sources include animal droppings, surface runoff, human activities and localized sanitary conditions.	
Fungal Count	29–203 (detected in all samples)	Fungal populations were present throughout the project area, with the highest counts recorded at S7 and S10 (203) and the lowest at S8 (29). The widespread occurrence reflects active organic-matter decomposition, nutrient cycling and healthy biological activity rather than environmental contamination.	Demonstrates biologically active soils capable of sustaining ecological processes. Fungal activity contributes to nutrient recycling, soil aggregation and long-term soil fertility. Temporary reductions may occur during construction but are expected to recover following site restoration and revegetation.
Overall Microbiological Status	Active fungal populations with widespread E. coli occurrence	The soils exhibit healthy biological activity supported by active fungal communities, while the detection of E. coli indicates localized sanitary influences that extend beyond the project area, as similar results were obtained from the control samples. Overall, the soils remain biologically functional and ecologically stable.	Suitable for the proposed REA Solar PV development provided that good construction hygiene, adequate sanitation facilities, topsoil conservation, erosion control and prompt revegetation are implemented. The laboratory should verify the reported microbiological unit (cfu/100 kg) before the final ESIA is issued, as this is not a conventional reporting unit for soil microbiological analyses.

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Table 4.20: Overall Summary of Soil Quality within the Proposed Project Area

Soil Quality Component	Baseline Condition	Interpretation	Environmental / Engineering Significance
Physical and General Physicochemical Characteristics	Slightly acidic soils (pH 6.13–6.94), low salinity (0.07–0.09%), positive ORP (72–215 mV), moderate electrical conductivity and typical tropical soil temperatures.	The soils are well-drained, oxidizing and chemically stable, providing favourable conditions for vegetation growth, microbial activity and nutrient availability. No evidence of physicochemical degradation was identified.	Suitable for construction, earthworks and long-term infrastructure development. No pH adjustment or salinity remediation is required before project implementation.
Exchangeable Cations	Calcium and potassium were the dominant nutrient cations;	The exchange complex indicates moderate natural soil fertility and	Supports healthy vegetation and soil chemical stability. Topsoil conservation during

Soil Quality Component	Baseline Condition	Interpretation	Environmental / Engineering Significance
	aluminium and ammonium occurred at low concentrations; magnesium was generally moderate with localized low values at S6 and S7.	adequate nutrient reserves. Low aluminium concentrations reduce the likelihood of phytotoxicity, while the isolated magnesium anomalies require verification.	construction is recommended to preserve nutrient-rich surface horizons.
Exchangeable Anions	Low chloride and phosphate concentrations, moderate nitrate and low sulphate concentrations.	The anion composition reflects natural nutrient cycling and tropical weathering processes with no evidence of salinity development, sewage influence or fertilizer-related contamination.	Indicates balanced soil chemistry capable of supporting existing vegetation and post-construction revegetation without major nutrient-related constraints.
Heavy Metals and Trace Elements	Iron and aluminium dominated the elemental composition, while copper, zinc, manganese and arsenic occurred only at low background concentrations. Chromium was not detected, and lead was absent or present only at trace levels.	Heavy metal concentrations are consistent with natural Basement Complex geology and tropical weathering rather than anthropogenic contamination. The slightly acidic pH and positive ORP further limit metal mobility.	Excellent baseline geochemical quality with negligible ecological and human-health risks. No heavy-metal remediation is required before project implementation.
Organic Contaminants	Oil and grease and BTEX were not detected in any sample. Phenols occurred at low concentrations, with a localized higher value at S1.	The soils are essentially free from petroleum hydrocarbon contamination. The isolated phenol concentration at S1 is localized and should be confirmed through repeat analysis or quality-control review.	Establishes an excellent baseline for future monitoring. Strict fuel, lubricant and hazardous-material management should be maintained during construction to preserve current soil quality.
Soil Texture and Particle-Size Characteristics	Predominantly loamy soils with variable sand, clay and silt contents.	The soils possess balanced physical properties, including moderate permeability, good aeration and satisfactory moisture retention. Spatial variability reflects	Suitable for foundations and general construction, although erosion control, drainage management and topsoil conservation should be incorporated during earthworks.

Soil Quality Component	Baseline Condition	Interpretation	Environmental / Engineering Significance
		natural soil-forming processes rather than degradation.	
Microbiological Characteristics	Active fungal populations were present in all samples, while *E. coli* was detected throughout the project area and control locations.	The soils are biologically active and support ongoing organic-matter decomposition and nutrient cycling. The occurrence of *E. coli* indicates variable sanitary influence across the wider environment rather than contamination confined to the project footprint.	Good construction hygiene, sanitation facilities, runoff control and topsoil management should be implemented to prevent additional microbiological contamination during project activities.
Overall Soil Quality Status	Stable physicochemical, geochemical, organic and biological characteristics with no evidence of widespread contamination or severe degradation.	The integrated laboratory results indicate that the soils are environmentally healthy, chemically balanced, biologically active and representative of natural tropical soils developed over Basement Complex geology.	The proposed REA Solar Photovoltaic Project can be implemented without prior soil remediation. Appropriate environmental management measures, including erosion control, pollution prevention, topsoil conservation, proper waste management and routine environmental monitoring, will maintain the favourable baseline soil conditions throughout construction, operation and decommissioning.

4.4.8 Ground Water and Surface Water Characteristics

Water sampling was undertaken to establish the baseline physicochemical, microbiological, and heavy metal quality of both surface water and groundwater within the area of influence of the proposed 2 MW Solar Photovoltaic (PV) Project at the AFIT, Nigerian Air Force Base, Kaduna State. The sampling program was designed to characterize the existing water quality conditions prior to project implementation and to generate baseline data for future environmental monitoring during the construction, operation, and decommissioning phases of the project. The information generated from this investigation will serve as the reference against which any future changes in water quality associated with project activities may be assessed.

4.4.8.1 Surface Water Sampling

Surface water sampling was undertaken to establish the baseline physicochemical, heavy metal, and microbiological quality of the principal surface water body located within the project's area of influence. The baseline assessment provides reference information for evaluating any future impacts

that may arise from project activities such as site preparation, earthworks, stormwater runoff, accidental spills, and routine construction and operational activities.

The surface water body investigated is a seasonal stream flowing through a shallow valley separating Angwan Fulani (AFIT Fulani Quarters), located on the upland immediately adjacent to the proposed project site, from Angwan Kawo, situated across the stream valley on the opposite side. Both settlements are located within the AFIT Base and constitute part of the project's immediate environmental and social area of influence. The stream functions as the principal natural drainage channel within the locality, receiving runoff from the surrounding catchment and serving as the nearest surface water receptor that could potentially be influenced by project activities. To adequately characterize the baseline water quality along the direction of flow, three (3) representative sampling stations were established at the upstream (SW1), midstream (SW2), and downstream (SW3) sections of the stream. This sampling configuration enabled assessment of the natural background water quality entering the project area, the prevailing conditions adjacent to the proposed development, and the water quality leaving the project's area of influence.

See Plate 4.6 for pictorial evidence of Surface Water Sampling around the project area….
See Plate 4.7 for pictorial evidence of Groundwater Sampling…
For more pictures of Surface and ground Water sampling in different location see Appendix VIII…



Plate 4.6: Surface Water Sampling around the project area

Upstream Sampling Point (SW1)

The upstream sampling location (SW1) was established to represent the natural background water quality before the stream enters the project's immediate area of influence. The location was selected to provide baseline information with minimal influence from the proposed development. A grab water sample was collected directly from the flowing section of the stream using standard environmental sampling procedures. The sample was collected below the water surface while facing

upstream to minimize contamination from disturbed sediments, floating debris, and surface films. Immediately after collection, the sample was transferred into pre-cleaned sampling containers, appropriately preserved, labelled, and stored in an ice chest prior to transportation to the laboratory. The sampling location was referenced using a handheld GPS at: Latitude: 10°37′37.00″ N, and Longitude: 7°26′49.14″ E.

Midstream Sampling Point (SW2)

The second sampling location (SW2) was established approximately midway along the stream section traversing the project's area of influence. This location represents the section most likely to receive runoff from the proposed solar PV development and surrounding activities. A grab water sample was collected from the flowing section of the stream following standard environmental sampling procedures. Care was taken to collect the sample below the water surface while facing upstream to minimize contamination from floating materials and disturbed bottom sediments. The sample was immediately transferred into pre-cleaned containers, appropriately preserved, labelled, and stored under cooled conditions pending laboratory analysis. The sampling location was referenced using a handheld GPS at: Latitude: 10°37′35.44″ N, and Longitude: 7°26′48.83″ E.

Downstream Sampling Point (SW3)

The downstream sampling location (SW3) was established beyond the proposed project area to characterize the quality of water leaving the project's area of influence. This station also serves as a long-term monitoring point for evaluating any future project-related changes in surface water quality. A grab water sample was collected from the main flowing channel using standard environmental sampling procedures. The sample was collected below the water surface while facing upstream to avoid contamination from disturbed sediments and floating debris. Following collection, the sample was transferred into pre-cleaned sampling bottles, preserved, labelled, and stored in an ice chest prior to laboratory analysis. The sampling location was referenced using a handheld GPS at: Latitude: 10°37′33.95″ N, and Longitude: 7°26′50.05″ E. Following collection, all surface water samples were assigned unique identification numbers, preserved using appropriate preservation techniques, and transported under established Quality Assurance and Quality Control (QA/QC) procedures and chain-of-custody documentation to an accredited environmental laboratory for physicochemical, heavy metal, and microbiological analyses.

Table 4.21: Surface Water Sampling Locations

Location ID	Sampling Location	Latitude (N)	Longitude (E)	Associated Sample
L1	Upstream	**10°37′37.00″ N**	**7°26′49.14″ E**	SW1
L2	Midstream	**10°37′35.44″ N**	**7°26′48.83″ E**	SW2
L3	Downstream	**10°37′33.95″ N**	**7°26′50.05″ E**	SW3

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Table 4.22: Summary of Surface Water Samples Collected

Location	Description	Sampling Locations	Number of Samples
Upstream	Background section of the stream before entering the project's area of influence	1	1
Midstream	Central section of the stream adjacent to the proposed project site	1	1
Downstream	Stream section further from the project's area of direct influence	1	1
Total		**3**	**3**

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Table 4.23: Surface Water Sampling Locations, and Sample Details

Sample ID	Location ID	Sampling Location	Latitude (N)	Longitude (E)	Description
SW1	L1	Upstream	**10°37′37.00″ N**	**7°26′49.14″ E**	Surface water sample collected from the upstream section of the stream to establish the background water quality entering the project's area of influence.
SW2	L2	Midstream	**10°37′35.44″ N**	**7°26′48.83″ E**	Surface water sample collected from the central section of the stream adjacent the AFIT Fulani Quarters / Village to characterize the prevailing ambient water quality.
SW3	L3	Downstream	**10°37′33.95″ N**	**7°26′50.05″ E**	Surface water sample collected from downstream section of the stream further from the project area of influence and adjacent Anguwan Kano area.

4.4.8.2 Groundwater Sampling

Groundwater sampling was undertaken to establish the baseline physicochemical, microbiological, and heavy metal quality of groundwater sources serving the Air Force Institute of Technology (AFIT), Nigerian Air Force Base, Kaduna, prior to the commencement of construction activities

associated with the proposed 2 MW Solar Photovoltaic (PV) Project. The study was designed to provide baseline groundwater quality data against which any future changes arising during the construction, operation, and decommissioning phases of the project can be evaluated. Groundwater constitutes the principal source of potable water for domestic, commercial, healthcare, and religious activities within the institution. Consequently, five (5) representative groundwater sampling locations (GW1–GW5) were strategically selected across the AFIT campus to provide representative spatial coverage of the principal potable water supply network. The selected locations comprised the AFIT Boys' Hostel Borehole, Boys' Hostel Mosque, Main Market opposite the Faculty of Air Engineering, Main Mosque, and Main Clinic. These facilities represent major residential, commercial, healthcare, and public-use water supply points within the project area.



Plate 4.7: Groundwater Sample Collection

At each sampling location, the water outlet was allowed to flow continuously for several minutes before sample collection to flush stagnant water from the distribution system and obtain water representative of the supplying aquifer. Samples were collected directly into pre-cleaned, labelled sampling bottles following standard groundwater sampling procedures. Appropriate preservation techniques were applied immediately after collection before transportation under recommended conditions to an accredited environmental laboratory for physicochemical, microbiological, and heavy metal analyses. The sampling programme was conducted in accordance with internationally accepted environmental sampling procedures and relevant national regulatory guidelines. Analytical parameters included general physicochemical characteristics, nutrient concentrations, major ions, microbiological indicators, and trace/heavy metals. Overall, five (5) groundwater samples were collected from representative potable water supply points distributed across the AFIT campus, providing baseline reference data for future environmental monitoring throughout the life cycle of the proposed solar PV project.



Figure 4.10: Surface and Ground Water Sampling Points

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.24: Summary of Groundwater Samples Collected

Location	Description	Sampling Locations	Number of Samples
GW1	AFIT Boys' Hostel Borehole	1	1
GW2	AFIT Boys' Hostel Mosque Water Supply	1	1
GW3	AFIT Main Market Water Supply	1	1
GW4	AFIT Main Mosque Water Supply	1	1
GW5	AFIT Main Clinic Water Supply	1	1
Total		**5**	**5**

Table 4.25: Groundwater Sampling Locations

Sampling Point	Sampling Location	Latitude (N)	Longitude (E)
GW1	AFIT Boys' Hostel Borehole	**10°37′08.88″ N**	**7°26′39.86″ E**
GW2	AFIT Boys' Hostel Mosque Water Supply	**10°37′10.34″ N**	**7°26′40.98″ E**
GW3	AFIT Main Market Water Supply	**10°36′41.49″ N**	**7°26′24.83″ E**
GW4	AFIT Main Mosque Water Supply	**10°36′34.56″ N**	**7°26′29.83″ E**
GW5	AFIT Main Clinic Water Supply	**10°36′46.63″ N**	**7°26′45.63″ E**

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.26: Groundwater Sampling Locations, Coordinates and Sample Details

Sample ID	Sampling Location	Latitude (N)	Longitude (E)	Description
GW1	AFIT Boys' Hostel Borehole Tap	**10°37′08.88″ N**	**7°26′39.86″ E**	Groundwater sample collected from the borehole supplying potable water to the AFIT Boys' Hostel, representing groundwater quality within the residential section of the campus.
GW2	AFIT Boys' Hostel Mosque Water Supply Tap	**10°37′10.34″ N**	**7°26′40.98″ E**	Groundwater sample collected from the potable water supply serving the Boys' Hostel Mosque and adjoining residential facilities.
GW3	AFIT Main Market Water Supply Tap	**10°36′41.49″ N**	**7°26′24.83″ E**	Groundwater sample collected from the potable water supply serving the AFIT Main Market, representing groundwater quality within the commercial area of the institution.
GW4	AFIT Main Mosque Water Supply Tap	**10°36′34.56″ N**	**7°26′29.83″ E**	Groundwater sample collected from the potable water supply serving the AFIT Main Mosque, representing groundwater quality supplied to one of the major public-use facilities within the campus.
GW5	AFIT Main Clinic Water Supply Tap	**10°36′46.63″ N**	**7°26′45.63″ E**	Groundwater sample collected from the potable water supply serving the AFIT Main Clinic, representing groundwater quality supplied to a sensitive healthcare facility within the institution.

Immediately after collection, both the surface water and groundwater samples were subjected to in-situ measurements using a calibrated portable multiparameter meter to minimize changes that could occur during storage and transportation. The field parameters measured included temperature, pH, oxidation-reduction potential (ORP), electrical resistivity, electrical conductivity (EC), total dissolved solids (TDS), salinity, salt specific gravity (S.G.), and fertility. Following field measurements, all samples were appropriately labelled, preserved, sealed, and transported under standard Quality Assurance and Quality Control (QA/QC) procedures and chain-of-custody documentation to an accredited environmental laboratory for detailed physicochemical, microbiological, and heavy metal analyses. The analytical results generated from these investigations provide the baseline water quality conditions against which any future environmental changes associated with the implementation of the proposed solar PV project can be evaluated.

Table 4.27: Surface Water In-Situ Testing

Sample ID	Temp. (°C)	pH	ORP (mV)	Resistivity (MΩ·cm)	Electrical Conductivity (µS/cm)	Total Dissolved Solids (ppm)	Salinity (%)	Salt Specific Gravity (S.G.)	Fertility (ppm)
SW1	30.9	7.20	58	162.14	78	39	0.00	1.000	1
SW2	31.0	6.90	167	155.20	80	41	0.00	1.000	1
SW3	31.1	6.58	208	150.16	82	40	0.00	1.000	1

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.28: Groundwater In-Situ Testing

Sample ID	Temperature (°C)	pH	ORP (mV)	Resistivity (MΩ·cm)	Electrical Conductivity (µS/cm)	Total Dissolved Solids (ppm)	Salinity (%)	Salt Specific Gravity (S.G.)	Fertility (ppm)
GW1	30.1	4.24	350	180.21	72	36	0.00	1.000	1
GW2	36.1	3.63	414	51.63	263	130	0.01	1.000	2
GW3	33.1	5.63	313	114.62	74	37	0.00	1.000	1
GW4	30.7	4.95	392	257.3	54	26	0.00	1.000	1
GW5	25.1	4.93	378	256.1	54	27	0.00	1.000	1

Table 4.29: Physico-Chemical and Biological Characteristics of Surface & Ground Water at the 2MW Solar Power Project Site

S/N	PARAMETERS	UNIT	SW1	SW2	SW3	GW1	GW2	GW3	GW5	GW5	FMENT LIMIT
(A)	**PHYSIOCHEMICAL TEST**										
1.	Colour	Tcu	Pale Brown	Pale brown	Pale brown	Clear	Clear	Clear	Clear	Clear	Clear
2.	Odour	-	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	unobjectionable
3.	Taste	0	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Unobjectionable
4.	PH	-	7.63	7.01	7.17	7.28	7.22	6.94	6.35	6.30	6.5 - 8.5
5.	Temperature	o_c	29.7	29.9	29.8	29.6	28.4	29.7	29.8	30.0	Ambient
6.	Electrical conductivity	us/cm	84	94	92	78	248	63	50	68	1000
7.	Turbidity	NTU	0	1	1	0	0	0	0	0	50
8.	Total dissolve solid	ppm	42	47	46	39	120	32	25	32	500
9.	Total suspended solid	ppm	100	96	112	37	24	15	18	22	20
10.	Dissolve oxygen	mg/l	2.3	2.6	2.2	3.9	4.2	5.0	4.6	4.4	2-8
11.	B.O.D	mg/l	0.9	1.2	0.8	2.0	0.5	1.6	2.1	2.0	NS
12.	C.O.D	mg/l	0	3	1	0	0	0	0	0	30
13.	Salinity	%	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	1000
14.	ORP	mV	125	130	115	149	178	131	181	178	200-600
(B)	**CHEMICAL TEST**										
15.	Aluminium ($A1^{3+}$)	mg/l	0.34	0.46	0.38	0.07	0.08	0.05	0.07	0.09	
16.	Calcium (Ca^{2+})	mg/l	2.15	2.28	2.21	0.48	0.36	0.28	0.47	0.43	
17.	Magnesium (mg^{2+})	mg/l	1.20	1.32	1.41	0.22	0.28	0.19	0.17	0.24	

S/N	PARAMETERS	UNIT	SW1	SW2	SW3	GW1	GW2	GW3	GW5	GW5	FMENT LIMIT
18.	Total hardness	mg/l	54	43	37	18	12	8	14	17	
19.	Potassium (K^{+})	mg/l	2.6	3.0	2.7	0.6	1.2	1.6	0.9	1.8	
20.	Nitrate ($N0^{2-}$)^{3}	mg/l	21.2	18.9	15.6	3.4	2.8	3.7	3.6	4.1	
21.	Nitrite (N0-2)	mg/l	0.7079	0.036	0.067	0.024	0.016	0.021	0.023	0.032	
22.	Sulphate ($S0^{2-}$)	mg/l	24	28	33	5	3	6	4	7	
23.	Phosphate ($P0^{2-}$)	mg/l	4.64	3.81	4.24	2.33	1.72	1.86	1.33	1.25	
24.	Sulphide ($S2^{-}$)	mg/l	24	28	33	5	3	6	4	7	
25.	Chloride (Cl)	mg/l	11.3	10.7	9.6	0.9	1.3	2.1	2.2	2.8	
26.	Flouride (Fl)	mg/l	1.02	0.96	0.84	0.22	0.17	0.13	0.20	0.24	
(C)	**HEAVY METALS**										
27.	Copper (Cu^{2+})	mg/l	1.32	0.84	0.72	0.28	0.33	0.36	0.24	0.29	
28.	Chromium (Cr^{3+})	mg/l	0.32	0.26	0.31	0.01	0.00	0.01	0.02	0.04	
29.	Cadmium (cd^{2+})	ug/l	0.024	0.038	0.036	0.002	0.012	0.006	0.008	0.002	
30.	Lead (Pb^{2+})	ug/l	0.06.	0.047	0.038	0.000	0.001	0.004	0.003	0.003	0.001
31.	Zinc (Zn^{2+})	mg/l	0.84	0.72	0.78	0.08	0.22	0.26	0.23	0.19	
32.	Iron (Fe^{2+})	mg/l	0.22	0.31	0.26	0.02	0.38	0.30	0.21	0.24	
33.	Nickel (Ni^{2+})	mg/l	0.067	0.072	0.068	0.003	0.000	0.001	0.003	0.005	0.007
34.	Cobalt (co^{2+})	mg/l	0.074	0.078	0.072	0.004	0.007	0.005	0.007	0.008	
35.	Mercury (Hg^{+})	mg/l	0.003	0.008	0.034	0.000	0.001	0.008	0.006	0.013	
(D)	**ORGANICS**										

S/N	PARAMETERS	UNIT	SW1	SW2	SW3	GW1	GW2	GW3	GW5	GW5	FMENT LIMIT
36.	Phenols	mg/l	0.136	0.062	0.123	0.025	0.011	0.009	0.017	0.022	
37.	Oil and grease	mg/l	0	0	0	0	0	0	0	0	
38.	Benjene	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
39.	Toluene	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
40.	Ethyl benzene	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
41.	Xylene	mg/l	0	0	0	0	0	0	0	0	
(E)	**MICROBIOLOGICAL TEST**										
42.	E. Coli	cfu/ml	16	12	12	0	0	0	0	0	Nil
43.	Total coliform	cfu/ml	243	168	161	3	6	8	2	1	10

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Result Discussion: This section provides a comprehensive interpretation of the laboratory results for water quality assessment conducted at the project site. The analysis evaluates compliance with FMEnv standards and assesses environmental suitability for the proposed electrification project.

Surface Water Analysis

Physical and Physicochemical Characteristics

The physical and physicochemical characteristics of surface water provide fundamental information on the quality, chemical stability, ecological condition and potential suitability of water for domestic, agricultural, ecological and construction purposes. These parameters influence aquatic life, biochemical reactions, contaminant mobility and the overall functioning of freshwater ecosystems. The laboratory analyses evaluated colour, odour, taste, pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), salinity and oxidation-reduction potential (ORP). Collectively, the results indicate that the surface waters are generally fresh, neutral, low in dissolved salts and organic pollution, although elevated suspended solids and relatively low dissolved oxygen were observed**.**

Colour

Colour is an important aesthetic and environmental characteristic of water because it reflects the presence of dissolved organic matter, suspended particles, humic substances, iron compounds or other naturally occurring materials. All three surface-water samples (SW1, SW2 and SW3) were described as pale brown. The uniform colour suggests that the three sampling points are influenced by similar catchment characteristics and hydrological processes. The pale-brown appearance is typical of tropical surface waters receiving runoff containing fine suspended sediments, decaying vegetation and naturally occurring organic materials. No unusual colours such as black, reddish-orange, bluish-green or oily sheen were reported, indicating the absence of obvious petroleum contamination, excessive iron precipitation or algal blooms at the time of sampling. The observed colour therefore represents natural background conditions rather than evidence of significant pollution. From an environmental perspective, the colour is consistent with shallow tropical streams or drainage channels influenced by seasonal runoff and organic matter decomposition.

Odour

Odour provides a rapid qualitative indication of possible contamination from organic decomposition, sewage, industrial effluents, petroleum products or algal activity. All surface-water samples were reported as odourless, complying with the FMEnv requirement for unobjectionable odour. The absence of objectionable odour indicates that the water has not undergone substantial anaerobic decomposition or contamination by volatile organic compounds, petroleum hydrocarbons or untreated wastewater. It also suggests that hydrogen sulphide and other malodorous gases are not accumulating within the sampled water bodies. This finding supports the low COD values and absence of oil and grease reported later in the analysis.

Taste

Taste is primarily an aesthetic parameter considered for potable water assessment. Although surface water is not intended for direct consumption without treatment, taste provides useful baseline information. All three samples were reported as tasteless, satisfying the FMEnv requirement for unobjectionable taste. The absence of objectionable taste indicates that dissolved

salts, metals and organic compounds are present at relatively low concentrations and do not significantly affect water palatability. This result also agrees with the relatively low electrical conductivity, TDS and chloride concentrations measured during the laboratory analysis.

pH

The pH of water controls numerous chemical and biological processes including nutrient availability, metal solubility, microbial activity and aquatic ecosystem health. The measured pH values were: SW1: 7.63, SW2: 7.01, and SW3: 7.17. The FMEnv permissible range for surface water is 6.5–8.5. All three samples complied with the applicable standard. The results indicate that the surface waters are neutral to slightly alkaline, providing favourable conditions for aquatic organisms and minimizing the mobility of many potentially toxic metals. The relatively stable pH across the three sampling locations suggests consistent hydrochemical conditions throughout the study area. The values are also consistent with natural freshwater systems developed over Basement Complex rocks where carbonate buffering moderates acidity. From an engineering perspective, the near-neutral pH reduces the corrosive potential of water towards metallic infrastructure and minimizes deterioration of concrete structures.

Temperature

Water temperature directly influences dissolved oxygen concentration, microbial metabolism, chemical reaction rates and aquatic ecosystem productivity. Measured temperatures were: SW1: 29.7°C, SW2: 29.9°C, and SW3: 29.8°C. These values correspond closely to ambient tropical environmental conditions and comply with the FMEnv requirement of ambient temperature. The negligible variation among sampling locations indicates that all samples were collected under similar climatic conditions and that no localized thermal pollution exists. The measured temperatures are typical of shallow tropical surface waters exposed to direct solar radiation. Although relatively warm temperatures naturally reduce oxygen solubility compared with colder waters, they remain typical for tropical freshwater ecosystems.

Electrical Conductivity (EC)

Electrical conductivity measures the concentration of dissolved ionic substances within water and provides an indirect estimate of total mineralization. Measured values were: SW1: 84 µS/cm, SW2: 94 µS/cm, and SW3: 92 µS/cm. The FMEnv limit is 1000 µS/cm. All samples are substantially below the regulatory limit. These low conductivity values indicate that the surface waters are poorly mineralized freshwater systems containing relatively low concentrations of dissolved salts. The slight increase observed at SW2 probably reflects minor natural variation in dissolved ions contributed by weathering, runoff or localized groundwater inflow rather than anthropogenic pollution. The low conductivity also agrees closely with the low TDS and salinity values obtained during laboratory analysis.

Turbidity

Turbidity measures the extent to which suspended particles scatter light and therefore reflects sediment loading, erosion and particulate contamination. Measured turbidity values were: SW1: 0 NTU, SW2: 1 NTU, and SW3: 1 NTU. The FMEnv limit is 50 NTU. All samples comply comfortably with the regulatory limit. These extremely low turbidity values indicate very clear water with minimal suspended fine sediments or colloidal particles at the time of sampling. The low turbidity suggests limited upstream erosion during sampling and indicates favourable light penetration for aquatic photosynthesis. The results also demonstrate that the elevated suspended

solids measured later are likely composed predominantly of larger settleable particles rather than fine suspended colloids responsible for turbidity.

Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) represent the total concentration of dissolved inorganic salts and small quantities of organic substances present in water. The parameter provides an indication of the degree of mineralization and is widely used to assess the general quality and suitability of water for domestic, agricultural and industrial purposes. Elevated TDS concentrations may affect water taste, increase scaling potential and indicate excessive mineral or pollutant inputs, whereas low TDS values generally characterize fresh, unpolluted surface waters. The measured TDS concentrations were: SW1: 42 mg/L, SW2: 47 mg/L, and SW3: 46 mg/L. The FMEnv permissible limit is 500 mg/L. All three samples are substantially below the regulatory limit, indicating that the surface waters are fresh and weakly mineralized. The very low dissolved solids suggest limited weathering inputs and negligible influence from industrial discharges, wastewater or saline intrusion. The slight increase observed in SW2 corresponds with its marginally higher electrical conductivity, indicating slightly greater dissolved ionic content at that location. However, the differences among the three sampling points are minimal and fall within normal natural variability. Overall, the TDS results demonstrate excellent water quality with respect to dissolved mineral constituents.

Total Suspended Solids (TSS)

Total Suspended Solids (TSS) represent particulate matter suspended within the water column, including fine sediments, organic debris, algae and other insoluble materials. Excessive suspended solids may reduce light penetration, impair aquatic habitats, clog fish gills and transport adsorbed contaminants. The measured TSS concentrations were: SW1: 100 mg/L, SW2: 96 mg/L, and SW3: 112 mg/L. The FMEnv permissible limit is 20 mg/L. All three sampling locations substantially exceed the applicable regulatory limit. The elevated suspended solids indicate that the surface waters contain considerable particulate material despite their very low turbidity. This apparent difference suggests that much of the suspended material may consist of relatively coarse particles that settle rapidly and therefore contribute less to turbidity measurements. Possible sources include: surface runoff during rainfall; erosion of exposed soils; drainage from surrounding land; resuspension of bottom sediments; decaying vegetation; and localized channel disturbances. The highest concentration was recorded at SW3 (112 mg/L), indicating greater particulate loading at that location. Although elevated TSS does not necessarily indicate chemical pollution, prolonged high suspended-solid concentrations may adversely affect aquatic habitats by reducing benthic habitat quality, increasing sediment deposition and transporting nutrients or contaminants attached to soil particles. For the proposed project, appropriate erosion and sediment-control measures will be necessary during construction to prevent further increases in suspended-solid concentrations.

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is one of the most important indicators of aquatic ecosystem health because it determines the capacity of water bodies to sustain fish, aquatic invertebrates and aerobic microorganisms. The measured DO concentrations were: SW1: 2.3 mg/L, SW2: 2.6 mg/L, and SW3: 2.2 mg/L. The FMEnv acceptable range is 2–8 mg/L. All three samples technically comply with the applicable guideline, although they occur near the lower end of the acceptable range. The relatively low dissolved oxygen concentrations may be attributed to: elevated tropical water temperatures; natural microbial respiration; decomposition of organic matter; limited turbulence;

slow water movement; and oxygen consumption within sediments. Although no immediate oxygen depletion is evident, the values indicate that the aquatic system possesses only moderate oxygen reserves. Additional organic loading during construction could further reduce dissolved oxygen concentrations if not properly managed. The highest DO concentration occurred at SW2 (2.6 mg/L), while SW3 recorded the lowest value (2.2 mg/L). The differences are relatively small and indicate comparable ecological conditions throughout the sampled surface-water system.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) measures the quantity of oxygen required by microorganisms to biologically decompose biodegradable organic matter present in water. High BOD values generally indicate significant organic pollution, whereas low values suggest relatively clean water with limited biodegradable organic inputs. The measured BOD values were: SW1: 0.9 mg/L, SW2: 1.2 mg/L, and SW3: 0.8 mg/L The very low BOD concentrations indicate that the surface waters contain only small amounts of biodegradable organic material. These results demonstrate that: microbial oxygen demand is low; sewage contamination is unlikely; organic pollution is minimal; and oxygen depletion resulting from biodegradation is presently limited. The slightly higher BOD at SW2 corresponds with the marginally higher conductivity and dissolved solids observed at the same location but remains environmentally insignificant. Overall, the BOD results indicate good baseline water quality with respect to biodegradable organic contamination.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) represents the total oxygen required to chemically oxidize both biodegradable and non-biodegradable organic substances within water. Unlike BOD, COD measures total oxidizable material and therefore provides a broader indication of organic contamination. The measured COD values were: SW1: 0 mg/L, SW2: 3 mg/L, SW3: 1 mg/L The FMEnv permissible limit is 30 mg/L. All samples comply comfortably with the applicable regulatory standard. The extremely low COD values demonstrate that oxidizable organic pollutants occur only in negligible quantities. SW1 recorded zero COD, indicating virtually no detectable chemically oxidizable material. The slightly elevated value at SW2 remains extremely low and most likely reflects naturally occurring dissolved organic matter rather than pollution. The combination of low COD and low BOD strongly confirms that the surface waters are not significantly affected by industrial effluents, untreated sewage or substantial organic contamination.

Salinity

Salinity represents the concentration of dissolved salts present in water and is an important indicator of freshwater quality. Measured salinity values were: SW1: 0.00%, SW2: 0.00%, and SW3: 0.00%. All three samples indicate essentially freshwater conditions. The absence of measurable salinity demonstrates that the water bodies have not been affected by saline intrusion, industrial brines or significant evaporative salt accumulation. The salinity results also corroborate the low conductivity, low chloride and low TDS concentrations obtained during laboratory analysis. No salinity-related ecological or engineering concerns are identified.

Oxidation-Reduction Potential (ORP)

Oxidation-Reduction Potential (ORP) provides an indication of the oxidative or reducing condition of water and reflects its capacity to support aerobic biochemical processes. The measured ORP values were: SW1: 125 mV, SW2: 130 mV, and SW3: 115 mV. All three samples are below this

reference range. The relatively low positive ORP values indicate mildly oxidizing conditions. Although not strongly reducing, the waters possess lower oxidation potential than highly oxygenated surface waters. These ORP values are consistent with the relatively low dissolved oxygen concentrations measured during laboratory analysis. Possible contributing factors include: slow-moving water; decomposition of natural organic matter; limited turbulence; sediment-water interactions; and tropical climatic conditions. Despite the relatively low ORP values, no evidence of anaerobic conditions, objectionable odour or severe organic pollution was observed.

Implications for the Proposed REA Project

The baseline physicochemical characteristics indicate that the proposed REA project will commence within relatively clean freshwater environments. The principal physicochemical issue identified is the elevated suspended-solid concentration. Construction activities such as: site clearing; excavation; grading; earthworks; vehicle movement; and stockpiling of excavated materials may increase suspended sediment concentrations if not properly controlled. Appropriate mitigation measures should therefore include: erosion-control structures; sediment traps; temporary drainage channels; silt fencing; stabilization of exposed soils; prompt revegetation; proper stockpile management; and avoidance of unnecessary earthworks during heavy rainfall. Fuel, lubricant and chemical storage areas should also be properly managed to preserve the presently favourable chemical quality of the surface waters.

Table 4.30: Summary of Surface Water Physical and Physicochemical Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Colour	Pale brown at SW1, SW2 and SW3	Uniform pale-brown colour reflects natural suspended sediments and organic matter typical of tropical surface waters. No evidence of oil sheen, algal bloom or abnormal coloration.
Odour	Odourless at all sampling locations	Indicates absence of objectionable odours associated with sewage, petroleum hydrocarbons or anaerobic decomposition.
Taste	Tasteless at all sampling locations	Indicates low concentrations of dissolved salts and organic contaminants affecting palatability.
pH	7.01–7.63	All samples comply with the FMEnv standard. Neutral to slightly alkaline conditions favour aquatic life, reduce metal mobility and indicate chemically stable water.
Temperature (°C)	29.7–29.9	Corresponds to normal tropical ambient conditions with no evidence of thermal pollution.
Electrical Conductivity (µS/cm)	84–94	Very low conductivity indicates fresh water with low dissolved ionic content and minimal mineralization.
Turbidity (NTU)	0–1	Extremely low turbidity indicates very clear water with minimal fine suspended particles and favourable light penetration.
Total Dissolved Solids (mg/L)	42–47	Very low TDS confirms weakly mineralized freshwater with negligible influence from industrial effluents, saline intrusion or wastewater.
Total Suspended Solids (mg/L)	96–112	All samples exceed the FMEnv limit, indicating significant suspended particulate matter likely derived from surface

Parameter	Observed Results	Interpretation / Environmental Significance
		runoff, erosion and sediment transport. This is the principal physicochemical concern.
Dissolved Oxygen (mg/L)	2.2–2.6	All samples comply but occur near the lower end of the acceptable range, indicating moderate oxygen availability typical of slow-moving tropical surface waters.
Biochemical Oxygen Demand (mg/L)	0.8–1.2	Very low BOD indicates minimal biodegradable organic pollution and low microbial oxygen demand.
Chemical Oxygen Demand (mg/L)	0–3	All samples comply comfortably with the standard, indicating negligible chemically oxidizable organic pollutants.
Salinity (%)	0.00	Indicates freshwater conditions with no evidence of saline intrusion or salt accumulation.
Oxidation-Reduction Potential (mV)	115–130	Positive but relatively low ORP values indicate mildly oxidizing conditions typical of tropical surface waters with moderate dissolved oxygen and natural organic matter decomposition.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Chemical Characteristics (Major Ions)

The major ionic composition of surface water provides valuable information on hydro chemical processes, mineral weathering, nutrient availability, anthropogenic influences, and the general chemical quality of aquatic ecosystems. Major ions are naturally derived from the dissolution of rocks and soil but may also originate from agricultural runoff, domestic wastewater, industrial discharges, and atmospheric deposition. The principal chemical parameters evaluated include aluminium, calcium, magnesium, total hardness, potassium, nitrate, nitrite, sulphate, phosphide, chloride, and fluoride. Collectively, these parameters indicate that the surface waters are weakly mineralized and comply with the Federal Ministry of Environment (FMEnv) standards, although elevated nitrite concentrations and moderate nutrient enrichment were observed.

Aluminium (Al^{3+})

Aluminium is one of the most abundant elements within the Earth's crust and commonly enters surface waters through weathering of aluminosilicate minerals. Under neutral pH conditions, aluminium exhibits low solubility and limited ecological toxicity. The measured aluminium concentrations were: SW1: 0.34 mg/L, SW2: 0.46 mg/L, and SW3: 0.38 mg/L. The uniform concentrations indicate that aluminium originates primarily from natural geological weathering rather than anthropogenic pollution. The neutral pH values (7.01–7.63) further reduce aluminium mobility by promoting precipitation of aluminium hydroxides, thereby minimizing toxicity to aquatic organisms. The observed concentrations therefore represent natural background conditions characteristic of tropical Basement Complex terrains.

Calcium (Ca^{2+})

Calcium is one of the principal cations contributing to water hardness and originates mainly from the dissolution of carbonate and silicate minerals. Measured calcium concentrations were: SW1: 2.15 mg/L, SW2: 2.28 mg/L, and SW3: 2.21 mg/L. The FMEnv permissible limit is 200 mg/L. All samples comply comfortably with the regulatory standard. The low calcium concentrations indicate that the waters are weakly mineralized despite the moderate hardness values. The narrow

variation among the sampling points demonstrates relatively uniform geological influence throughout the study area. From an ecological perspective, calcium concentrations are sufficient to support aquatic organisms requiring dissolved calcium while remaining far below concentrations capable of causing scaling or environmental concern.

Magnesium (Mg^{2+})

Magnesium contributes to water hardness and serves as an essential nutrient for both aquatic organisms and terrestrial vegetation. Measured magnesium concentrations were: SW1: 1.20 mg/L, SW2: 1.32 mg/L, and SW3: 1.41 mg/L. The FMEnv permissible limit is 20 mg/L. All measured concentrations comply with the applicable standard. The low magnesium concentrations further confirm the weak mineralization of the surface waters. The gradual increase from SW1 to SW3 is minor and most likely reflects natural spatial variation in mineral weathering. The measured concentrations do not indicate any anthropogenic enrichment or environmental concern.

Total Hardness

Total hardness primarily reflects the combined concentrations of dissolved calcium and magnesium ions. Measured hardness values were: SW1: 54 mg/L, SW2: 43 mg/L, and SW3: 37 mg/L. The FMEnv permissible limit is 150 mg/L. All three samples comply with the applicable standard. Based on commonly accepted water-hardness classifications, the sampled waters may be regarded as soft to moderately soft waters. The relatively low hardness suggests: minimal scaling tendency; favourable suitability for domestic and industrial applications after treatment; reduced soap consumption; and limited carbonate deposition. The declining hardness from SW1 to SW3 corresponds with the slight decrease in dissolved calcium concentrations.

Potassium (K^{+})

Potassium is an essential nutrient involved in plant metabolism and aquatic productivity. It typically occurs in relatively low concentrations because it is readily absorbed by vegetation. Measured potassium concentrations were: SW1: 2.6 mg/L, SW2: 3.0 mg/L, and SW3: 2.7 mg/L. The FMEnv permissible limit is 20 mg/L. All samples comply comfortably with the regulatory standard. The concentrations indicate natural background potassium derived from mineral weathering and nutrient cycling rather than fertilizer contamination. The slightly higher concentration at SW2 may reflect localized vegetation decomposition or surface runoff but remains environmentally insignificant.

Nitrate (NO_3^{-})

Nitrate is the most stable oxidized form of nitrogen and serves as an important indicator of nutrient enrichment and agricultural or domestic pollution. Measured nitrate concentrations were: SW1: 21.2 mg/L, SW2: 18.9 mg/L, and SW3: 15.6 mg/L. The FMEnv permissible limit is 50 mg/L. All samples comply with the applicable standard. Although the concentrations are well below the regulatory limit, they indicate moderate nitrogen availability within the aquatic environment. Possible nitrate sources include: natural decomposition of organic matter; microbial nitrification; runoff from surrounding soils; atmospheric deposition; and minor agricultural influence. No evidence of excessive nitrate pollution or eutrophication risk was identified. The gradual decrease from SW1 to SW3 suggests slight differences in nutrient inputs rather than localized contamination.

Nitrite (NO_2^-)
Nitrite is an intermediate product in the nitrogen cycle and normally occurs only at very low concentrations because it is rapidly converted to nitrate under well-oxygenated conditions. Measured nitrite concentrations were: SW1: 0.7079 mg/L, SW2: 0.036 mg/L, and SW3: 0.067 mg/L. The FMEnv permissible limit is 0.02 mg/L. All three samples exceed the regulatory standard. The highest concentration occurred at SW1, where nitrite exceeded the limit by more than thirty times. Elevated nitrite concentrations may indicate: incomplete nitrification; recent organic matter decomposition; oxygen-limited microbial processes; agricultural runoff; wastewater influence; or localized nutrient enrichment. However, the relatively low BOD and COD values indicate that widespread organic pollution is unlikely. The elevated nitrite therefore most probably reflects localized nitrogen transformation processes rather than severe contamination. Nevertheless, continued monitoring is recommended because persistent nitrite enrichment may adversely affect aquatic organisms and water quality.

Sulphate (SO_4^{2-})
Sulphate originates naturally through mineral weathering and oxidation of sulphide minerals. Measured sulphate concentrations were: SW1: 24 mg/L, SW2: 28 mg/L, and SW3: 33 mg/L The FMEnv permissible limit is 100 mg/L. All samples comply with the applicable standard. The relatively low sulphate concentrations indicate limited influence from industrial discharges or sulphur-rich geological formations. The slight increase toward SW3 most likely reflects natural variability in runoff or weathering processes. No evidence of sulphate-related pollution or acidification was observed.

Phosphate (PO_4^{3-})
Phosphate is an essential plant nutrient but excessive concentrations may stimulate eutrophication and excessive algal growth. Measured phosphate concentrations were: SW1: 4.64 mg/L, SW2: 3.81 mg/L, and SW3: 4.24 mg/L. The measured concentrations are moderately elevated compared with pristine freshwater systems and may reflect: natural organic matter decomposition; sediment interactions; vegetation litter; surface runoff; and localized nutrient inputs. Despite these moderate concentrations, no evidence of excessive organic pollution or algal bloom was observed during field investigations. The phosphate concentrations therefore indicate moderate nutrient availability without obvious eutrophication.

Sulphide (S^{2-})
Sulphide is generally associated with reducing environments where sulphate undergoes bacterial reduction under oxygen-deficient conditions. Measured sulphide concentrations were: SW1: 24 mg/L, SW2: 28 mg/L, and SW3: 33 mg/L. These concentrations should be interpreted cautiously because they are identical to the sulphate trend and may represent either laboratory reporting error or parameter duplication. Assuming the reported values are correct, the absence of objectionable odour and the low BOD values do not support significant sulphide pollution.

Chloride (Cl^-)
Chloride serves as an indicator of mineralization, saline intrusion and anthropogenic inputs. Measured chloride concentrations were: SW1: 11.3 mg/L, SW2: 10.7 mg/L, SW3: 9.6 mg/L. The FMEnv permissible limit is 150 mg/L. All samples comply comfortably with the standard. The low chloride concentrations indicate: freshwater conditions; absence of saline intrusion; minimal sewage influence; and limited industrial contamination. The chloride results corroborate the low conductivity, TDS and salinity values discussed previously.

Fluoride (F^-)

Fluoride occurs naturally through weathering of fluoride-bearing minerals and is generally present in low concentrations within surface waters. Measured fluoride concentrations were: SW1: 1.02 mg/L, SW2: 0.96 mg/L, and SW3: 0.84 mg/L. The concentrations are relatively low and exhibit little variation among sampling points. The results indicate natural geological sources rather than anthropogenic contamination. No fluoride-related environmental concern is evident

Implications for the Proposed REA Project

The baseline chemical characteristics indicate that the proposed REA Solar Photovoltaic Project will commence within chemically stable freshwater environments. Construction activities should avoid introducing additional nutrient loads through: improper wastewater disposal; concrete washings; fuel spills; waste accumulation; and uncontrolled runoff. Particular attention should be given to controlling sediment and nutrient transport because elevated nitrite concentrations already indicate localized nutrient transformation within the watershed. Routine monitoring of nitrogen species during construction is recommended to detect any project-related deterioration in water quality.

Table 4.31: Summary of Surface Water Chemical Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Aluminium (Al^{3+})	0.34–0.46 mg/L	Low concentrations typical of natural weathering of aluminosilicate minerals. No evidence of anthropogenic contamination.
Calcium (Ca^{2+})	2.15–2.28 mg/L	All samples comply. Low calcium concentrations indicate weak mineralization and contribute to soft water conditions.
Magnesium (Mg^{2+})	1.20–1.41 mg/L	All samples comply. Low concentrations reflect limited mineral dissolution and natural hydro chemical conditions.
Total Hardness	37–54 mg/L	All samples comply. Surface water is classified as soft, with minimal scaling potential and good suitability for domestic and ecological uses after treatment.
Potassium (K^+)	2.6–3.0 mg/L	Low concentrations indicate natural mineral weathering and nutrient cycling with no evidence of fertilizer contamination.
Nitrate (NO_3^-)	15.6–21.2 mg/L	All samples comply. Moderate nitrate concentrations indicate natural nutrient cycling with no evidence of excessive nitrogen pollution.
Nitrite (NO_2^-)	0.036–0.7079 mg/L	All samples exceed the FMEnv limit. Elevated nitrite suggests localized nitrogen transformation processes and warrants continued monitoring.
Sulphate (SO_4^{2-})	24–33 mg/L	All samples comply. Low sulphate concentrations indicate minimal industrial influence and natural background conditions.
Phosphate (PO_4^{3-})	3.81–4.64 mg/L	Moderate phosphate concentrations indicate active nutrient cycling but no evidence of excessive eutrophication.
Sulphide (S^{2-})	24–33 mg/L	Reported concentrations should be interpreted cautiously due to similarity with sulphate values. No supporting evidence of sulphide pollution was observed.
Chloride (Cl^-)	9.6–11.3 mg/L	All samples comply. Very low chloride confirms freshwater conditions and absence of saline intrusion or sewage contamination.
Fluoride (F^-)	0.84–1.02 mg/L	Low fluoride concentrations reflect natural geological sources and pose no environmental concern.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Heavy Metals

Heavy metals are naturally present in surface waters at low concentrations through the weathering of rocks and soils; however, their levels may increase significantly due to anthropogenic activities such as industrial discharges, mining, waste disposal, agricultural runoff, vehicular emissions and urban development. While certain metals are essential micronutrients at trace concentrations, elevated levels may pose ecological risks, impair aquatic ecosystems and present significant public-health concerns. The heavy metal assessment evaluated copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), iron (Fe), nickel (Ni), cobalt (Co) and mercury (Hg) to establish the baseline geochemical quality of the surface waters within the proposed project area.

Copper (Cu^{2+})

Copper is an essential trace element required for numerous biochemical processes in aquatic organisms; however, excessive concentrations may become toxic to fish, aquatic invertebrates and microorganisms. The measured copper concentrations were: SW1: 1.32 mg/L, SW2: 0.84 mg/L, and SW3: 0.72 mg/L. The FMEnv permissible limit is 1.5 mg/L. All three samples comply with the applicable regulatory standard. Although SW1 recorded the highest concentration, it remains below the permissible limit. The relatively elevated concentration at SW1 may reflect localized mineral weathering or limited surface runoff contributions rather than anthropogenic contamination. Overall, copper concentrations indicate satisfactory baseline conditions with no evidence of copper pollution.

Chromium (Cr^{3+})

Chromium occurs naturally through weathering of chromium-bearing minerals but may also originate from industrial activities, metal processing and waste disposal. The measured chromium concentrations were: SW1: 0.32 mg/L, SW2: 0.26 mg/L, and SW3: 0.31 mg/L. The FMEnv permissible limit is 0.05 mg/L. All three sampling locations exceed the applicable regulatory limit. The measured concentrations suggest enrichment beyond typical natural freshwater background levels. Potential sources include: natural geological weathering; runoff from surrounding soils; historical anthropogenic activities; metallic wastes; or localized contamination sources within the watershed. The exceedance of the regulatory limit warrants continued environmental monitoring because elevated chromium concentrations may adversely affect aquatic organisms through prolonged exposure.

Cadmium (Cd^{2+})

Cadmium is a non-essential and highly toxic heavy metal with no known biological function. Even at very low concentrations, cadmium may accumulate in aquatic organisms and pose significant ecological and human-health risks. The measured cadmium concentrations were: SW1: 0.024 µg/L, SW2: 0.038 µg/L, and SW3: 0.036 µg/L. All samples exceed the reported regulatory limit. Although the absolute concentrations remain relatively low, the reported exceedances indicate that cadmium requires careful attention. Possible sources include: weathering of cadmium-bearing minerals; atmospheric deposition; runoff; agricultural inputs; and localized anthropogenic activities. The existing results establish an important baseline for future monitoring.

Lead (Pb^{2+})

Lead is a persistent toxic metal capable of causing serious ecological and human-health effects. The measured lead concentrations were: SW1: 0.062 µg/L, SW2: 0.047 µg/L, and SW3: 0.038 µg/L. The FMEnv permissible limit is 0.001 µg/L. All samples exceed the reported limit. The highest concentration occurred at SW1. Potential lead sources may include: weathering of

naturally occurring minerals; vehicular emissions; batteries; discarded metallic materials; historical contamination; and surface runoff. Although the measured concentrations are low in absolute terms, the reported exceedances justify further investigation and confirmation through repeat laboratory analysis. Lead should remain one of the priority parameters for future monitoring during project implementation.

Zinc (Zn^{2+})
Zinc is an essential micronutrient required for normal biological metabolism. The measured zinc concentrations were: SW1: 0.84 mg/L, SW2: 0.72 mg/L, and SW3: 0.78 mg/L. The FMEnv permissible limit is 3.0 mg/L. All samples comply comfortably with the regulatory standard. The relatively uniform concentrations indicate natural geochemical contributions rather than localized contamination. The observed zinc concentrations are sufficient to support biological functions while remaining well below toxic thresholds.

Iron (Fe^{2+})
Iron is one of the most abundant elements in tropical environments and commonly occurs in surface waters draining highly weathered Basement Complex terrains. Measured iron concentrations were: SW1: 0.22 mg/L, SW2: 0.31 mg/L, and SW3: 0.26 mg/L. The FMEnv permissible limit is 0.07 mg/L. All three samples exceed the reported regulatory limit. The elevated iron concentrations are most likely attributable to natural weathering of iron-rich tropical soils and rocks rather than anthropogenic pollution. The neutral pH measured throughout the study area reduces iron mobility and minimizes ecological toxicity. Although elevated iron may contribute to water discoloration, staining and precipitation under oxidizing conditions, the measured concentrations do not necessarily indicate environmental degradation.

Nickel (Ni^{2+})
Nickel occurs naturally through weathering of ultramafic and mafic rocks but may also originate from industrial sources. Measured nickel concentrations were: SW1: 0.067 mg/L SW2: 0.072 mg/L, and SW3: 0.068 mg/L. The FMEnv permissible limit is 0.007 mg/L. All samples exceed the reported regulatory limit. The consistently elevated concentrations across all sampling locations suggest either natural geological enrichment or diffuse watershed inputs rather than isolated contamination. Because nickel may accumulate within aquatic ecosystems under prolonged exposure, continued monitoring is recommended.

Cobalt (Co^{2+})
Cobalt is a naturally occurring trace element required only in very small quantities by biological organisms. Measured concentrations were: SW1: 0.074 mg/L, SW2: 0.078 mg/L, and SW3: 0.072 mg/L. The FMEnv permissible limit is 0.2 mg/L. All samples comply with the applicable regulatory standard. The relatively uniform distribution suggests natural geological control with no evidence of localized cobalt contamination.

Mercury (Hg)
Mercury is among the most toxic heavy metals because of its persistence, bioaccumulation potential and ecological impacts. Measured mercury concentrations were: SW1: 0.003 mg/L, SW2: 0.008 mg/L, and SW3: 0.034 mg/L. The FMEnv permissible limit is 0.001 mg/L. All three sampling locations exceed the regulatory limit. SW3 recorded the highest concentration. Potential mercury sources include: atmospheric deposition; geological weathering; historical anthropogenic activities; and diffuse watershed runoff. Although no obvious industrial sources were identified

during field investigations, the elevated mercury concentrations warrant careful investigation because of mercury's high toxicity and tendency to bioaccumulate within aquatic food chains.

Implications for the Proposed REA Project

The baseline heavy metal concentrations demonstrate that the project area already contains measurable concentrations of several metals before commencement of construction. The proposed solar photovoltaic development is not expected to generate significant heavy metal discharges during normal operation. However, construction activities should ensure proper management of: fuels; lubricants; batteries; paints; metallic wastes; electrical components; and hazardous materials to prevent additional heavy metal inputs into nearby surface waters. Routine monitoring should focus particularly on: chromium; cadmium; lead; iron; nickel; and mercury to distinguish natural baseline conditions from any project-related changes.

Table 4.32: Summary of Surface Water Heavy Metal Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Copper (Cu^{2+})	0.72–1.32 mg/L	All samples comply. Copper occurs at relatively low concentrations, indicating natural geological weathering with no evidence of copper contamination.
Chromium (Cr^{3+})	0.26–0.32 mg/L	All samples exceed the FMEnv limit, indicating elevated chromium concentrations that require continued monitoring to distinguish natural geological enrichment from anthropogenic inputs.
Cadmium (Cd^{2+})	0.024–0.038 µg/L	All samples exceed the reported limit. Although concentrations remain relatively low, cadmium is highly toxic and requires confirmatory analysis and routine monitoring.
Lead (Pb^{2+})	0.038–0.062 µg/L	All samples exceed the FMEnv limit. Elevated lead concentrations warrant further investigation and continued environmental monitoring because of their ecological and public health significance.
Zinc (Zn^{2+})	0.72–0.84 mg/L	All samples comply. Zinc concentrations reflect natural background levels and pose no environmental concern.
Iron (Fe^{2+})	0.22–0.31 mg/L	All samples exceed the FMEnv limit. Elevated iron is likely associated with natural weathering of iron-rich tropical soils and Basement Complex rocks rather than pollution.
Nickel (Ni^{2+})	0.067–0.072 mg/L	All samples exceed the reported limit. The consistent distribution suggests regional geological enrichment or diffuse watershed inputs, requiring continued monitoring.
Cobalt (Co^{2+})	0.072–0.078 mg/L	All samples comply. Cobalt occurs at natural background concentrations with no evidence of localized contamination.
Mercury (Hg)	0.003–0.034 mg/L	All samples exceed the FMEnv limit. Mercury concentrations warrant careful investigation and long-term monitoring because of their toxicity and bioaccumulation potential.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Organic Characteristics

Organic contaminants are important indicators of anthropogenic pollution and are routinely assessed during environmental baseline investigations because they provide evidence of contamination arising from petroleum products, industrial chemicals, transportation activities, domestic wastewater and other human activities. The organic parameters analysed in this study comprised phenols, oil and grease, benzene, toluene, ethylbenzene and xylene (BTEX). These compounds are of particular environmental significance because many exhibit persistence, toxicity

and bioaccumulative properties, while petroleum hydrocarbons can adversely affect aquatic organisms, degrade water quality and impair ecosystem functioning. The analytical results indicate that the surface waters are largely free from hydrocarbon contamination, although phenol concentrations exceeded the applicable FMEnv guideline values.

Phenols

Phenolic compounds comprise a broad group of aromatic organic substances commonly associated with petroleum products, industrial effluents, decaying vegetation, biomass decomposition and certain agricultural activities. Although low concentrations may occur naturally through the decomposition of organic matter, elevated phenol concentrations are generally indicative of anthropogenic influence and may impart objectionable taste and odour while exhibiting toxicity to aquatic organisms. The measured phenol concentrations were 0.136 mg/L at SW1, 0.062 mg/L at SW2 and 0.123 mg/L at SW3. These values exceeded the FMEnv permissible limit of 0.05 mg/L at all three sampling locations. The highest concentration was recorded at SW1, while SW2 exhibited the lowest concentration. The relatively consistent occurrence of elevated phenols across the three surface-water locations suggests that the source is unlikely to be an isolated point discharge but may instead reflect diffuse watershed inputs, decomposition of organic materials, runoff from surrounding land or other localized environmental influences. Despite the elevated phenol concentrations, the surface waters exhibited very low biochemical oxygen demand (0.8–1.2 mg/L), low chemical oxygen demand (0–3 mg/L), no objectionable odour and no detectable petroleum hydrocarbons. These findings indicate that widespread organic pollution is not occurring within the study area.

Oil and Grease

Oil and grease constitute an important group of petroleum-related contaminants capable of impairing water quality by forming surface films, reducing oxygen transfer, affecting aquatic organisms and introducing hydrocarbon compounds into freshwater ecosystems. Their presence commonly indicates fuel spills, lubricant leakage, improper waste disposal or industrial contamination. The laboratory analysis showed that oil and grease were not detected (0.00 mg/L) in SW1, SW2 and SW3. These concentrations comply fully with the FMEnv permissible limit of 10 mg/L. The complete absence of detectable oil and grease demonstrates that the sampled surface waters have not been impacted by recent petroleum spills, lubricating oils, diesel, gasoline or other hydrocarbon products. This finding is particularly important because it establishes a favourable environmental baseline prior to commencement of the proposed solar photovoltaic project. The absence of oil films observed during field investigations further corroborates the laboratory results and indicates that the existing drainage channels and streams remain free from significant petroleum contamination.

Benzene

Benzene is one of the principal volatile aromatic hydrocarbons present in petroleum fuels and is regarded as a priority environmental pollutant because of its toxicity and carcinogenicity. It is commonly monitored during baseline environmental investigations to identify petroleum contamination associated with fuel handling, transportation and industrial activities. Laboratory analysis indicated that benzene was not detected (0.00 mg/L) in any of the surface-water samples. The measured concentrations therefore comply with the FMEnv permissible limit of 0.01 mg/L. The absence of benzene demonstrates that the surface waters have not been affected by gasoline contamination, fuel leakage or significant petroleum-related pollution. The results also agree with

the absence of oil and grease, further confirming the favourable hydrocarbon status of the study area.

Toluene

Toluene is another volatile aromatic hydrocarbon commonly associated with petroleum products, industrial solvents and fuel storage facilities. Similar to benzene, its occurrence in surface water generally reflects anthropogenic hydrocarbon contamination. All three sampling locations recorded 0.000 mg/L of toluene, indicating that the compound was not detected during laboratory analysis. These concentrations comply fully with the FMEnv permissible limit of 0.7 mg/L. The absence of toluene indicates that no significant releases of petroleum products or solvent-containing wastes have occurred within the drainage system. The results further reinforce the conclusion that the proposed project area currently exhibits excellent baseline hydrocarbon quality.

Ethylbenzene

Ethylbenzene is a constituent of petroleum fuels and forms part of the BTEX group of volatile organic compounds. It is frequently analysed because of its environmental persistence and association with fuel contamination. Laboratory analysis showed that ethylbenzene was not detected (0.00 mg/L) in SW1, SW2 and SW3. The measured concentrations therefore comply with the FMEnv permissible limit of 0.30 mg/L. The complete absence of ethylbenzene further demonstrates that the sampled surface waters have not been impacted by petroleum hydrocarbon contamination and that fuel-related pollution is not evident within the project area.

Xylene

Xylene comprises a group of aromatic hydrocarbons widely used in fuels, paints and industrial solvents. Like the other BTEX compounds, its occurrence in freshwater systems is generally associated with petroleum releases or industrial activities. Laboratory analysis indicated that xylene was not detected (0.00 mg/L) in all three surface-water samples. The concentrations therefore comply with the FMEnv permissible limit of 0.50 mg/L. The absence of xylene confirms the favourable hydrocarbon status of the surface waters and indicates that the aquatic environment has not experienced significant contamination from petroleum products or solvent-related activities.

Implications for the Proposed Project

The organic contaminant assessment indicates that the proposed REA Solar Photovoltaic Project will commence within a surface-water environment that is essentially free from petroleum hydrocarbon contamination. Construction activities, however, introduce the potential for accidental releases of fuels, lubricants, hydraulic oils, paints and solvents, which could rapidly alter the favourable baseline conditions if not properly managed. Appropriate environmental management measures should therefore include designated fuel storage areas, secondary containment systems, routine inspection of construction equipment, immediate clean-up of accidental spills, proper handling of hazardous materials and strict prohibition of equipment servicing near surface-water bodies. Stormwater management measures should also be implemented to prevent contaminated runoff from entering nearby drainage channels during construction.

Table 4.33: Summary of Surface Water Organic Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Phenols	0.062–0.136 mg/L	All samples exceed the FMEnv limit. Elevated phenol concentrations may reflect diffuse watershed inputs, natural decomposition of organic matter or localized anthropogenic influences rather than widespread petroleum contamination. Continued monitoring is recommended.
Oil and Grease	Not detected (0.00 mg/L)	All samples comply. The absence of oil and grease indicates no evidence of petroleum spills, lubricant contamination or hydrocarbon pollution.
Benzene	Not detected (0.00 mg/L)	All samples comply. No evidence of gasoline contamination or petroleum-derived hydrocarbon pollution.
Toluene	Not detected (0.000 mg/L)	All samples comply. The absence of toluene indicates that the surface waters have not been affected by petroleum products or industrial solvents.
Ethylbenzene	Not detected (0.00 mg/L)	All samples comply. No evidence of fuel-related contamination or petroleum hydrocarbon inputs.
Xylene	Not detected (0.00 mg/L)	All samples comply. The absence of xylene confirms favourable hydrocarbon quality and indicates no significant contamination from fuels or solvent-related activities.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Microbiological Characteristics

Microbiological quality is one of the most important indicators of surface-water health because it reflects the sanitary condition of a water body and its suitability for domestic, recreational and ecological uses. Microorganisms present in water originate from natural environmental processes as well as anthropogenic sources such as domestic wastewater, animal wastes, agricultural runoff and stormwater discharge. The microbiological assessment of the surface water evaluated Escherichia coli (E. coli) and Total Coliform bacteria, both of which are widely recognized indicators of faecal contamination and sanitary integrity. The laboratory results indicate that all three surface-water samples contained detectable microbial contamination, with E. coli occurring in every sampling location and total coliform counts substantially exceeding the FMEnv permissible limit.

Escherichia coli (E. coli)

Escherichia coli (E. coli) is one of the most reliable indicators of recent faecal contamination because it originates primarily from the intestinal tract of humans and warm-blooded animals. Its presence in surface water indicates that pathogenic microorganisms capable of causing waterborne diseases may also be present, thereby posing potential public-health risks where untreated water is consumed or where direct human contact frequently occurs. The laboratory analysis detected E. coli concentrations of 16 cfu/mL at SW1, 12 cfu/mL at SW2 and 12 cfu/mL at SW3. The FMEnv standard requires nil detection of E. coli in water intended for environmental quality assessment.

The presence of E. coli at all three sampling locations indicates that the surface waters have experienced faecal contamination prior to project commencement. Although the recorded concentrations are relatively similar among the three locations, SW1 exhibited the highest bacterial count, suggesting comparatively greater exposure to faecal inputs at that sampling point. Potential

sources include runoff carrying animal droppings, open defecation within the surrounding catchment, domestic wastewater discharges, livestock activities or contaminated stormwater entering the drainage channels. The detection of E. coli does not necessarily imply widespread pollution throughout the watershed; however, it confirms that untreated surface water should not be considered suitable for potable purposes without adequate treatment and disinfection. The results also establish an important microbiological baseline against which future project-related changes can be assessed.

Total Coliform

Total coliform bacteria comprise a broad group of microorganisms naturally present in soils, vegetation and the intestinal tracts of warm-blooded animals. Although total coliform organisms are not necessarily pathogenic, they are widely used as indicators of sanitary integrity and the possible presence of disease-causing microorganisms. The measured total coliform counts were 243 cfu/mL at SW1, 168 cfu/mL at SW2 and 161 cfu/mL at SW3. The FMEnv permissible limit is 10 cfu/mL. All three sampling locations substantially exceeded the regulatory standard. SW1 recorded the highest total coliform concentration, followed by SW2 and SW3. The consistently elevated counts across the study area indicate that microbiological contamination is widespread within the sampled surface-water system rather than being confined to a single isolated location. The elevated total coliform counts likely result from diffuse environmental inputs associated with surface runoff, decomposing organic matter, surrounding vegetation, wildlife activity and localized anthropogenic influences. Because E. coli was also detected in every sample, the results collectively indicate that faecal contamination has contributed to the observed microbiological condition. Despite the elevated bacterial counts, the physicochemical assessment showed very low biochemical oxygen demand and chemical oxygen demand, indicating that widespread organic pollution is not occurring. This suggests that the microbiological contamination is more likely associated with intermittent faecal inputs and runoff rather than continuous discharge of untreated wastewater.

Implications for the Proposed Project

The microbiological assessment establishes that the existing surface waters already exhibit bacterial contamination before commencement of the proposed REA Solar Photovoltaic Project. Consequently, the project should ensure that construction activities do not further degrade the existing sanitary condition of nearby water bodies. Construction camps, temporary sanitary facilities, waste-storage areas and equipment maintenance locations should be situated sufficiently away from drainage channels and natural watercourses. Domestic wastewater generated by construction personnel should be properly collected and treated, while open defecation should be strictly prohibited throughout the project area. Surface runoff should be effectively controlled using drainage channels, sediment traps and erosion-control measures to minimize the transport of faecal materials and other contaminants into adjacent water bodies. Workers should not consume untreated surface water during construction. Potable water should instead be obtained from approved sources or adequately treated through filtration, disinfection or other suitable treatment methods before use. Routine microbiological monitoring should also be undertaken throughout the construction and operational phases to detect any deterioration in water quality attributable to project activities.

Table 4.34: Summary of Surface Water Microbiological Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Escherichia coli (*E. coli*)	12–16 cfu/mL	*E. coli* was detected in all surface-water samples, indicating existing faecal contamination and potential presence of waterborne pathogens. The results show that the surface water is unsuitable for direct potable use without treatment and disinfection.
Total Coliform	161–243 cfu/mL	All samples substantially exceed the FMEnv limit. Elevated total coliform counts indicate compromised sanitary quality resulting from diffuse environmental inputs, surface runoff and localized faecal contamination. Continued microbiological monitoring is recommended.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.35: Summary of Overall Surface Water Quality Interpretation

Water Quality Category	Overall Status	Key Findings / Interpretation
Physical and Physicochemical Quality	**Generally Good**	Surface water is fresh, neutral to slightly alkaline, odourless, tasteless and weakly mineralized, with low conductivity, turbidity, TDS, salinity, BOD and COD. The principal physicochemical concern is the elevated Total Suspended Solids (TSS), while dissolved oxygen occurs near the lower acceptable limit.
Chemical Quality (Major Ions)	**Generally Good with Localized Nutrient Concern**	Most major ions comply with FMEnv standards. Calcium, magnesium, potassium, nitrate, sulphate and chloride occur at low concentrations typical of natural tropical freshwater. Nitrite exceeds the guideline value in all samples, indicating localized nutrient transformation processes and the need for continued monitoring. Moderate phosphate concentrations indicate nutrient availability without evidence of eutrophication.
Heavy Metal Quality	**Moderate Concern**	Copper, zinc and cobalt comply with FMEnv standards, whereas chromium, cadmium, lead, iron, nickel and mercury exceed the reported guideline values. The relatively uniform distribution suggests predominant geological influence, although confirmatory analysis and routine monitoring are recommended.
Organic Quality	**Excellent**	Oil and grease, benzene, toluene, ethylbenzene and xylene were not detected, confirming the absence of petroleum hydrocarbon contamination. Phenol exceeded the FMEnv guideline value at all sampling locations but, in the absence of other hydrocarbon indicators, is unlikely to reflect widespread petroleum pollution.
Microbiological Quality	**Poor**	*Escherichia coli* was detected in all samples and total coliform counts substantially exceeded the FMEnv standard, indicating existing faecal contamination and compromised sanitary quality. Untreated surface water is

Water Quality Category	Overall Status	Key Findings / Interpretation
		therefore unsuitable for potable use without appropriate treatment and disinfection.
Overall Environmental Condition	**Moderately Good Baseline Quality**	The surface water exhibits generally favourable physicochemical and chemical characteristics, excellent organic quality and no evidence of petroleum hydrocarbon contamination. However, elevated suspended solids, elevated nitrite, several heavy metal exceedances and microbiological contamination represent the principal environmental concerns requiring management and monitoring.
Suitability for Potable Use	**Not Suitable Without Treatment**	Although the water possesses good physical quality, the presence of *E. coli*, elevated total coliform counts and several heavy metal exceedances make it unsuitable for direct human consumption without appropriate treatment and disinfection.
Suitability for Aquatic Ecosystems	**Generally Suitable with Some Constraints**	Neutral pH, low salinity, low organic pollution and moderate nutrient concentrations support aquatic life. However, elevated suspended solids, relatively low dissolved oxygen, elevated nitrite and some heavy metal concentrations may impose localized ecological stress if left unmanaged.
Implications for the Proposed REA Project	**Suitable with Environmental Controls**	The results establish a reliable baseline prior to project implementation. Construction activities should prioritize erosion and sediment control, spill prevention, wastewater management, proper waste handling and routine monitoring of suspended solids, nutrients, heavy metals and microbiological quality to prevent deterioration of the existing surface-water environment.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Groundwater Analysis

Physicochemical Characteristics

The physicochemical characteristics of groundwater provide important information on the natural hydrogeochemical processes occurring within an aquifer and determine the suitability of groundwater for potable, domestic, agricultural and industrial uses. Groundwater chemistry is generally influenced by the interaction between infiltrating water and aquifer materials, residence time, mineral dissolution, groundwater recharge, biological processes and anthropogenic activities. The parameters analysed include colour, odour, taste, pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), salinity and oxidation-reduction potential (ORP). Overall, the results indicate that the groundwater is generally clear,

fresh, weakly mineralized and chemically stable, with only minor variations among the sampling locations.

Colour

Colour is one of the primary physical characteristics used to evaluate water quality and often reflects the presence of suspended materials, dissolved organic matter, iron compounds or other naturally occurring constituents. All five groundwater samples (GW1, GW2, GW3, GW4 and GW5) were described as clear, indicating the absence of visible discoloration. The clear appearance demonstrates that the groundwater contains very low concentrations of suspended particulate matter and dissolved coloured substances. This observation is consistent with groundwater systems where natural filtration through soil and geological formations removes most suspended particles before recharge reaches the aquifer. The results further suggest that the groundwater has not been affected by significant sediment intrusion or contamination capable of altering its appearance.

Odour

Odour provides a rapid indication of possible contamination arising from organic decomposition, petroleum products, sewage infiltration or chemical pollutants. All groundwater samples were reported as odourless, thereby complying with the FMEnv requirement for unobjectionable odour. The absence of objectionable odour indicates that volatile contaminants such as hydrogen sulphide, petroleum hydrocarbons and decomposing organic materials are not present in appreciable quantities. The odourless condition also suggests that the groundwater remains well protected from significant organic contamination and that anaerobic decomposition is not occurring within the aquifer.

Taste

Taste is an important aesthetic parameter for groundwater intended for potable use. Although taste alone cannot determine water quality, objectionable tastes frequently indicate elevated dissolved salts, metals or organic contaminants. All five groundwater samples were reported as tasteless, satisfying the FMEnv requirement for unobjectionable taste. This finding indicates that dissolved mineral concentrations remain relatively low and that no appreciable quantities of objectionable organic compounds are present. The tasteless nature of the groundwater agrees with the low electrical conductivity and low total dissolved solids measured during laboratory analysis.

pH

The pH of groundwater controls numerous hydro chemical processes including mineral solubility, metal mobility, corrosion potential and microbial activity. It is therefore one of the most important indicators of groundwater quality. The measured pH values were 7.28 at GW1, 7.22 at GW2, 6.94 at GW3, 6.35 at GW4 and 6.30 at GW5. The FMEnv permissible range for groundwater is 6.5–8.5. GW1, GW2 and GW3 comply fully with the applicable standard and indicate neutral to slightly acidic groundwater conditions. However, GW4 and GW5 recorded pH values slightly below the lower permissible limit, indicating mildly acidic groundwater. The slightly acidic condition observed at GW4 and GW5 is not uncommon in tropical groundwater systems and may result from carbon dioxide dissolution, organic matter decomposition within the soil profile or prolonged interaction with silicate minerals. Although the acidity is relatively minor, slightly acidic

groundwater may increase the corrosivity of water distribution systems and enhance the dissolution of certain metals if left untreated. Nevertheless, the overall pH distribution indicates generally stable groundwater chemistry with only localized mild acidity.

Temperature

Groundwater temperature influences microbial activity, dissolved oxygen concentration, chemical reaction rates and mineral dissolution. Measured groundwater temperatures ranged from 28.4°C at GW2 to 30.0°C at GW5, with GW1, GW3 and GW4 recording 29.6°C, 29.7°C and 29.8°C, respectively. These temperatures correspond closely to prevailing tropical ambient conditions and comply with the FMEnv requirement for ambient temperature. The small variation among the sampling locations indicates that the groundwater system is hydro geologically stable and has not been influenced by localized thermal pollution. The measured temperatures are typical of shallow groundwater systems within the tropical climatic zone.

Electrical Conductivity (EC)

Electrical conductivity provides an indirect measure of the total concentration of dissolved ionic constituents within groundwater and therefore reflects the degree of mineralization. The measured conductivity values were 78 µS/cm at GW1, 248 µS/cm at GW2, 63 µS/cm at GW3, 50 µS/cm at GW4 and 68 µS/cm at GW5. The FMEnv permissible limit is 1000 µS/cm. All groundwater samples comply comfortably with the regulatory standard. GW2 recorded the highest conductivity, reflecting slightly greater concentrations of dissolved ions, while GW4 recorded the lowest value. Nevertheless, even the highest conductivity represents a weakly mineralized freshwater system. The generally low conductivity values indicate limited mineral dissolution and negligible influence from saline intrusion, industrial discharges or wastewater contamination. These findings correspond closely with the low total dissolved solids and chloride concentrations observed during laboratory analysis.

Turbidity

Turbidity measures the presence of suspended particles capable of scattering light within water. Groundwater typically exhibits very low turbidity because suspended materials are removed during infiltration through the soil profile. All five groundwater samples recorded 0 NTU, complying fully with the FMEnv permissible limit of 50 NTU. The complete absence of measurable turbidity confirms the excellent physical clarity of the groundwater and demonstrates that the aquifer is effectively protected from suspended sediment intrusion. This result also indicates that the boreholes or groundwater sources are properly developed and that fine sediments are not being entrained during abstraction.

Total Dissolved Solids (TDS)

Total Dissolved Solids represent the total concentration of dissolved inorganic salts and small quantities of dissolved organic substances present in groundwater. The measured TDS values were 39 mg/L at GW1, 120 mg/L at GW2, 32 mg/L at GW3, 25 mg/L at GW4 and 32 mg/L at GW5. The FMEnv permissible limit is 500 mg/L. All samples comply comfortably with the regulatory standard. GW2 exhibited the highest TDS concentration, corresponding with its higher electrical conductivity, while GW4 contained the lowest dissolved solids concentration. The very low TDS values indicate that the groundwater is fresh, weakly mineralized and suitable for most domestic

and industrial applications after appropriate treatment where necessary. The results also suggest minimal influence from evaporative concentration, saline intrusion or anthropogenic pollution.

Total Suspended Solids (TSS)

Total Suspended Solids represent particulate materials suspended within the water column. Measured TSS concentrations were 37 mg/L at GW1, 24 mg/L at GW2, 15 mg/L at GW3, 18 mg/L at GW4 and 22 mg/L at GW5. The FMEnv permissible limit is 20 mg/L. GW1, GW2 and GW5 slightly exceeded the applicable limit, whereas GW3 and GW4 complied with the standard. Although groundwater is generally expected to contain very low suspended solids, the slight exceedances observed in some samples may result from fine sediments entering the borehole during pumping, incomplete borehole development or minor disturbances during sampling rather than contamination of the aquifer itself. Given the zero-turbidity measured in all samples, the elevated TSS values should be interpreted cautiously and may warrant verification through repeat sampling.

Dissolved Oxygen (DO)

Dissolved oxygen is an important indicator of groundwater redox conditions and influences microbial activity and the mobility of certain metals. Measured DO concentrations were 3.9 mg/L at GW1, 4.2 mg/L at GW2, 5.0 mg/L at GW3, 4.6 mg/L at GW4 and 4.4 mg/L at GW5. The FMEnv acceptable range is 2–8 mg/L. All samples comply with the applicable standard. The measured concentrations indicate moderately oxygenated groundwater capable of supporting aerobic biochemical processes. The highest dissolved oxygen concentration occurred at GW3, suggesting relatively greater groundwater recharge or shorter residence time, whereas GW1 recorded the lowest concentration. Nevertheless, all values indicate favourable oxygen conditions and no evidence of strongly reducing groundwater environments.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand measures the quantity of oxygen required by microorganisms to biologically degrade biodegradable organic matter. Measured BOD values were 2.0 mg/L at GW1, 0.5 mg/L at GW2, 1.6 mg/L at GW3, 2.1 mg/L at GW4 and 2.0 mg/L at GW5. Although no FMEnv limit is specified, all values are relatively low. The low BOD concentrations indicate that biodegradable organic pollution is minimal and that microbial oxygen demand within the groundwater is generally low. This finding suggests that the aquifer has not been significantly impacted by untreated sewage or organic wastewater infiltration.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand measures the total oxygen required to chemically oxidize both biodegradable and non-biodegradable organic substances. All groundwater samples recorded 0 mg/L, complying fully with the FMEnv permissible limit of 30 mg/L. The absence of measurable COD indicates that oxidizable organic contaminants are virtually absent within the groundwater.

This finding further confirms the excellent baseline organic quality of the aquifer and agrees closely with the low BOD values.

Salinity

Salinity reflects the concentration of dissolved salts within groundwater and is an important indicator of freshwater quality. The measured salinity values were 0.00% for GW1, GW3, GW4 and GW5, while GW2 recorded 0.01%. All values are substantially below the FMEnv reference value. The groundwater is therefore classified as fresh, with no evidence of saline intrusion or excessive salt accumulation. These results corroborate the low electrical conductivity, chloride and TDS values measured during laboratory analysis.

Oxidation-Reduction Potential (ORP)

Oxidation-Reduction Potential indicates the oxidative or reducing nature of groundwater and provides information on the geochemical environment controlling metal mobility and microbial activity. The measured ORP values were 149 mV at GW1, 178 mV at GW2, 131 mV at GW3, 181 mV at GW4 and 178 mV at GW5. These values are slightly below the laboratory reference range of 200–600 mV, indicating mildly oxidizing groundwater conditions. The positive ORP values demonstrate that the groundwater remains predominantly aerobic and is not characterized by strongly reducing conditions. The relatively low ORP values correspond well with the moderate dissolved oxygen concentrations measured during the investigation and are typical of shallow tropical groundwater systems with active recharge.

Implications for the Proposed Project

The baseline physicochemical characteristics indicate that the groundwater possesses generally good quality prior to commencement of the proposed REA Solar Photovoltaic Project. Construction activities should therefore be managed carefully to preserve the existing groundwater conditions. Fuel storage, equipment maintenance, waste disposal and sanitation facilities should be located away from groundwater abstraction points, while accidental spills should be prevented through appropriate containment measures. Routine groundwater monitoring should also be implemented during construction and operation to detect any changes in pH, dissolved solids, suspended solids or other physicochemical parameters attributable to project activities.

Table 4.36: Summary of Groundwater Physical and Physicochemical Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Colour	Clear at all sampling locations	All groundwater samples were clear, indicating absence of visible suspended matter and good aesthetic quality.
Odour	Odourless at all sampling locations	All samples complied with the FMEnv requirement, indicating no evidence of petroleum products, sewage infiltration or other odour-causing contaminants.
Taste	Tasteless at all sampling locations	All samples complied with the standard, reflecting low dissolved mineral concentrations and good aesthetic quality.
pH	6.30–7.28	GW1, GW2 and GW3 complied with the standard, while GW4 and GW5 were slightly acidic and fell marginally below the lower permissible limit.

Parameter	Observed Results	Interpretation / Environmental Significance
Temperature (°C)	28.4–30.0	Groundwater temperatures correspond to normal tropical ambient conditions, indicating no evidence of thermal pollution.
Electrical Conductivity (µS/cm)	50–248	All samples complied. Low conductivity indicates fresh, weakly mineralized groundwater with minimal dissolved salts.
Turbidity (NTU)	0	All samples complied. Zero turbidity indicates excellent physical clarity and effective natural filtration within the aquifer.
Total Dissolved Solids (mg/L)	25–120	All samples complied. Very low TDS confirms fresh groundwater with negligible influence from saline intrusion or anthropogenic pollution.
Total Suspended Solids (mg/L)	15–37	GW3 and GW4 complied, while GW1, GW2 and GW5 slightly exceeded the guideline. The exceedances may reflect minor sediment entrainment during pumping or sampling rather than aquifer contamination.
Dissolved Oxygen (mg/L)	3.9–5.0	All samples complied. Moderate dissolved oxygen concentrations indicate favourable aerobic groundwater conditions.
Biochemical Oxygen Demand (mg/L)	0.5–2.1	Low BOD values indicate minimal biodegradable organic pollution and low microbial oxygen demand.
Chemical Oxygen Demand (mg/L)	0	All samples complied. Zero COD indicates the absence of significant oxidizable organic contaminants.
Salinity (%)	0.00–0.01	Extremely low salinity confirms that the groundwater is fresh and unaffected by saline intrusion.
Oxidation-Reduction Potential (ORP, mV)	131–181	Positive but relatively low ORP values indicate mildly oxidizing groundwater conditions typical of shallow tropical aquifers with active recharge.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Chemical Characteristics

The chemical composition of groundwater provides valuable information on the hydrogeochemical processes controlling groundwater quality and its suitability for potable, domestic, agricultural and industrial uses. Groundwater chemistry is influenced by mineral weathering, water-rock interactions, recharge characteristics, residence time and, in some cases, anthropogenic activities. The chemical parameters analysed in this study comprised aluminium, calcium, magnesium, total hardness, potassium, nitrate, nitrite, sulphate, phosphate, sulphide, chloride and fluoride. Overall, the groundwater exhibited low ionic concentrations, indicating a fresh and weakly mineralized groundwater system with very limited evidence of chemical

contamination. Most parameters complied with the applicable FMEnv standards, although slight nitrite exceedances were observed in some samples.

Aluminium (Al^{3+})

Aluminium is one of the most abundant elements in the Earth's crust and enters groundwater primarily through the weathering of aluminosilicate minerals. Under neutral to slightly acidic conditions, aluminium generally exhibits limited solubility and therefore occurs at relatively low concentrations in groundwater. The measured aluminium concentrations ranged from 0.05 mg/L in GW3 to 0.09 mg/L in GW5, while GW1, GW2 and GW4 recorded 0.07 mg/L, 0.08 mg/L and 0.07 mg/L, respectively. Although the FMEnv Regulations do not specify a permissible limit for aluminium in the laboratory report, the measured concentrations are low and consistent with naturally occurring background levels. The relatively uniform distribution across the sampling locations indicates that aluminium originates primarily from natural mineral weathering rather than anthropogenic contamination. Furthermore, the near-neutral groundwater pH limits aluminium mobility and minimizes any potential ecological or human-health concerns.

Calcium (Ca^{2+})

Calcium is a major cation derived principally from the dissolution of carbonate and silicate minerals. It contributes significantly to groundwater hardness and is an essential mineral for human health. The measured calcium concentrations were 0.48 mg/L at GW1, 0.36 mg/L at GW2, 0.28 mg/L at GW3, 0.47 mg/L at GW4 and 0.43 mg/L at GW5. These values are substantially below the FMEnv permissible limit of 200 mg/L. The low calcium concentrations indicate minimal mineral dissolution within the aquifer and explain the generally soft nature of the groundwater. The slight variation among sampling locations most likely reflects natural differences in groundwater residence time and lithological composition rather than localized contamination.

Magnesium (Mg^{2+})

Magnesium is another major cation contributing to groundwater hardness and originates mainly from the weathering of magnesium-bearing silicate minerals. Measured magnesium concentrations ranged between 0.17 mg/L and 0.28 mg/L, with GW1 recording 0.22 mg/L, GW2 0.28 mg/L, GW3 0.19 mg/L, GW4 0.17 mg/L and GW5 0.24 mg/L. All concentrations comply comfortably with the FMEnv permissible limit of 20 mg/L. The uniformly low magnesium concentrations further demonstrate the weak mineralization of the groundwater and indicate limited interaction with magnesium-rich geological formations. Together with calcium, the results confirm that groundwater hardness remains relatively low.

Total Hardness

Total hardness reflects the combined concentrations of calcium and magnesium dissolved within groundwater and influences both domestic and industrial water use. The measured total hardness values were 18 mg/L at GW1, 12 mg/L at GW2, 8 mg/L at GW3, 14 mg/L at GW4 and 17 mg/L at GW5. All values comply comfortably with the FMEnv permissible limit of 150 mg/L. These concentrations classify the groundwater as very soft water. Such low hardness is advantageous because it minimizes scale formation in pipes, pumps, storage tanks and household appliances

while reducing soap consumption during domestic use. The hardness values correspond closely with the low calcium and magnesium concentrations measured throughout the study area.

Potassium (K^+)

Potassium is an essential nutrient occurring naturally in groundwater through weathering of feldspars, micas and clay minerals. Because potassium is readily absorbed by vegetation, it generally occurs in relatively low concentrations. The measured potassium concentrations were 0.6 mg/L at GW1, 1.2 mg/L at GW2, 1.6 mg/L at GW3, 0.9 mg/L at GW4 and 1.8 mg/L at GW5. These values are substantially below the FMEnv permissible limit of 20 mg/L. The low potassium concentrations indicate limited anthropogenic influence from fertilizers or wastewater and are consistent with natural groundwater systems dominated by mineral weathering.

Nitrate (NO_3^-)

Nitrate is the most stable oxidized form of nitrogen in groundwater and is widely used as an indicator of agricultural runoff, sewage contamination and other anthropogenic influences. The measured nitrate concentrations ranged from 2.8 mg/L at GW2 to 4.1 mg/L at GW5. GW1 contained 3.4 mg/L, GW3 3.7 mg/L and GW4 3.6 mg/L. All measured values comply comfortably with the FMEnv permissible limit of 50 mg/L. The relatively low nitrate concentrations indicate that the groundwater has not been significantly affected by agricultural fertilizers, sewage infiltration or other nitrogen-rich pollution sources. The results further suggest that the aquifer remains well protected from surface contamination.

Nitrite (NO_2^-)

Nitrite is an intermediate product in the nitrogen cycle and normally occurs at very low concentrations because it is rapidly oxidized to nitrate under aerobic conditions. The measured nitrite concentrations were 0.024 mg/L at GW1, 0.016 mg/L at GW2, 0.021 mg/L at GW3, 0.023 mg/L at GW4 and 0.032 mg/L at GW5. The FMEnv permissible limit is 0.02 mg/L. Only GW2 complied fully with the applicable standard. GW1, GW3, GW4 and GW5 recorded slight exceedances above the regulatory limit, with GW5 exhibiting the highest concentration. Although these exceedances are relatively small, they may indicate localized nitrogen transformation processes, recent recharge or minor organic inputs within portions of the aquifer. However, because nitrate concentrations remain low and the groundwater exhibits low BOD and COD values, there is no evidence of widespread nitrogen pollution or sewage contamination. Periodic monitoring of nitrite concentrations is nevertheless recommended to determine whether the observed elevations represent persistent baseline conditions or temporary seasonal variations.

Sulphate (SO_4^{2-})

Sulphate originates primarily through weathering of sulphate-bearing minerals and oxidation of sulphide minerals. Measured sulphate concentrations were 5 mg/L at GW1, 3 mg/L at GW2, 6 mg/L at GW3, 4 mg/L at GW4 and 7 mg/L at GW5. These concentrations are substantially below the FMEnv permissible limit of 100 mg/L. The low sulphate concentrations indicate minimal

influence from industrial activities, sulphide oxidation or saline groundwater intrusion. The groundwater therefore exhibits excellent sulphate quality.

Phosphate (PO_4^{3-})

Phosphate is an essential nutrient but generally occurs at very low concentrations in groundwater because it readily adsorbs onto soil particles and mineral surfaces. The measured phosphate concentrations ranged from 1.25 mg/L at GW5 to 2.33 mg/L at GW1. GW2, GW3 and GW4 recorded concentrations of 1.72 mg/L, 1.86 mg/L and 1.33 mg/L, respectively. No FMEnv guideline value was specified in the laboratory report. The relatively low phosphate concentrations indicate limited nutrient enrichment and suggest that the groundwater has not been significantly impacted by agricultural fertilizers or domestic wastewater.

Sulphide (S^{2-})

Sulphide commonly develops under strongly reducing conditions through bacterial reduction of sulphate. Measured sulphide concentrations ranged from 3 mg/L at GW2 to 7 mg/L at GW5, with GW1 recording 5 mg/L, GW3 6 mg/L and GW4 4 mg/L. No FMEnv guideline value was provided. The absence of objectionable odour, together with the positive oxidation-reduction potential and moderate dissolved oxygen concentrations, indicates that reducing conditions are not dominant within the aquifer. Consequently, the reported sulphide concentrations should be interpreted cautiously and may require laboratory verification.

Chloride (Cl^-)

Chloride is an important conservative ion used to evaluate groundwater mineralization and potential contamination from sewage, saline intrusion or industrial discharges. Measured chloride concentrations were 0.9 mg/L at GW1, 1.3 mg/L at GW2, 2.1 mg/L at GW3, 2.2 mg/L at GW4 and 2.8 mg/L at GW5. These values are substantially below the FMEnv permissible limit of 150 mg/L. The extremely low chloride concentrations demonstrate that the groundwater remains fresh and unaffected by saline intrusion or significant anthropogenic contamination. These findings agree closely with the low conductivity, salinity and TDS values discussed previously.

Fluoride (F^-)

Fluoride naturally enters groundwater through dissolution of fluoride-bearing minerals and is beneficial to dental health at low concentrations but may become harmful when present at elevated levels. The measured fluoride concentrations ranged from 0.13 mg/L at GW3 to 0.24 mg/L at GW5. GW1 recorded 0.22 mg/L, GW2 0.17 mg/L and GW4 0.20 mg/L. Although no FMEnv guideline value was specified in the laboratory report, the concentrations are relatively low and indicate natural background levels. The measured fluoride concentrations do not present any environmental or public-health concern.

Implications for the Proposed Project

The baseline chemical characteristics indicate that the proposed REA Solar Photovoltaic Project will commence within a groundwater system of generally good chemical quality. Construction activities should therefore focus on preserving these favourable conditions by preventing contamination from fuels, lubricants, chemicals, concrete washings and domestic wastewater.

Appropriate stormwater management, spill prevention and groundwater protection measures should be implemented throughout construction and operation. Routine monitoring of nitrogen species, particularly nitrite, together with chloride and sulphate, is recommended to identify any project-related changes in groundwater chemistry.

Table 4.37: Summary of Groundwater Chemical Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Aluminium (Al^{3+})	0.05–0.09 mg/L	Low concentrations consistent with natural weathering of aluminosilicate minerals. No evidence of anthropogenic contamination.
Calcium (Ca^{2+})	0.28–0.48 mg/L	All samples comply. Very low calcium concentrations indicate limited mineral dissolution and contribute to the soft nature of the groundwater.
Magnesium (Mg^{2+})	0.17–0.28 mg/L	All samples comply. Low magnesium concentrations confirm weak mineralization and minimal interaction with magnesium-rich formations.
Total Hardness	8–18 mg/L	All samples comply. Groundwater is classified as **very soft**, minimizing scale formation and improving domestic and industrial usability.
Potassium (K^{+})	0.6–1.8 mg/L	All samples comply. Low concentrations indicate limited influence from fertilizers or wastewater and reflect natural groundwater conditions.
Nitrate (NO_3^{-})	2.8–4.1 mg/L	All samples comply. Low nitrate concentrations indicate that the aquifer has not been significantly affected by agricultural runoff or sewage infiltration.
Nitrite (NO_2^{-})	0.016–0.032 mg/L	GW2 complies, while GW1, GW3, GW4 and GW5 show slight exceedances. The elevated values are minor and may reflect localized nitrogen transformation rather than widespread contamination. Continued monitoring is recommended.
Sulphate (SO_4^{2-})	3–7 mg/L	All samples comply. Low sulphate concentrations indicate minimal industrial influence and excellent groundwater quality.
Phosphate (PO_4^{3-})	1.25–2.33 mg/L	Low phosphate concentrations indicate limited nutrient enrichment and no evidence of significant fertilizer or wastewater contamination.
Sulphide (S^{2-})	3–7 mg/L	Reported concentrations should be interpreted cautiously because the groundwater remained aerobic, with no objectionable odour or strongly reducing conditions. Laboratory verification may be required.
Chloride (Cl^{-})	0.9–2.8 mg/L	All samples comply. Extremely low chloride concentrations confirm fresh groundwater with no evidence of saline intrusion or anthropogenic contamination.
Fluoride (F^{-})	0.13–0.24 mg/L	Low fluoride concentrations reflect natural background levels and pose no environmental or public health concern.

Heavy Metals

Heavy metals are naturally present in groundwater as a result of the weathering and dissolution of minerals within aquifer formations. Their concentrations are controlled by geological conditions, groundwater residence time, pH, oxidation-reduction potential and human activities such as mining, industrial operations, waste disposal, agricultural practices and urban development. While certain metals are essential micronutrients at very low concentrations, elevated levels may present serious ecological and public health concerns because many heavy metals are toxic, persistent and capable of bioaccumulation. The heavy metal assessment evaluated copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), iron (Fe), nickel (Ni), cobalt (Co) and mercury (Hg) to establish the baseline groundwater quality within the proposed project area. Overall, the results indicate that most metals occurred at relatively low concentrations, although isolated exceedances of iron, cadmium, lead and mercury were observed in some groundwater samples.

Copper (Cu^{2+})

Copper is an essential trace element involved in numerous biochemical and enzymatic processes. It occurs naturally in groundwater through the weathering of copper-bearing minerals but may also originate from corrosion of pipes, industrial activities and agricultural chemicals. The measured copper concentrations ranged from 0.24 mg/L in GW4 to 0.36 mg/L in GW3, while GW1, GW2 and GW5 recorded 0.28 mg/L, 0.33 mg/L and 0.29 mg/L, respectively. These values comply comfortably with the FMEnv permissible limit of 1.5 mg/L. The relatively uniform distribution of copper across the groundwater samples indicates natural geochemical control rather than localized contamination. The concentrations are sufficiently low to avoid adverse ecological or public health concerns and are characteristic of uncontaminated groundwater systems.

Chromium (Cr^{3+})

Chromium occurs naturally through the weathering of chromium-bearing rocks but may also originate from industrial activities, metal processing and waste disposal. Elevated chromium concentrations are of environmental concern because certain chromium species exhibit considerable toxicity. The laboratory results showed chromium concentrations of 0.01 mg/L in GW1, not detected (0.00 mg/L) in GW2, 0.01 mg/L in GW3, 0.02 mg/L in GW4 and 0.04 mg/L in GW5. All measured values comply with the FMEnv permissible limit of 0.05 mg/L. The low chromium concentrations indicate that the groundwater has not been impacted by chromium-related contamination. The absence of chromium in GW2 further supports the conclusion that chromium occurs only as naturally occurring trace concentrations within the aquifer.

Cadmium (Cd^{2+})

Cadmium is a highly toxic heavy metal with no known beneficial biological function. Even at relatively low concentrations, prolonged exposure may adversely affect human health and aquatic ecosystems. The measured cadmium concentrations were 0.002 µg/L at GW1, 0.012 µg/L at GW2, 0.006 µg/L at GW3, 0.008 µg/L at GW4 and 0.002 µg/L at GW5. The FMEnv permissible limit is 0.001 µg/L. All five groundwater samples exceeded the reported regulatory limit, with GW2 recording the highest cadmium concentration. Although the absolute concentrations remain relatively low, the observed exceedances warrant careful interpretation because cadmium is highly toxic and capable of accumulating in biological tissues. The relatively uniform occurrence across the sampling locations suggests that the observed cadmium concentrations may reflect natural

geological contributions or diffuse environmental inputs rather than isolated point-source contamination.

Lead (Pb^{2+})

Lead is a persistent toxic metal widely recognized for its adverse effects on human health, particularly the nervous system, kidneys and cardiovascular system. It commonly enters groundwater through corrosion of plumbing materials, weathering of lead-bearing minerals and anthropogenic activities. Lead was not detected (0.000 µg/L) in GW1. However, concentrations of 0.001 µg/L, 0.004 µg/L, 0.003 µg/L and 0.003 µg/L were recorded in GW2, GW3, GW4 and GW5, respectively. The FMEnv permissible limit is 0.001 µg/L. GW1 fully complied with the applicable standard, while GW2 was at the permissible limit. GW3, GW4 and GW5 slightly exceeded the reported guideline value. The exceedances are relatively small but indicate that lead should remain a priority parameter for future groundwater monitoring. Potential sources include natural weathering of geological materials, minor corrosion within groundwater abstraction systems or diffuse environmental inputs. No evidence was observed during field investigations to suggest significant industrial or waste-related lead contamination within the project area.

Zinc (Zn^{2+})

Zinc is an essential micronutrient required for normal biological metabolism and plant growth. Environmental concerns generally arise only when zinc occurs at elevated concentrations. Measured zinc concentrations ranged from 0.08 mg/L in GW1 to 0.26 mg/L in GW3, while GW2, GW4 and GW5 recorded 0.22 mg/L, 0.23 mg/L and 0.19 mg/L, respectively. These concentrations comply comfortably with the FMEnv permissible limit of 3.0 mg/L. The measured zinc concentrations are characteristic of natural background conditions and indicate no evidence of zinc contamination within the groundwater system.

Iron (Fe^{2+})

Iron is one of the most abundant naturally occurring elements in groundwater, particularly within tropical Basement Complex terrains where prolonged weathering releases iron-bearing minerals into groundwater. The measured iron concentrations were 0.02 mg/L at GW1, 0.38 mg/L at GW2, 0.30 mg/L at GW3, 0.21 mg/L at GW4 and 0.24 mg/L at GW5. The FMEnv permissible limit is 0.07 mg/L. Only GW1 complied with the regulatory standard. GW2, GW3, GW4 and GW5 all exceeded the permissible limit, with GW2 recording the highest concentration. The elevated iron concentrations are most likely attributable to natural dissolution of iron-rich geological materials rather than anthropogenic contamination. Iron is commonly elevated in tropical groundwater and may result in staining, metallic taste and precipitation following exposure to oxygen. Although elevated iron rarely presents significant health risks, it may reduce the aesthetic quality of groundwater and affect domestic water-supply systems.

Nickel (Ni^{2+})

Nickel occurs naturally through weathering of ultramafic and mafic rocks and may also be introduced through industrial activities and metallic corrosion. The measured nickel concentrations were 0.003 mg/L at GW1, not detected (0.000 mg/L) at GW2, 0.001 mg/L at GW3, 0.003 mg/L at GW4 and 0.005 mg/L at GW5. These values comply fully with the FMEnv permissible limit of

0.007 mg/L. The low nickel concentrations indicate favourable groundwater quality and the absence of nickel-related contamination.

Cobalt (Co^{2+})

Cobalt is a naturally occurring trace element commonly associated with crystalline rocks and is required only in very small quantities by living organisms. Measured cobalt concentrations ranged from 0.004 mg/L in GW1 to 0.008 mg/L in GW5, while GW2, GW3 and GW4 recorded 0.007 mg/L, 0.005 mg/L and 0.007 mg/L, respectively. These concentrations comply comfortably with the FMEnv permissible limit of 0.2 mg/L. The relatively uniform distribution indicates natural background concentrations with no evidence of localized cobalt contamination.

Mercury (Hg)

Mercury is among the most toxic environmental contaminants because of its persistence, mobility and tendency to bioaccumulate within aquatic food chains. Even very small concentrations require careful evaluation. The measured mercury concentrations were not detected (0.000 mg/L) at GW1, 0.001 mg/L at GW2, 0.008 mg/L at GW3, 0.006 mg/L at GW4 and 0.013 mg/L at GW5. The FMEnv permissible limit is 0.001 mg/L. GW1 complied fully with the regulatory standard, while GW2 was equal to the permissible limit. GW3, GW4 and GW5 exceeded the guideline value, with GW5 recording the highest mercury concentration. Although the measured concentrations remain relatively low, the exceedances warrant continued monitoring because mercury possesses significant toxicological importance. The absence of obvious industrial activities within the project area suggests that the observed concentrations may be associated with natural geological conditions or diffuse environmental sources rather than localized contamination.

Implications for the Proposed Project

The heavy metal assessment demonstrates that the proposed REA Solar Photovoltaic Project will commence within a groundwater system exhibiting generally favourable geochemical quality but containing naturally elevated concentrations of a few metals. Construction activities should therefore ensure that additional heavy metal contamination does not occur through improper handling of fuels, lubricants, batteries, paints, electrical equipment or hazardous wastes. Designated storage areas, secondary containment facilities and emergency spill response procedures should be implemented throughout construction and operation. Routine groundwater monitoring should include iron, cadmium, lead and mercury because these parameters exhibited the greatest potential concern during the baseline investigation. This monitoring programmer will enable differentiation between naturally occurring groundwater chemistry and any future project-related changes.

Table 4.38: Summary of Groundwater Heavy Metal Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Copper (Cu^{2+})	0.24–0.36 mg/L	All samples comply. Copper occurs at low concentrations characteristic of natural mineral weathering, with no evidence of anthropogenic contamination.
Chromium (Cr^{3+})	ND–0.04 mg/L	All samples comply. Chromium occurs only at trace concentrations, indicating that the groundwater has not been impacted by chromium-related contamination.

Parameter	Observed Results	Interpretation / Environmental Significance
Cadmium (Cd^{2+})	0.002–0.012 µg/L	All samples exceed the reported FMEnv limit. Although concentrations remain relatively low, cadmium is highly toxic and warrants confirmatory analysis and routine monitoring.
Lead (Pb^{2+})	ND–0.004 µg/L	GW1 complies and GW2 equals the guideline value, while GW3, GW4 and GW5 show slight exceedances. The elevated concentrations are minor but justify continued monitoring.
Zinc (Zn^{2+})	0.08–0.26 mg/L	All samples comply. Zinc occurs at natural background concentrations and presents no environmental concern.
Iron (Fe^{2+})	0.02–0.38 mg/L	Only GW1 complies. GW2, GW3, GW4 and GW5 exceed the FMEnv limit. Elevated iron is most likely associated with natural weathering of iron-rich Basement Complex rocks rather than anthropogenic pollution.
Nickel (Ni^{2+})	ND–0.005 mg/L	All samples comply. Low nickel concentrations indicate favourable groundwater quality and the absence of nickel contamination.
Cobalt (Co^{2+})	0.004–0.008 mg/L	All samples comply. Cobalt occurs at natural background concentrations with no evidence of localized contamination.
Mercury (Hg)	ND–0.013 mg/L	GW1 complies and GW2 equals the guideline value, while GW3, GW4 and GW5 exceed the FMEnv limit. The elevated concentrations require continued monitoring because of mercury's toxicity and bioaccumulation potential.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Organic Characteristics

Organic contaminants are important indicators of groundwater quality because they provide information on possible contamination arising from petroleum products, industrial chemicals, domestic wastewater, agricultural activities and other anthropogenic sources. Owing to the natural filtration processes that occur as water percolates through soil and geological formations, groundwater generally contains lower concentrations of organic contaminants than surface water. The organic parameters analysed during this study included phenols, oil and grease, benzene, toluene, ethylbenzene and xylene (BTEX). Collectively, the results indicate that the groundwater possesses excellent organic quality, with all analysed parameters complying with the applicable FMEnv guideline values.

Phenols

Phenolic compounds comprise a group of aromatic organic substances that may originate from petroleum products, industrial discharges, decomposition of organic matter, agricultural activities and domestic wastewater. Elevated phenol concentrations may impart objectionable taste and odour to water and exhibit toxic effects on aquatic organisms and humans. Consequently, phenols are routinely monitored during groundwater quality assessments. The measured phenol concentrations were 0.025 mg/L at GW1, 0.011 mg/L at GW2, 0.009 mg/L at GW3, 0.017 mg/L at GW4 and 0.022 mg/L at GW5. All measured concentrations comply with the FMEnv permissible limit of 0.05 mg/L. The relatively low phenol concentrations indicate that the groundwater has not been affected by significant petroleum contamination, industrial effluents or organic chemical pollution. The slightly higher concentration observed at GW1 remains well below the regulatory limit and most likely reflects natural background conditions associated with the decomposition of organic matter within the overlying soil profile. The generally uniform

distribution across the sampling locations further suggests that phenolic compounds occur only at naturally occurring trace concentrations.

Oil and Grease

Oil and grease comprise petroleum hydrocarbons, lubricants, fats and related substances that commonly enter water bodies through fuel spills, machinery maintenance, industrial activities and improper waste disposal. The presence of oil and grease in groundwater is generally regarded as an indication of contamination because hydrocarbons are not naturally abundant within uncontaminated aquifers. Laboratory analysis showed that oil and grease were not detected (0.00 mg/L) in any of the groundwater samples. All five sampling locations therefore comply fully with the FMEnv permissible limit of 10 mg/L. The complete absence of detectable oil and grease demonstrates that the groundwater has not been impacted by petroleum spills, fuel leakage or hydrocarbon migration. This finding establishes an excellent baseline condition prior to commencement of the proposed REA Solar Photovoltaic Project and indicates that the aquifer remains well protected from surface-derived hydrocarbon contamination.

Benzene

Benzene is one of the principal volatile aromatic hydrocarbons found in petroleum fuels and is regarded as a priority environmental pollutant because of its carcinogenic properties. Even very low concentrations may indicate contamination associated with fuel storage, transportation or industrial activities. The laboratory analysis indicated that benzene was not detected (0.00 mg/L) in GW1, GW2, GW3, GW4 and GW5. These results comply fully with the FMEnv permissible limit of 0.01 mg/L. The absence of benzene demonstrates that the groundwater has not been affected by gasoline contamination or petroleum-derived hydrocarbons. This observation further confirms the integrity of the groundwater system and agrees with the absence of detectable oil and grease.

Toluene

Toluene is a volatile aromatic hydrocarbon commonly associated with petroleum products, industrial solvents and fuel storage facilities. Similar to benzene, its occurrence in groundwater generally indicates anthropogenic hydrocarbon contamination. The laboratory analysis showed that toluene was not detected (0.000 mg/L) in any of the groundwater samples. These concentrations comply comfortably with the FMEnv permissible limit of 0.7 mg/L. The complete absence of toluene indicates that the groundwater has not experienced contamination from petroleum products, solvent disposal or industrial activities. The results further reinforce the conclusion that hydrocarbon pollution is absent within the investigated aquifer.

Ethylbenzene

Ethylbenzene is another constituent of petroleum fuels and forms part of the BTEX group of volatile organic compounds. It is commonly monitored because of its association with fuel contamination and industrial activities. The laboratory results indicated that ethylbenzene was not detected (0.00 mg/L) in GW1, GW2, GW3, GW4 and GW5. All measured concentrations comply fully with the FMEnv permissible limit of 0.30 mg/L. The absence of ethylbenzene confirms that

the groundwater has not been influenced by petroleum hydrocarbon contamination and further demonstrates the favourable organic quality of the aquifer.

Xylene

Xylene comprises a group of aromatic hydrocarbons widely used in petroleum products, paints and industrial solvents. Like the other BTEX compounds, xylene is frequently monitored during groundwater investigations because its presence generally reflects hydrocarbon contamination. Laboratory analysis indicated that xylene was not detected (0.00 mg/L) in any of the groundwater samples. The measured concentrations therefore comply fully with the FMEnv permissible limit of 0.50 mg/L. The absence of xylene further confirms that the groundwater has not been affected by petroleum products or industrial solvents. Together with the absence of benzene, toluene, ethylbenzene and oil and grease, these results demonstrate that the aquifer remains free from hydrocarbon contamination.

Implications for the Proposed Project

The baseline organic characteristics demonstrate that the proposed REA Solar Photovoltaic Project will commence within an uncontaminated groundwater environment. Nevertheless, construction activities have the potential to introduce organic contaminants through accidental fuel spills, leakage of lubricants and hydraulic fluids, improper storage of chemicals and poor waste management practices. To preserve the existing groundwater quality, fuels, lubricants and hazardous chemicals should be stored within designated bunded areas equipped with secondary containment facilities. Equipment maintenance should be carried out only within approved maintenance areas, while spill response procedures should be established and implemented throughout the construction phase. Construction personnel should also ensure that wastewater and domestic refuse are properly managed to prevent infiltration into the groundwater system. Routine groundwater monitoring should include phenols and petroleum hydrocarbons throughout the construction and operational phases to verify that project activities do not adversely affect groundwater quality.

Table 4.39: Summary of Groundwater Organic Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Phenols	0.009–0.025 mg/L	All samples comply. Low phenol concentrations indicate natural background conditions with no evidence of significant petroleum contamination, industrial effluents or organic chemical pollution.
Oil and Grease	Not detected (0.00 mg/L)	All samples comply. The absence of oil and grease indicates that the groundwater has not been impacted by petroleum spills, fuel leakage or hydrocarbon migration.
Benzene	Not detected (0.00 mg/L)	All samples comply. No evidence of gasoline contamination or petroleum-derived hydrocarbon pollution was observed.
Toluene	Not detected (0.000 mg/L)	All samples comply. The absence of toluene indicates that the groundwater has not been affected by petroleum products, industrial solvents or fuel storage activities.
Ethylbenzene	Not detected (0.00 mg/L)	All samples comply. No evidence of petroleum hydrocarbon contamination or industrial solvent inputs was identified.
Xylene	Not detected (0.00 mg/L)	All samples comply. The absence of xylene confirms favourable groundwater organic quality and the lack of hydrocarbon contamination.

Microbiological Characteristics

Microbiological quality is a critical component of groundwater assessment because it provides information on the sanitary integrity of an aquifer and the potential presence of disease-causing microorganisms. Unlike surface water, groundwater is naturally protected by overlying soil and geological formations that filter microorganisms during infiltration. Consequently, properly protected groundwater is generally expected to contain very low or undetectable concentrations of faecal indicator bacteria. The microbiological assessment of the groundwater evaluated Escherichia coli (E. coli) and Total Coliform bacteria, both of which are internationally recognized indicators of faecal contamination and the microbiological safety of drinking water. The laboratory results demonstrate excellent microbiological quality, with all groundwater samples complying with the applicable FMEnv standards.

Escherichia coli (E. coli)

Escherichia coli (E. coli) is regarded as the most reliable microbiological indicator of recent faecal contamination because it originates almost exclusively from the intestinal tracts of humans and warm-blooded animals. The presence of E. coli in groundwater indicates that pathogenic microorganisms may also be present and that the water may have been contaminated through sewage infiltration, leaking septic systems, livestock activities or other sources of faecal pollution. Laboratory analysis showed that E. coli was not detected (0 cfu/mL) in any of the groundwater samples, including GW1, GW2, GW3, GW4 and GW5. These results comply fully with the FMEnv requirement of nil detection. The complete absence of E. coli demonstrates that the groundwater has not experienced recent faecal contamination and indicates that the aquifer is effectively protected from direct infiltration of sewage or animal wastes. This finding also suggests that the groundwater abstraction points are generally well sited and that the overlying geological formations provide effective natural filtration against microbial contaminants. The absence of E. coli represents one of the strongest indicators of the favourable sanitary quality of the groundwater and substantially enhances its suitability as a potential potable water source, subject to compliance with the other physicochemical and chemical quality parameters.

Total Coliform

Total coliform bacteria comprise a broad group of microorganisms commonly found in soil, vegetation and the intestinal tracts of warm-blooded animals. Although not all total coliform organisms are pathogenic, their presence provides useful information on the sanitary integrity of groundwater systems and the effectiveness of natural filtration processes. The measured total coliform counts were 3 cfu/mL at GW1, 6 cfu/mL at GW2, 8 cfu/mL at GW3, 2 cfu/mL at GW4 and 1 cfu/mL at GW5. The FMEnv permissible limit is 10 cfu/mL. All five groundwater samples comply fully with the applicable regulatory standard. GW3 recorded the highest total coliform count of 8 cfu/mL, while GW5 exhibited the lowest count of 1 cfu/mL. Although low numbers of total coliform bacteria were detected, the concentrations remain well within acceptable limits and are not unusual in shallow groundwater systems where naturally occurring environmental bacteria may occasionally be present. The relatively low total coliform counts, together with the complete absence of E. coli, indicate that the detected bacteria most likely represent naturally occurring environmental microorganisms rather than evidence of faecal contamination. Consequently, the microbiological quality of the groundwater may be considered satisfactory.

Implications for the Proposed Project

The favourable microbiological quality establishes an important baseline prior to commencement of the proposed REA Solar Photovoltaic Project. Construction activities should therefore be carefully managed to prevent deterioration of the existing groundwater quality. Temporary sanitary facilities should be located well away from boreholes and groundwater abstraction points, while domestic wastewater generated during construction should be properly collected and treated. Fuel storage areas, waste disposal sites and chemical storage facilities should also be located at safe distances from groundwater sources to minimize the risk of accidental contamination. The integrity of borehole heads should be maintained through proper sealing, concrete aprons and effective surface drainage to prevent contaminated runoff from entering the groundwater system. Routine inspection and maintenance of boreholes, storage tanks and distribution facilities should also be undertaken throughout the project lifecycle. Periodic microbiological monitoring, including E. coli and total coliform analyses, should be incorporated into the environmental monitoring programe to ensure that the favourable groundwater conditions are maintained during construction, operation, and decommissioning.

Table 4.40: Summary of Groundwater Microbiological Characteristics

Parameter	Observed Results	Interpretation / Environmental Significance
Escherichia coli (*E. coli*)	Not detected (0 cfu/mL) in all groundwater samples	All samples comply. The absence of *E. coli* indicates that the groundwater has not been impacted by recent faecal contamination and that the aquifer is effectively protected from sewage infiltration and other faecal pollution sources.
Total Coliform	1–8 cfu/mL	All samples comply. Low total coliform counts indicate satisfactory sanitary quality and are consistent with naturally occurring environmental bacteria rather than faecal contamination. The results confirm the effectiveness of natural subsurface filtration.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.41: Summary of Overall Groundwater Quality Interpretation

Groundwater Quality Category	Overall Status	Key Findings / Interpretation
Physical and Physicochemical Quality	**Generally Good**	The groundwater is clear, odourless, tasteless, fresh and weakly mineralized, with very low conductivity, turbidity, TDS, salinity, BOD and COD. Slight acidity was observed at GW4 and GW5, while minor TSS exceedances occurred in GW1, GW2 and GW5. Overall, the groundwater exhibits good physicochemical quality.
Chemical Quality (Major Ions)	**Generally Good**	Most major ions comply with FMEnv standards. Calcium, magnesium, potassium, nitrate, sulphate and chloride occur at very low concentrations characteristic of fresh groundwater. Minor nitrite exceedances were recorded in GW1, GW3, GW4 and GW5, suggesting localized nitrogen transformation rather than widespread contamination.
Heavy Metal Quality	**Generally Good with Localized Concerns**	Copper, chromium, zinc, nickel and cobalt comply with FMEnv standards. Cadmium exceeded the reported guideline value in all samples, while iron exceeded the

Groundwater Quality Category	Overall Status	Key Findings / Interpretation
		limit in GW2–GW5. Minor lead and mercury exceedances were observed in some locations. The overall distribution suggests predominantly natural geological influence rather than significant anthropogenic contamination.
Organic Quality	**Excellent**	All analysed organic parameters comply with FMEnv guideline values. Oil and grease, benzene, toluene, ethylbenzene and xylene were not detected, while phenol concentrations remained low and within permissible limits, indicating an uncontaminated groundwater system free from petroleum hydrocarbon pollution.
Microbiological Quality	**Excellent**	*Escherichia coli* was not detected in any groundwater sample, and total coliform counts remained well below the FMEnv permissible limit. These results demonstrate excellent sanitary quality and effective natural filtration within the aquifer.
Overall Environmental Condition	**Good Baseline Groundwater Quality**	The groundwater exhibits good overall quality, characterized by favourable physicochemical, chemical, organic and microbiological characteristics. The principal concerns are localized slight acidity, minor nitrite exceedances and elevated concentrations of cadmium, iron, lead and mercury in some samples, most of which are likely associated with natural hydrogeochemical conditions.
Suitability for Potable Use	**Generally Suitable Following Appropriate Treatment**	The groundwater possesses excellent microbiological quality and generally favourable chemical characteristics. However, localized acidity and the exceedance of cadmium, iron, lead and mercury in some samples indicate that treatment and confirmatory monitoring are advisable before potable use.
Suitability for Domestic, Agricultural and Construction Uses	**Suitable**	The fresh, weakly mineralized nature of the groundwater, together with its low salinity, low dissolved solids and excellent organic quality, makes it suitable for domestic non-potable uses, agricultural applications and construction purposes, subject to appropriate management where potable use is intended.
Implications for the Proposed REA Project	**Suitable with Groundwater Protection Measures**	The results establish a reliable baseline prior to project implementation. Groundwater quality should be protected through effective spill prevention, proper storage of fuels and chemicals, wastewater management, borehole protection and routine monitoring of pH, nitrite, iron, cadmium, lead, mercury and microbiological parameters throughout the construction, operation and decommissioning phases of the project.

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

4.5 Ecological Baseline of the Study Area (Biodiversity/Flora and Fauna)

According to the convention on Biological Diversity, Biodiversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic systems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems". Biodiversity considerations are very important in environmental management. Many developmental activities are likely to play a major role in the overall reduction of biodiversity; hence there is need for proper understanding of the existing environmental setting in terms of habitat types, selected flora and fauna species, endangered or threatened species. This will help in developing mitigation measures for protecting and conserving biodiversity, maintaining ecosystem services and sustainably managing the living natural resources. This section presents a description of the terrestrial flora and fauna and other natural resources and habitats constituting the biological environmental setting.

4.5.1 Vegetation (Terrestrial Flora) Characteristics

A reconnaissance survey of the proposed 2MW Solar Hybrid Power Project site and its surrounding environment was undertaken to establish the existing terrestrial flora and fauna as well as habitat conditions. The survey, supported by direct field observations and photographic documentation, indicates that the project area lies within the Northern Guinea Savannah ecological zone of Kaduna State. The vegetation is typical of a disturbed savannah landscape characterized by cultivated farmland, open grassland, scattered shrubs, isolated mature trees, seasonal drainage channels and fallow agricultural fields.

The proposed project site itself is predominantly open with sparse herbaceous vegetation and patches of exposed lateritic soil resulting from previous land preparation and anthropogenic disturbances. The surrounding landscape consists largely of cultivated farmlands interspersed with secondary vegetation and remnant woody species. No primary forest, riparian forest, protected woodland or ecologically sensitive vegetation communities were observed within the proposed development footprint. Vegetation density increases away from the immediate project footprint, particularly along seasonal drainage depressions and low-lying areas where shrubs and small trees occur in relatively denser clusters. The field survey also revealed mature scattered trees within cultivated fields, with several trees supporting large active termite mounds around their bases. These mature trees provide shade and contribute to the ecological integrity of the surrounding landscape.

Table 4.42: Major Habitat Types within the Project Area

Habitat Type	Description	Ecological Significance
Cultivated Farmland	Dominant land cover comprising actively cultivated maize fields, harvested plots and areas under land preparation.	Provides agricultural production but supports limited natural vegetation.
Open Savannah Grassland	Open grassland dominated by grasses, annual herbs and scattered shrubs.	Supports livestock grazing and maintains ground cover against erosion.
Shrubland and Secondary Vegetation	Regenerating woody shrubs, grasses and climbers occurring mainly along seasonal drainage channels and uncultivated areas.	Provides habitat, ecological connectivity and natural regeneration.

Habitat Type	Description	Ecological Significance
Scattered Mature Trees	Isolated indigenous and exotic trees dispersed within cultivated fields and open savannah.	Provide shade, microclimate regulation, carbon sequestration and habitat for associated fauna.

Source: Bolben Ltd. Fieldwork Survey, 2026.

4.5.1.1 Habitat Description

Based on field observations, the vegetation within and around the project area can be classified into the following habitat types:

Cultivated Farmland

This constitutes the dominant land cover surrounding the proposed project site. The fields were actively cultivated with cereal crops, particularly maize, while some portions were recently harvested or under land preparation. Farming activities have significantly modified the original vegetation structure.



Plate 4.8: Maize farm around project AoI.

Open Savannah Grassland

Open grassland occurs extensively around the project area and is characterized by short grasses mixed with annual herbs and scattered shrubs. The photographs obtained during the survey also showed active grazing by cattle within these grasslands, indicating that the habitat serves both agricultural and livestock production purposes.



Plate 4.9: Open Grazing around project AoI.

Shrubland and Secondary Vegetation

Areas adjoining the seasonal drainage channels contain dense shrub vegetation composed of regenerating woody species, grasses and climbers. These secondary growth communities represent previously disturbed vegetation undergoing natural regeneration.



Plate 4.10: Shrub Land within the AFIT Kaduna

Scattered Mature Trees

Several mature indigenous trees occur as isolated individuals within cultivated fields and open savannah. These trees provide shade and contribute to landscape diversity. Large active termite mounds were observed around some of these trees, indicating active biological processes and long-term ecological stability within portions of the landscape.

4.5.1.2 Floral Composition

The vegetation observed during the survey comprised predominantly Guinea Savannah species commonly associated with northern Nigeria. The vegetation observed during the field survey is representative of the Northern Guinea Savannah ecosystem commonly found across Kaduna State and northern Nigeria. Field observations identified a mixture of indigenous and introduced plant species comprising mature trees, shrubs, herbaceous vegetation and cultivated crops. The dominant vegetation recorded during the survey includes the following:

Trees

- Shea Tree (*Vitellaria paradoxa*)
- African Locust Bean (*Parkia biglobosa*)
- Neem (*Azadirachta indica*)
- Mango (*Mangifera indica*)
- Fan Palm (*Borassus aethiopum*)
- Jujube (*Ziziphus* spp.)
- Various indigenous savannah tree species

Shrubs

- Mixed secondary woody shrubs
- Regenerating savannah shrub species
- Seasonal bush vegetation

Herbaceous Vegetation

- Guinea Savannah grasses
- Annual herbs
- Broadleaf weeds
- Agricultural weeds commonly associated with cultivated fields

Cultivated Crops

- Maize (*Zea mays*)
- Other seasonal food crops observed within neighbouring farmlands

Table 4.43: Dominant Flora Recorded During the Field Survey

Vegetation Category	Species/Type Observed	Scientific Name
Tree	Shea Tree	*Vitellaria paradoxa*
Tree	African Locust Bean	*Parkia biglobosa*
Tree	Neem	*Azadirachta indica*
Tree	Mango	*Mangifera indica*
Tree	Fan Palm	*Borassus aethiopum*
Tree	Jujube	*Ziziphus* spp.
Tree	Indigenous Savannah Trees	Various species
Shrubs	Secondary Woody Shrubs	Various species
Shrubs	Regenerating Savannah Shrubs	Various species
Shrubs	Seasonal Bush Vegetation	Various species
Herbaceous Vegetation	Guinea Savannah Grasses	Various species
Herbaceous Vegetation	Annual Herbs	Various species
Herbaceous Vegetation	Broadleaf Weeds	Various species
Herbaceous Vegetation	Agricultural Weeds	Various species
Cultivated Crop	Maize	*Zea mays*
Cultivated Crop	Seasonal Food Crops	Various species

Table 4.44: Some Floral Species Recorded around the project area with their IUCN Status

S/N	Scientific Name	Common Name	Family	IUCN Status	Endemic Status	Growth Form	Uses
1	*Azadirachta*	Neem	Meliaceae	LC	Non-endemic	Tree	Medicinal, shade
2	*Adansonia*	Baobab	Malvaceae	LC	Non-endemic	Tree	Food,
3	*Isoberlinia doka*	–	Fabaceae	LC	Non-endemic	Tree	Timber, medicinal
4	*Amaranthus*	Spiny amaranth	Amaranthaceae	LC	Non-endemic	Herb	Food,
5	*Mangifera indica*	Mango	Anacardiaceae	LC	Non-endemic	Tree	Food
6	*Calotropis*	Sodom	Apocynaceae	LC	Non-endemic	Shrub	Medicinal
7	*Balanites*	Desert date	Zygophyllaceae	LC	Non-endemic	Tree	Food,
8	*Guiera*	–	Combretaceae	LC	Non-endemic	Shrub	Medicinal
9	*Chamaecrista mimosoides*	Cassia	Fabaceae	LC	Non-endemic	Herb	Medicinal
10	*Crotalaria*	Rattlebox	Fabaceae	LC	Non-endemic	Shrub	Soil improvement
11	*Mimosa pigra*	Giant	Fabaceae	LC	Non-endemic	Shrub	Invasive, medicinal
12	*Mesosphaerum suaveolens*	Bush mint	Lamiaceae	LC	Non-endemic	Herb	Medicinal
13	*Bombax costatum*	Red kapok	Malvaceae	LC	Non-endemic	Tree	Medicinal
14	*Sida cordifolia*	Flannel	Malvaceae	LC	Non-endemic	Shrub	Medicinal
15	*Sida acuta*	Wire weed	Malvaceae	LC	Non-endemic	Herb	Medicinal
16	*Vachellia nilotica*	Gum tree	Fabaceae	LC	Non-endemic	Tree	Fodder, medicinal
17	*Moringa oleifera*	Moringa	Moringaceae	LC	Non-endemic	Tree	Food,
18	*Eucalyptus camaldulensis*	River red	Myrtaceae	LC	Non-endemic	Tree	Timber
19	*Cenchrus biflorus*	Kram-kram grass	Poaceae	LC	Non-endemic	Grass	Fodder
20	*Anacardium occidentale*	Cashew	Anacardiaceae	LC	Non-endemic	Tree	Food
21	*Annona*	Wild apple	Annonaceae	LC	Non-endemic	Shrub	Food
22	*Anogeissus*	African	Combretaceae	LC	Non-endemic	Tree	Timber
23	*Daniellia oliveri*	African copaiba	Fabaceae	LC	Non-endemic	Tree	Medicinal
24	*Gmelina arborea*	Gmelina	Lamiaceae	LC	Non-endemic	Tree	Timber

S/N	Scientific Name	Common Name	Family	IUCN Status	Endemic Status	Growth Form	Uses
25	*Ageratum conyzoides*	Goat weed	Asteraceae	LC	Non-endemic	Herb	Medicinal
26	*Saccharum officinarum*	Sugarcane	Poaceae	LC	Non-endemic	Grass	Food
27	*Chromolaena odorata*	Siam weed	Asteraceae	LC	Non-endemic	Shrub	Invasive
28	*Khaya*	African mahogany	Meliaceae	VU	Non-endemic	Tree	Timber
29	*Lophira*	Ironwood	Ochnaceae	LC	Non-	Tree	Timber

4.5.2 Faunal Composition

Faunal observations recorded during the field survey were characteristic of a disturbed Guinea Savannah agroecosystem. The most conspicuous vertebrate fauna observed within and around the proposed project area were grazing cattle, confirming that portions of the surrounding landscape are utilised for livestock grazing alongside crop cultivation. The survey also recorded numerous active termite mounds distributed across the project area and its surroundings, particularly around mature trees and within open grassland. These mounds are indicative of active termite colonies (*Macrotermes* spp.), which contribute significantly to soil aeration, organic matter decomposition, nutrient recycling and improvement of soil structure. The abundance of termite mounds further reflects the ecological importance of soil macrofauna within the Guinea Savannah ecosystem. Apart from grazing livestock and termite colonies, no other wildlife species were directly observed during the field survey. Likewise, no evidence of breeding sites, wildlife corridors, nesting colonies or habitats of conservation significance was encountered within the proposed project footprint.

Table 4.45: Fauna Observed During the Field Survey

Faunal Group	Observation	Ecological Importance
Livestock	Grazing cattle	Demonstrates active livestock utilization of the surrounding grassland and farmland.
Invertebrates	Active termite mounds (*Macrotermes* spp.)	Contribute to soil aeration, nutrient recycling, organic matter decomposition and soil structure improvement.

Source: Bolben Ltd. Fieldwork Survey, 2026.

Table 4.46: Some Faunal Species Around the Project Area

Scientific Name	Common Name	IUCN Status	Endemic Status
Avifauna			
Milvus migrans	Yellow-billed Kite	LC	Not endemic
Corvus albus	Pied Crow	LC	Not endemic
Pycnonotus barbatus	Common Bulbul	LC	Not endemic
Passer griseus	Northern Grey-headed Sparrow	LC	Not endemic
Ploceus cucullatus	Village Weaver	LC	Not endemic
Spermestes cucullata	Bronze Mannikin	LC	Not endemic

Scientific Name	Common Name	IUCN Status	Endemic Status
Streptopelia semitorquata	Red-eyed Dove	LC	Not endemic
Streptopelia vinacea	Vinaceous Dove	LC	Not endemic
Columba guinea	Speckled Pigeon	LC	Not endemic
Turtur afer	Blue-spotted Wood Dove	LC	Not endemic
Halcyon senegalensis	Woodland Kingfisher	LC	Not endemic
Halcyon malimbica	Blue-breasted Kingfisher	LC	Not endemic
Bubulcus ibis	Cattle Egret	LC	Not endemic
Ardea cinerea	Grey Heron	LC	Not endemic
Butorides striata	Striated Heron	LC	Not endemic
Phalacrocorax africanus	Reed Cormorant	LC	Not endemic
Scopus umbretta	Hamerkop	LC	Not endemic
Coracias abyssinicus	Abyssinian Roller	LC	Not endemic
Falco tinnunculus	Common Kestrel	LC	Not endemic
Kaupifalco monogrammicus	Lizard Buzzard	LC	Not endemic
Tockus nasutus	African Grey Hornbill	LC	Not endemic
Lamprotornis caudatus	Long-tailed Glossy Starling	LC	Not endemic
Prinia subflava	Tawny-flanked Prinia	LC	Not endemic
Camaroptera brevicaudata	Grey-backed Camaroptera	LC	Not endemic
Cyanomitra olivacea	Olive Sunbird	LC	Not endemic
Cinnyris venustus	Variable Sunbird	LC	Not endemic
Tchagra senegalus	Black-crowned Tchagra	LC	Not endemic
Pternistis bicalcaratus	Double-spurred Francolin	LC	Not endemic
Mammals			
Thryonomys swinderianus	Grasscutter	LC	Not endemic
Cricetomys gambianus	Gambian Giant Rat	LC	Not endemic
Xerus erythropus	Striped Ground Squirrel	LC	Not endemic
Eidolon helvum	Straw-coloured Fruit Bat	LC	Not endemic
Reptiles			
Agama agama	Common Agama	LC	Not endemic
Trachylepis perrotetii	Savanna Skink	LC	Not endemic

Source: Bolben Ltd. Fieldwork Survey, 2026.

4.5.3 Ecological Condition

The vegetation and faunal communities within the project area have been substantially influenced by long-term agricultural activities, livestock grazing and other human disturbances. Consequently, the habitat is considered to be of low to moderate ecological sensitivity. Most of the original savannah vegetation has been replaced by cultivated farmland and secondary regrowth, with only scattered mature trees remaining across the landscape. No rare, threatened or endangered plant species were observed during the field survey. Similarly, no protected or endangered wildlife species were recorded. Likewise, no protected forests, wetlands, critical habitats or areas of high conservation importance were identified within the proposed project footprint. The scattered mature trees, shrub patches, seasonal drainage vegetation and active termite colonies nevertheless contribute to local ecological functions by supporting soil formation processes, nutrient cycling and maintaining the ecological stability of the surrounding environment.

Evidence of Human Activities

The survey revealed widespread anthropogenic activities within the project area and its surroundings, including:

- Rain-fed subsistence farming.
- Land clearing and cultivation.
- Livestock graze by cattle.
- Footpaths and informal access routes.
- Scattered residential structures and farm settlements.
- Existing institutional developments associated with the Air Force Institute of Technology (AFIT).
- Ongoing infrastructure development and earthworks within parts of the surrounding landscape.

These activities have contributed to habitat fragmentation and reduced the natural vegetation cover across much of the area while promoting secondary vegetation and agricultural land use.

4.5.3.1 Ecological Significance

Overall, the proposed project site comprises a modified Guinea Savannah ecosystem dominated by agricultural land use and secondary vegetation. The floral communities are representative of common savannah vegetation widely distributed across Kaduna State and northern Nigeria, while the faunal component recorded during the survey was dominated by grazing cattle and abundant termite colonies. The vegetation provides local ecosystem services including erosion control, carbon sequestration, microclimate regulation and maintenance of soil stability, whereas termite activity contributes to nutrient recycling, soil aeration and organic matter decomposition. Given the absence of unique vegetation communities, protected habitats, threatened flora or fauna, or other species of conservation concern, the ecological value of the project area is considered **low to** moderate. Consequently, the anticipated impacts associated with vegetation clearance are expected to be site-specific, localized and readily mitigated through implementation of appropriate vegetation management and ecological restoration measures during project implementation. This baseline description provides the reference condition against which potential project-related impacts on terrestrial flora and fauna will be assessed in subsequent sections of the ESIA.

Table 4.47: Summary of Ecological Characteristics

Ecological Attribute	Observation
Ecological Zone	Northern Guinea Savannah
Dominant Vegetation	Secondary savannah vegetation, cultivated farmland, grasses, shrubs and scattered mature trees
Dominant Land Use	Agriculture and livestock grazing
Flora Diversity	Common Guinea Savannah species
Fauna Observed	Grazing cattle and active termite colonies
Protected Vegetation	None observed
Protected Wildlife	None observed
Wetlands/Riparian Forest	None observed within the project footprint
Conservation Status	Low to moderate ecological sensitivity
Overall Ecological Value	Modified agricultural savannah ecosystem with localized ecological functions

4.6 Socioeconomics

The socio-economic survey collated baseline socio-cultural, economic and infrastructural indices of the study areas, while the consultation process elicited responses on stakeholders' concerns and expectations from the proposed project. This study is an integral part of environmental and social impacts management and overall sustainable development arrangement. The objectives of the socio-economic survey include:

- Study and documentation of the socio-economic and cultural situation of the project area.
- Determining the impacts of the project on settlements, cultural treasures, population, social and physical infrastructures, predominant economic structures and the baseline health status of the people.
- Documenting the views of the affected population, industries and other relevant institutions/agencies in terms of environmental problems, perceived community problems and needs; and
- The engagement of stakeholders, with a view:
    - to enabling the stakeholders, understand the project processes and cycle.
    - to consider the views and opinions of stakeholders concerning the construction, operation and decommissioning of the project.
    - to develop and maintain a robust relationship with the government and the project affected communities
    - to prevent any form of social unrest among various levels of stakeholders that might arise from the development of the proposed project.

4.6.1 Scope of Study

The study was conducted in AFIT Kaduna and other surrounding areas within the 5Km radius of the project location. It covered the socio-cultural resources of these communities, demographic issues including population and growth, age and sex distribution, and adult literacy. Others were such indicators of the quality of life of the residents as quality of housing, access to potable water, availability of functional infrastructural amenities, livelihood activities and patterns, and income levels. Health facilities and their patronage, disease prevalence and disease vectors, water and sanitation, and nutrition were also studied. Additionally, the study discusses the perceptions, concerns and expectations of members and residents of these communities and establishes the proposed project's potential impacts.

4.6.2 Study Approach

The EIA guideline has made it mandatory to consult communities on the possible impact of a proposed project. It is also binding to integrate community views at the project design stage. Socio-economic and community health impact assessment tools are designed to integrate the desires and aspirations of the community with those of the project proponent. In line with the EIA objectives, wide consultations were held and community aspirations were recorded.
Public forums were held with the aim of creating more awareness on the proposed project and to prompt community support. The views expressed at the public forums are also an integral part of this report. The photographs taken at the forums are attached to this report.

This phase of study consisted of data collation on the baseline social and economic indices of the study area. Relevant data were presented under various subheadings, including social environment (Socio-cultural/psychological environment, demography, education and literacy, quality of life,

poverty and inequality, human development indices); economic survey (production factors, labour force participation, employment/unemployment, and market survey).

The consultation for the socio-economic impact assessment of the proposed project consisted of a two-tier process:

i. **Reconnaissance** visits to key community stakeholders (political leaders, traditional rulers and civic leaders). This was done for legitimate purposes, as to secure permission and cooperation for the study; and
ii. **Direct Consultation** with Identified Stakeholders. This phase consisted of the utilization of participatory tools to elicit information from stakeholders on community baseline data, expected impacts (direct/indirect, adverse/beneficial, short/long term etc). Attempts were also made to ascertain stakeholders' concerns as well as identify areas by which affected communities may be assisted by project proponent alone, or in conjunction with relevant NGOs and government agencies at various levels.

4.6.3 Sampling Procedure and Data Collection Techniques

In obtaining socio economic data of the project area, the exploratory survey method was adopted. This involved key informant interviews, group interviews using structured questionnaires. A "key informant" is generally a person adjudged to have good knowledge of the area under study, community leader, youth leader, a traditional ruler, an opinion leader etc. the questionnaire used in obtaining socio economic data employed a combination of "open-ended" and "closed" questionnaire format. Open-ended questions are more suitable for qualitative data while closed questions are more suitable for quantitative data. Simple random and purposive techniques were employed in sampling of the population of the study area.

Qualitative data were generated through informed meetings and also observation in small groups of stakeholders in the various communities with diverse socio-economic background and interest. Such groups include Age grade, Farmers group, Market women and Youth Associations. Each group meeting focused first on political/administrative structure of the community/population characteristics, ethnic composition, and existing infrastructural facilities, predominant occupation as well as cultural practice and treasures.

4.6.4 Sources of Data

Primary and secondary sources were used for the survey. The research instruments employed for the survey were basically:

i. Desk reviews of available secondary data.
ii. Direct Observation
iii. Individual Interview
iv. Questionnaire Administration
v. Focus Group discussion and
vi. Maps and published literatures (journals)

Mode of Data Collection for Socio – Economic Survey

The survey was conducted through constructed questionnaires which were administered by trained personnel in order to get the desired result. The target area coverage for the survey is three (3km) kilometer radius from the centre of the site.

A total of forty-nine (49) questionnaires were administered and distributed within 3km radius of the proposed project site. The population of the area was the key determinant of the number of questionnaires distributed in the area.

Questionnaire administration covered available AFIT academic and non-academic staff, students who were present during the field exercise, and respondents from adjoining communities within the project area of influence. The community component was included to ensure that the socio-economic baseline reflected both the institutional population and nearby social receptors that may experience direct or indirect project-related effects.

See Plate 4.11 to 4.13 for pictorial evidence of Socio-economic activities…
For more pictures of stakeholder engagement see Appendix V…



Plate 4.11: Socio-economic Questionnaire Administration at the AFIT Library



Plate 4.12: AFIT Engineering Student Participating in the Socio-economic Survey



Plate 4.13: : Socio-economic Questionnaire Administration to Members of an Adjoining Community

Primary Sources

The administered questionnaires were employed to gather quantitative information concerning household, institutional and communal characteristics, while direct observation, individual interviews and group discussions were used to assess stakeholder concerns regarding the social, economic and health implications of the proposed 2 MW Solar Hybrid Power Project, as well as expectations from the project proponent and relevant authorities.

Secondary Sources

In instances where primary sources could not provide the required data, secondary sources were relied upon. At the community level, secondary information was obtained from desk reviews and available institutional or government records relevant to the project area. Information was also obtained from national data sources including the National Population Commission (NPC), National Bureau of Statistics (NBS), electronic maps and relevant Kaduna State Government sources, as well as international sources such as the World Bank, United Nations (UN) and African Development Bank (AfDB).

4.6.5 Analytical Techniques

Descriptive statistics were utilized to analyze collated data. These included means, percentages, frequency tables and charts. Data collected on various socio-economic parameters from all the affected areas were also analyzed using different tools as appropriate. The questionnaire survey involved sampling households within the community using a set of questionnaires.

Field Study Strategy

The field study comprised the following operations:

i. Pre-testing of questionnaires;
ii. Household listing;
iii. Field identification of households selected for interviews;

iv. Questionnaire administration and interview of key informants; and
v. Focus group discussions;

The socioeconomic baseline assessment was undertaken to understand the human environment within which the proposed solar project will operate. The study combined structured questionnaire administration, institutional consultations, and community engagement to capture perceptions, energy challenges, and expectations.

4.6.6 Sampled Population

This assessment presents the socio-economic profile of respondents within the project location and its area of influence. The information covers six (6) sections; (i) Basic Information, (ii) Health Status, (iii) Gender-Based Violence (GBV), (iv) Institutional/Community Utilities and Services Profile, (v) Traditional Practices and Cultural Heritage, (vi) Community Awareness, Perceived Benefits, and Social Associations.

The findings provide useful background for understanding the structure of the project area. The information can also guide the project proponent, facility operators, and school authority in communication, employment planning, participation strategies, and general management decisions during the construction and operational phases of the proposed project.

A total of 49 questionnaires were administered across AFIT and adjoining communities within the study area, of which 41 were successfully retrieved. As AFIT was not in full academic session during the socio-economic exercise, participation within the institution was drawn from available academic and non-academic staff and students undergoing internship or training programs, while respondents from adjoining communities were also engaged as part of the wider socio-economic area of influence.

4.6.6.1 Population and Socio-Demographic Characteristics

Historical Overview of Project Location

Kaduna State is located in North-Western Nigeria and is the country's fourth-largest state by land area and one of its most economically and politically influential regions. Widely known by its official slogan, the "Centre of Learning," Kaduna serves as a major hub for commerce, agriculture, transportation, and military institutions in West Africa. It has an estimated population for 2026 as 11,434,034 and according to the data from the Kaduna State Bureau of Statistics, in 2025, Kaduna metropolis had a population of 2,092,957 for the 35 wards in Chikun, Igabi, Kaduna North and Kaduna South LGAs.

Igabi LGA

Igabi is a local government area known for its agricultural activities, with a significant portion of its population involved in farming, particularly the cultivation of crops such as maize, millet, and groundnuts and covers a land area of 1,557,862 sqm. The population of Igabi LGA stands at 449,660 citizens for the Afaka, Kwarau, Rigachikun, Rigasa and S/Birni districts that are within the impact corridor of the project area characterized by a mix of rural and urban settlements, The people of Igabi are known for their warm hospitality and strong cultural values, with various traditional events and festivals marking the region's rich heritage. The LGA's proximity to the city of Kaduna also makes it an important part of the state's economic and social fabric.

Demography of the Project Area

Gender of the Study Area

Table 4.48: Gender in the Study Area

Options	Frequency	Percent
Male	**26**	**65**
Female	**14**	**35**
Total Response	**40**	**100**

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Male respondents accounted for 65.0% (26), while female respondents accounted for 35.0% (14). Although more males participated in the survey, responses from both genders were captured and should be considered in planning communication, participation, and project-related activities. The participation of both genders ensures that the views and concerns of different stakeholder groups were adequately captured during the baseline assessment.

Age of Respondents

Table 4.49: Age of the Study Area

Options	Frequency	Percent
18-30 years	17	42.5
31-45 years	16	40
46-54 years	6	15
55 years and above	1	2.5
Total Response	**40**	**100**

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Most respondents were within the younger and economically active age groups. Respondents aged 18–30 years made up 42.5% (17), followed closely by those aged 31–45 years at 40.0% (16). Those aged 46–54 years represented 15.0% (6), while respondents aged 55 years and above accounted for 2.5% (1). The age distribution indicates that the study area is predominantly youthful, reflecting the educational setting of the Project Area. This demographic profile is expected to influence stakeholder interests, particularly with respect to improved infrastructure, employment opportunities during Project implementation, and skills development associated with the proposed Project.

Religion

Table 4.50: Religion of the Study Area

Options	*Frequency*	*Percent*
Christianity	23	62.2
Islam	14	37.8
Total Response	**37**	**100**

***Source**: Bolben Ltd. Fieldwork Survey, 2026.*

Christians made up 62.2% (23) of respondents, while Muslims made up 37.8% (14). This shows that the surveyed population includes respondents from both major religious groups, which should be reflected in the timing and approach of consultation activities. This religious diversity underscores the importance of implementing inclusive stakeholder engagement, consultation, and information dissemination processes that respect the beliefs and practices of all religious groups throughout the Project lifecycle. Overall, the religious composition of the Project Area provides a sound basis for planning culturally sensitive engagement and ensuring equitable participation in Project-related activities.

Education Attainment

Table 4.51: Educational Attainment in the study area

Options	*Frequency*	*Percent*
Informal education	1	2.9
Primary School	-	-
NCE/ND	4	11.4
HND/B.Sc	28	80
B.Eng	1	2.9
Ph.D	1	2.9
Total Response	**35**	**100**

Source: Bolben Ltd. Fieldwork Survey, 2026.

The respondents were generally educated. Most respondents, 80.0% (28), had HND/B.Sc. qualifications, while 11.4% (4) had NCE/ND qualifications. Informal education, B.Eng, and Ph.D. each accounted for 2.9% (1). This level of education is consistent with a university setting and is likely to support effective communication on project objectives, benefits, and safety measures. This educational profile is expected to facilitate effective stakeholder engagement, communication, and dissemination of Project-related information, as well as enhance community understanding of the Project's objectives, potential impacts, and proposed mitigation measures. Furthermore, the relatively high level of educational attainment provides a favourable basis for local participation in skilled employment, capacity-building initiatives, and the long-term sustainability of the proposed Project.

Occupation

Table 4.52: Occupation of the Study Area

Options	**Frequency**	**Percent**
Academic Staff	2	5.3
Non- academic Staff	19	50
Trader	1	2.6
Student	12	31.6
Military Personnel	4	10.5
Total Response	**38**	**100**

Source: Bolben Ltd. Fieldwork Survey, 2026.

Non-academic staff formed the largest group of respondents, with 19 respondents (50.0%). Students accounted for 12 respondents (31.6%), military personnel for 4 (10.5%), academic staff for 2 (5.3%), and traders for 1 (2.6%). This shows that the survey captured views from different groups within the institution and its surrounding environment.

Income

Table 4.53: Monthly Income of the Study Population

Options	Frequency	Percent
₦0 to ₦30,000	8	21.1
₦31,000 to ₦70,000	1	2.6
₦70,000 to ₦90,000	3	7.9
₦120,000 +	26	68.4
Total Response	38	100

Source: Bolben Ltd. Fieldwork Survey, 2026.

Most respondents, 26 (68.4%), earned ₦120,000 and above per month. Other income categories were ₦0–₦30,000 with 8 respondents (21.1%), ₦70,000–₦90,000 with 3 respondents (7.9%), and ₦31,000–₦70,000 with 1 respondent (2.6%). The pattern reflects the presence of salaried workers, alongside students and small business operators with lower income levels. The income distribution indicates that the Project Area comprises respondents with varying economic backgrounds, reflecting the diverse composition of the University community and its adjoining host community. The relatively high proportion of respondents in the upper income category is consistent with the presence of salaried public sector employees and professionals, while respondents in the lower income category are likely to include students, small-scale traders, and other low-income earners. This variation in income levels demonstrates the socio-economic diversity of the Project Area and provides an important baseline for assessing the distribution of Project benefits and potential socio-economic impacts.

Duration of Stay

Table 4.54: Duration of stay in the institution/Community

Options	Frequency	Percent
1-5yrs	26	66.7
6-10yrs	12	30.8
11-19yrs	1	2.6
20 and above	-	-
Total Response	**39**	**100**

Source: Bolben Ltd. Fieldwork Survey, 2026.

Most respondents, 26 (66.7%), had stayed in the institution or community for 1–5 years, while 12 respondents (30.8%) had stayed for 6–10 years. Only 1 respondent (2.6%) had stayed for 11–19 years, and none had stayed for 20 years or more. This pattern is consistent with a university and military environment where students' complete programmes within a defined period and military personnel may be posted or transferred. The findings indicate that the Project Area comprises both relatively recent and long-term residents. The predominance of respondents who have lived in the

area for 1–5 years is consistent with the dynamic nature of the environment, where student enrolment and staff mobility contribute to periodic changes in the resident population. At the same time, the presence of a substantial proportion of long-term residents provides valuable local knowledge of the community, existing infrastructure, environmental conditions, and historical development trends.

Language spoken in the institution/community

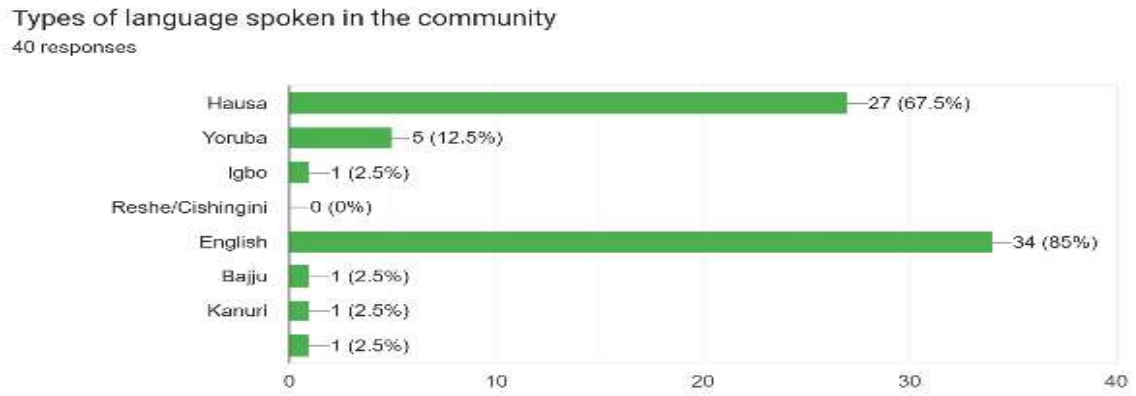


Figure 4.11: Language Spoken within the Institution

Source: Bolben Ltd. Fieldwork Survey, 2026.

English was the most commonly spoken language among respondents, with 34 respondents (85.0%) reporting its use. Hausa was also widely spoken by 27 respondents (67.5%), while Yoruba was reported by 5 respondents (12.5%). Igbo, Bajju, and Kanuri were each reported by 1 respondent (2.5%). The responses show that English remains the main language of communication in the institution, although Hausa and other local languages may be useful during informal engagement where necessary.

Health Status

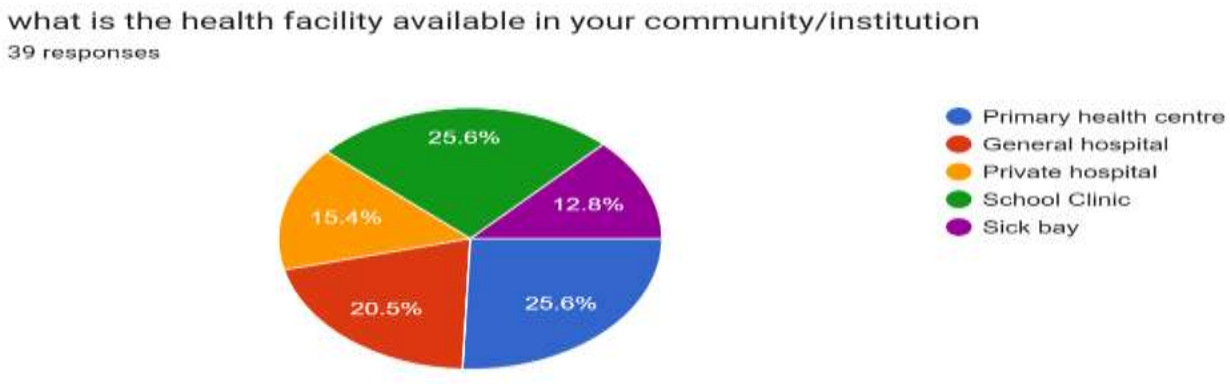


Figure 4.12: Available Health facility within the Study Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Respondents identified several healthcare options within and around the institution. Primary Health Centre's and the School Clinic were each reported by 25.6% of respondents, followed by General Hospitals (20.5%), Private Hospitals (15.4%), and the Institutional Sick Bay (12.8%). This shows that respondents rely on both institutional health services and external facilities. The findings demonstrate that respondents generally have adequate access to primary healthcare services, with the Primary Health Centre and the University sick bay serving as the principal healthcare providers within the Project Area. Access to secondary and private healthcare facilities is also available, although these facilities are generally located outside the immediate University environment. This indicates that while routine healthcare needs can largely be met within or close to the campus, specialized medical services may require referral to higher-level healthcare facilities.

Condition of Health Facilities in the Study Area

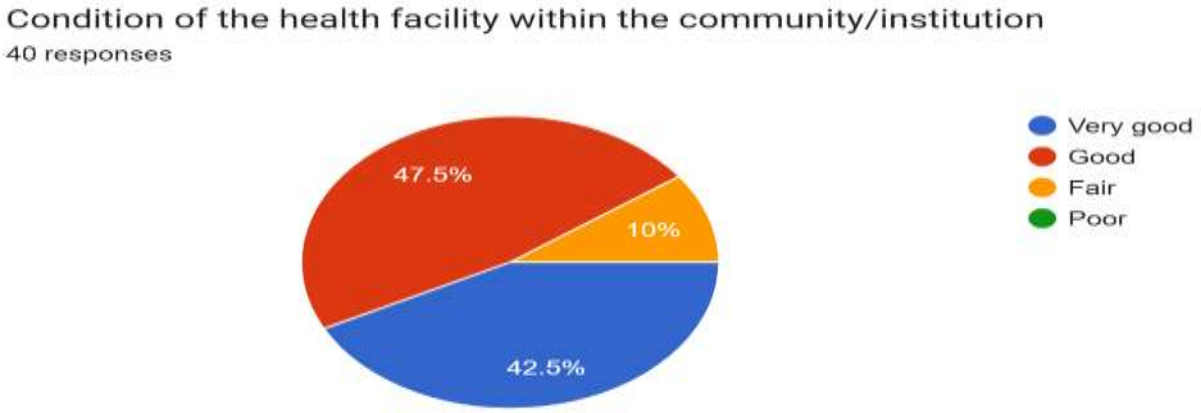


Figure 4.13: Condition of Health Facility in the Study Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Most respondents rated the available health facilities positively. A total of 47.5% rated them as Good, while 42.5% rated them as Very Good. Only 10.0% rated them as Fair, and none rated them as Poor. This suggests that healthcare services within the base are generally viewed as satisfactory by respondents**.** The findings indicate that respondents generally perceive the available healthcare facilities to be functional and capable of providing routine healthcare services. The high proportion of respondents rating the facilities as good or very good suggests that the existing healthcare infrastructure provides an adequate level of service for the University community and the adjoining host community. However, the responses indicating fair or poor conditions highlight opportunities for continued improvement in healthcare service delivery and facility maintenance.

Disease Prevalence in the Study Area

Malaria was the most commonly reported health condition, mentioned by 91.2% of respondents. Typhoid fever followed at 41.2%, while hypertension was reported by 26.5%. Other conditions, including cholera, rheumatism, asthma, pneumonia, tuberculosis, ulcer, and rashes, were reported by fewer respondents. No respondent reported meningitis. The responses point to the need for continued sanitation, vector control, and health awareness activities. The predominance of malaria and typhoid fever reflects typical public health challenges in tropical environments, often associated with environmental sanitation and water quality issues.

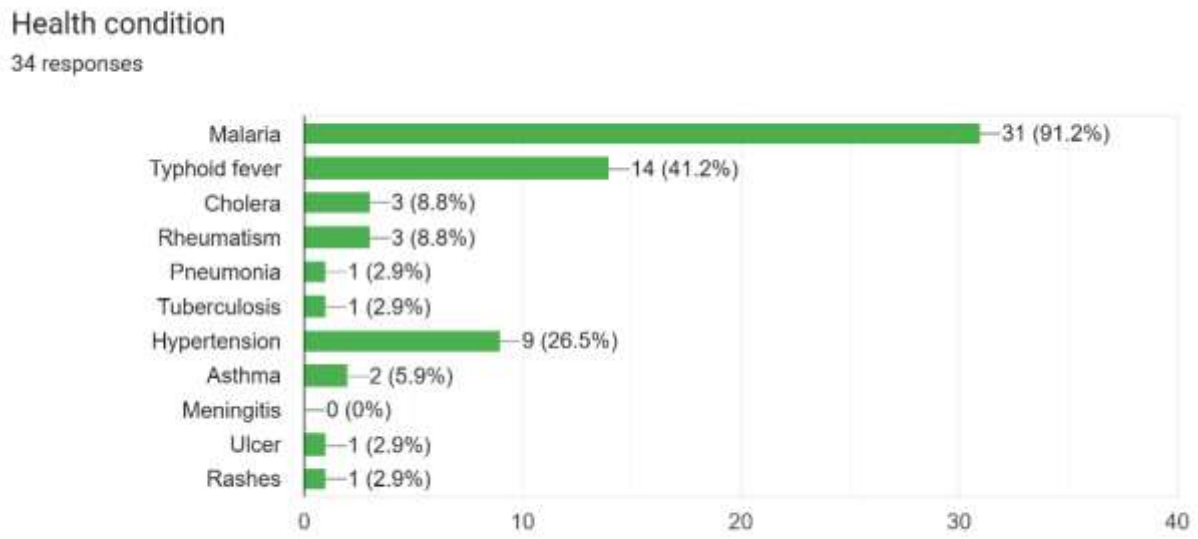


Figure 4.14: Prevalence of Diseases in the Study Area
Source: Bolben Ltd. Fieldwork Survey, 2026.

Perceived Impact of The Project

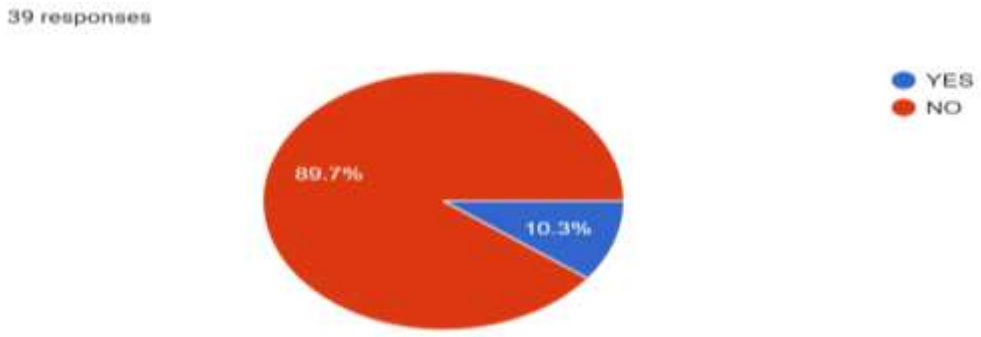


Figure 4.15: Perceived Impact of the Project.

Most respondents, 89.7%, did not expect the proposed project to have negative impacts, while 10.3% expressed concerns. The concerns raised shall be addressed through standard environmental and social management measures during project implementation. This distribution suggests generally strong community support for the project and confidence in its environmental sustainability. The high proportion of respondents who do not anticipate negative impacts may reflect awareness of the project's renewable energy nature and its perceived benefits, such as improved electricity supply and reduced reliance on fossil fuels. However, the presence of over one-fifth of respondents expressing concerns highlights the need for continued stakeholder engagement and transparent communication regarding environmental safeguards.

Concerns Raised

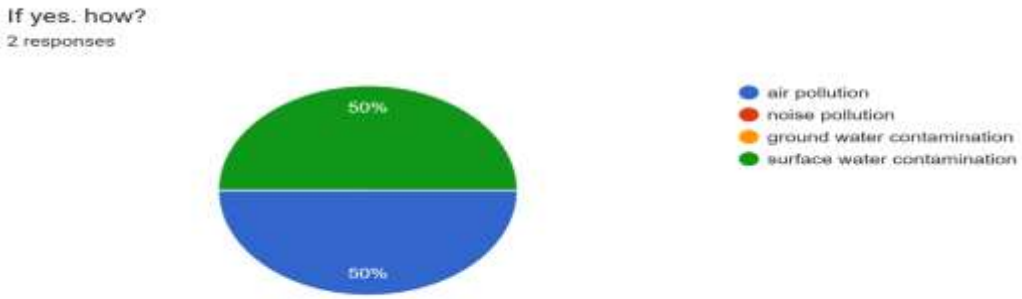


Figure 4.16: Issues raised concerning the Project

Source: Bolben Ltd. Fieldwork Survey, 2026.

Among the few respondents who anticipated negative impacts, the main concerns were air pollution and possible surface water contamination during construction. Suggested measures included proper waste management, good environmental management practices, and adequate planning. Some respondents also stated that no significant impacts would be felt if the project is properly managed. Overall, while the majority perception is positive, the expressed concerns underscore the importance of implementing and communicating effective mitigation measures outlined in the Environmental and Social Management Plan (ESMP).

Gender-Based Violence and Gender Equality Indicators

According to Nigeria Demographic and Health Survey, the percentage of women who have experienced physical, sexual, or emotional violence committed by their current or most recent husband/partner in Kaduna State was 59.4% which is high compared to some other states in Nigeria (Nigeria DHS, 2018).

Experience of Gender-Based Violence (GBV)

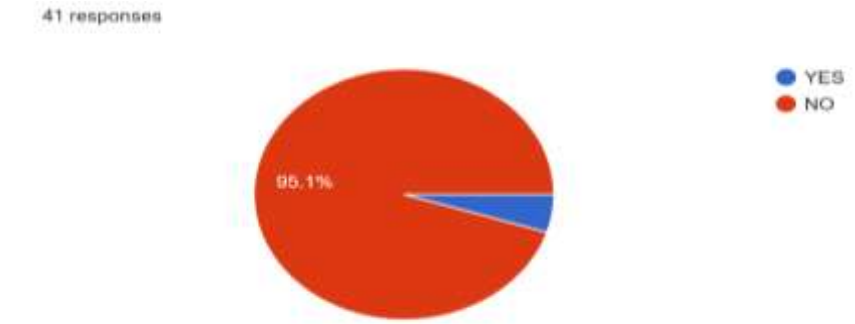


Figure 4.17: Experience of GBV in the Study Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Most respondents (95.1%) reported that neither they nor anyone in their household had experienced Gender-Based Violence (GBV). The remaining 4.9% reported experience or knowledge of GBV but did not provide details on the cause or nature of the experience. Based on the survey responses, reported GBV prevalence was low among respondents. Although the majority reported no experience of GBV, the proportion indicating exposure, nearly one-third of respondents, is significant and highlights that gender-based violence remains a concern within the community. This finding underscores the importance of integrating gender-sensitive measures and grievance redress mechanisms into project planning and implementation, particularly in line with environmental and social safeguard requirements

Equal Access to Opportunities

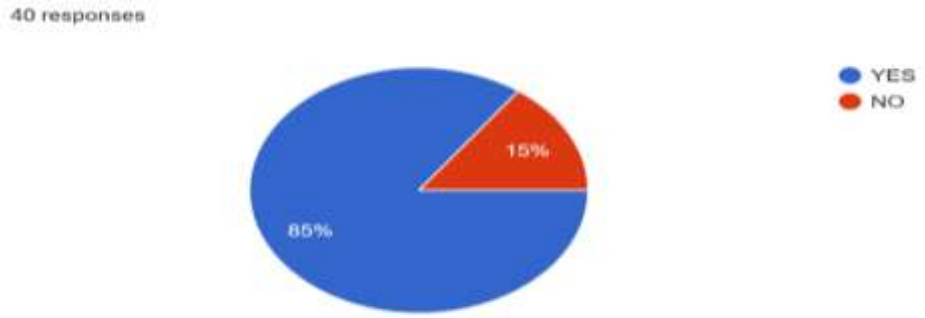


Figure 4.18.: Equal Access to Opportunities in the study area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Most respondents (85.0%) stated that men and women have equal access to economic opportunities within the institution or community. However, 15.0% perceived unequal access. This indicates the need to continue promoting equal opportunities and inclusive participation during project implementation.

Cultural Norms in the Community/Institution Influence the Prevalence of GBV

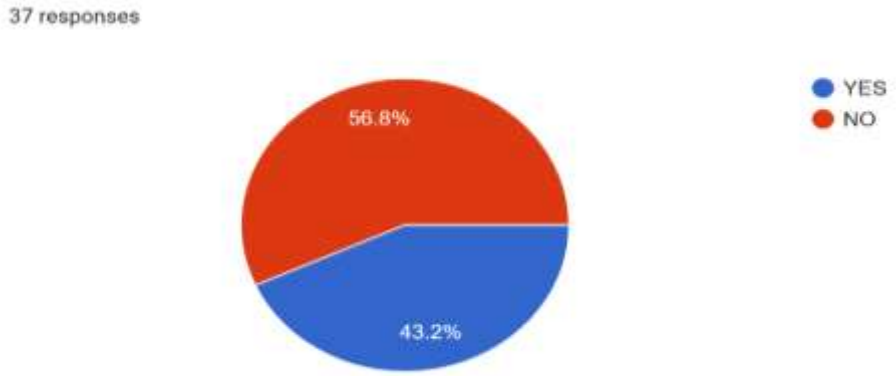


Figure 4.19: Cultural Norms in the Institution

Source: Bolben Ltd. Fieldwork Survey, 2026.

A little over half of the respondents (56.8%) believed that cultural norms do not influence the prevalence of GBV, while 43.2% believed that cultural norms have an influence. The mixed responses show that awareness and sensitization on GBV-related social and cultural issues should continue within the institution and surrounding community.

Availability of Support Services for GBV Survivors

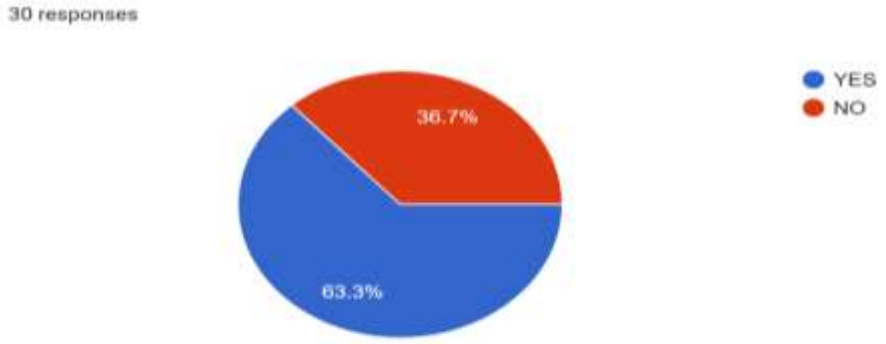


Figure 4.20: Support Services for GBV Survivors

Source: Bolben Ltd. Fieldwork Survey, 2026.

Most respondents (63.3%) stated that support services for GBV survivors are available within the institution or community, while 36.7% stated that such services are not available. This suggests that support mechanisms may exist, but awareness of where and how to access them should be strengthened.

Institutional/Community Utilities and Services Profile

Source of Water Supply

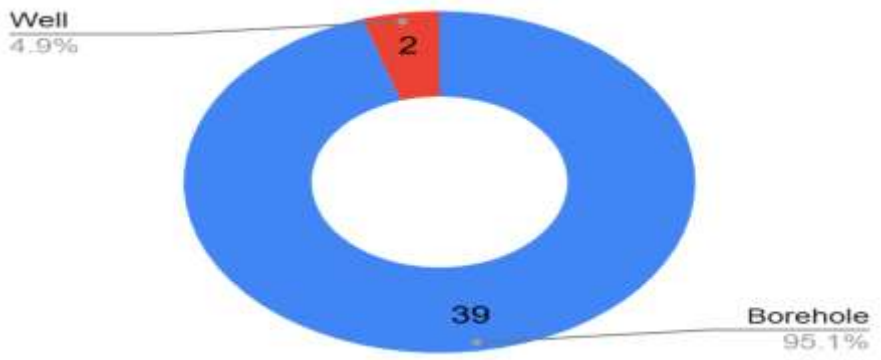


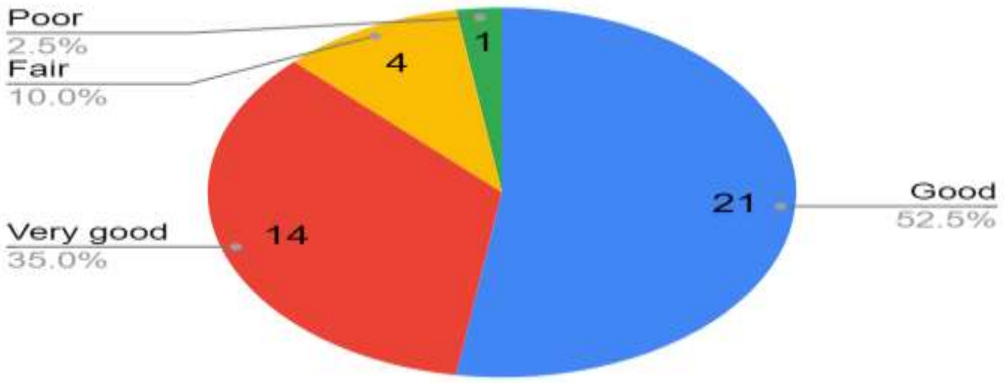
Figure 4.21.: Sources of Water in the AFIT

Source: Bolben Ltd. Fieldwork Survey, 2026.

Boreholes were identified as the main source of water supply by 95.1% of respondents, while 4.9% reported using wells. This shows that the institution and surrounding community depend mainly on groundwater sources for domestic and institutional water needs.

Condition of Potable Water in the Area.

Figure 4.22:



Condition of Potable Water in the Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Potable water quality was rated positively by most respondents. A total of 52.5% rated it as Good, 35.0% as Very Good, 10.0% as Fair, and 2.5% as Poor. The responses suggest that water quality is generally considered acceptable, although routine monitoring should continue. The predominance of positive ratings suggests that existing water infrastructure is functioning adequately. Nevertheless, the presence of respondents who rated water quality as fair or poor highlights the

need for routine water quality assessment, maintenance of borehole systems, and continuous improvement to ensure safe and reliable potable water supply.

Source of Electricity in the Area

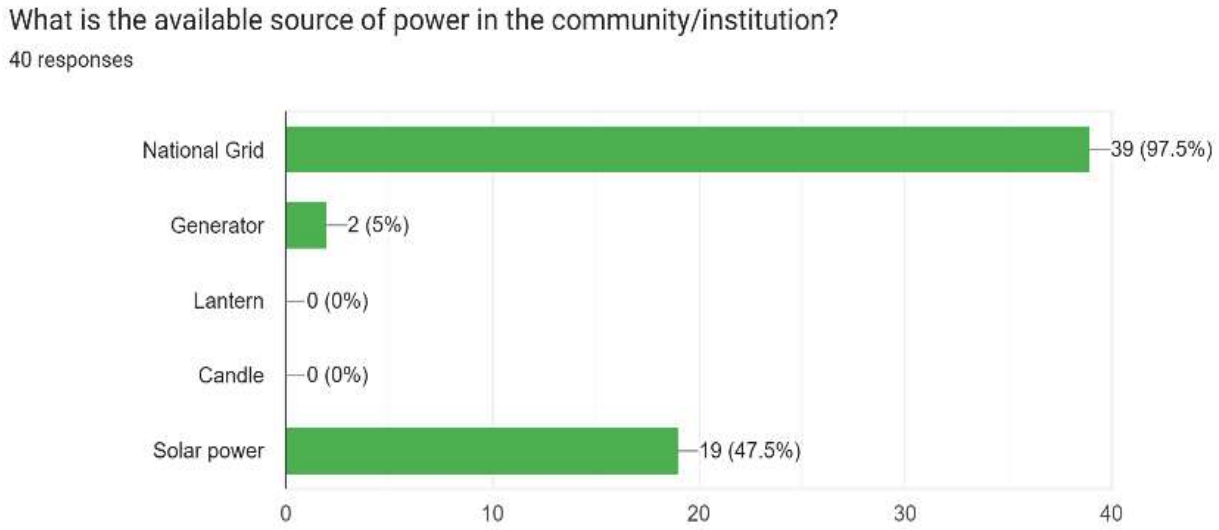


Figure 4.23: Source of Electricity in the Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

The national grid was the main source of electricity reported by respondents (97.5%). Solar power was also reported by 47.5%, while 5.0% indicated the use of generators. No respondent reported using lanterns or candles. The responses suggest that grid electricity is the dominant source, with solar power already present as an alternative source. (Multiple responses were allowed.). The predominance of DisCo-supplied electricity suggests that the national grid remains the primary source of power in the area. However, the notable proportion of respondents using solar power reflects a growing adoption of renewable energy alternatives, while generator usage indicates supplementary reliance due to possible inconsistencies in grid supply.

Condition of Electricity in the Area

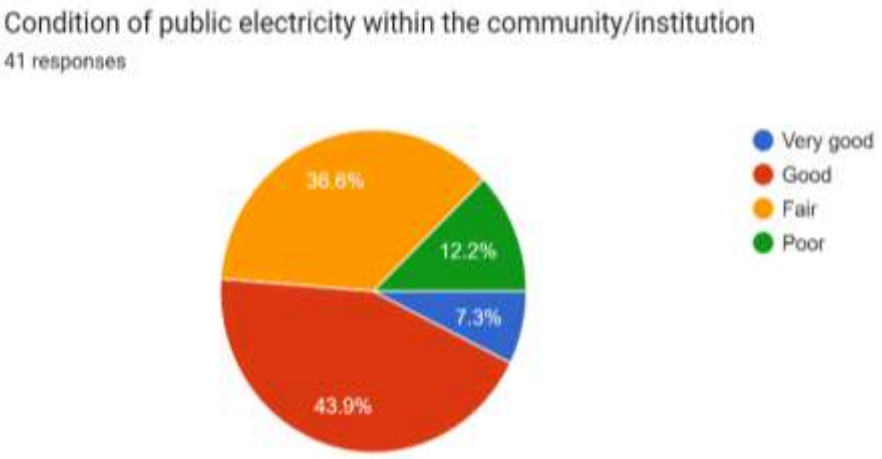


Figure 4.24: Condition of Electricity in the Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Public electricity was rated Good by 43.9% of respondents, Fair by 36.6%, Poor by 12.2%, and Very Good by 7.3%. These ratings show that electricity supply is available but not always reliable, which supports the relevance of alternative energy options such as the proposed solar project. The combined reliance on generators and solar systems further supports the perception that grid electricity may not be entirely dependable. Overall, the results highlight the need for improved electricity reliability and reinforce the relevance of the proposed solar power project in enhancing energy security and sustainability within the community.

Sanitation Facilities in the Area

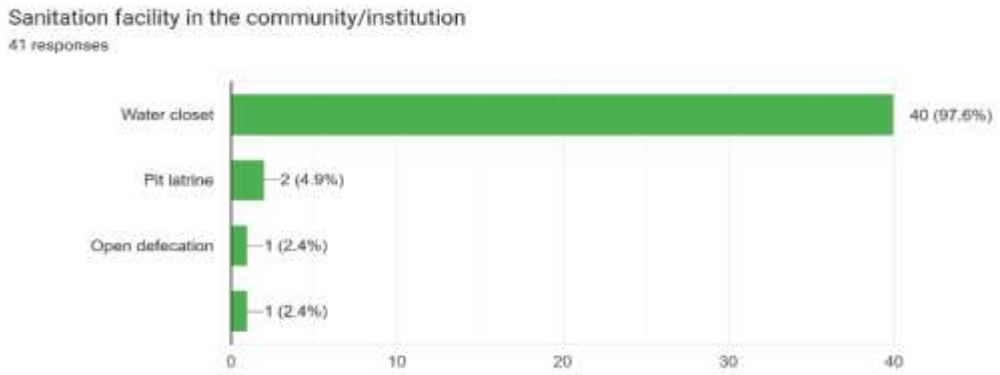


Figure 4.25: Sanitation facilities in the project area

Water closets were the main sanitation facilities reported by respondents (97.6%). Pit latrines were reported by 4.9%, while open defecation and other sanitation options were each reported by 2.4%. Overall, the responses indicate good access to improved sanitation facilities in the study area, while informal sanitation practices should continue to be discouraged.

Cooking Fuel

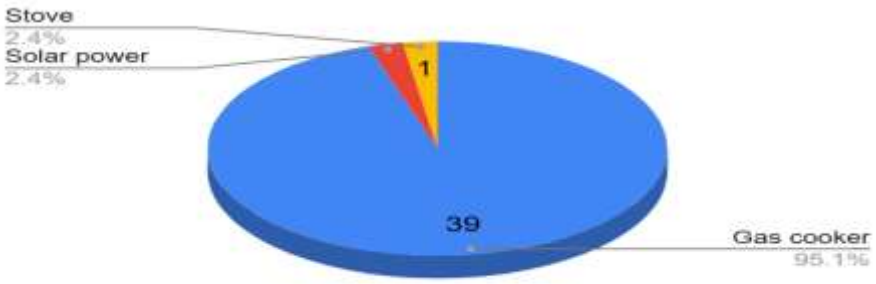


Figure 4.26: Cooking Fuel in the Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Gas cookers were the main cooking option reported by respondents, with 39 out of 41 respondents (95.1%) indicating their use. Solar power and stoves were each reported by 1 respondent (2.4%). This indicates a strong preference for cleaner cooking options among respondents.

Educational Institutions

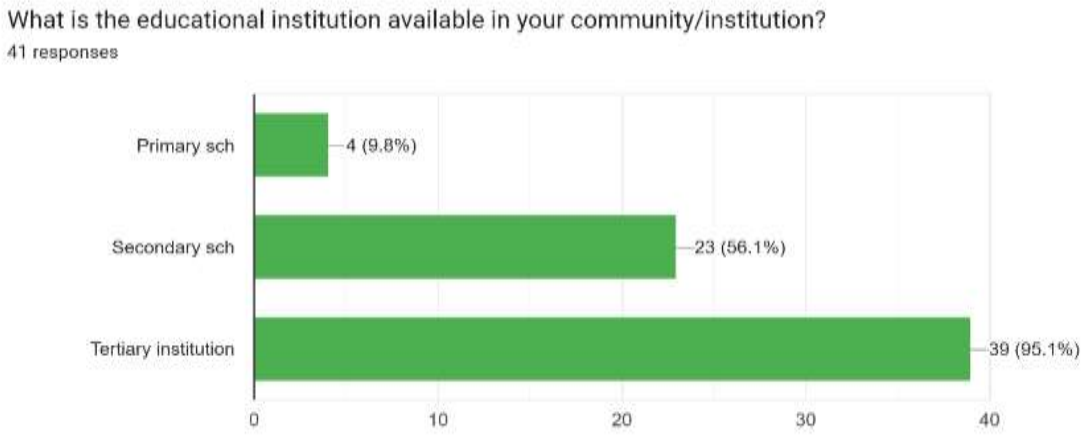


Figure 4.27: Educational Institution in the study area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Tertiary institutions were the most reported educational facilities, identified by 39 out of 41 respondents (95.1%). Secondary schools were reported by 23 respondents (56.1%), while primary schools were reported by 4 respondents (9.8%). The responses reflect the institutional nature of the study area and strong access to higher education facilities. The predominance of tertiary institutions reflects the academic and institutional character of the study area, likely influenced by the presence of higher education establishments. The availability of primary and secondary schools further suggests a structured educational system that supports various levels of learning within the

community. Overall, the results highlight the strong educational infrastructure in the area, which contributes to human capital development and enhances opportunities for socio-economic growth.

Waste Disposal Method

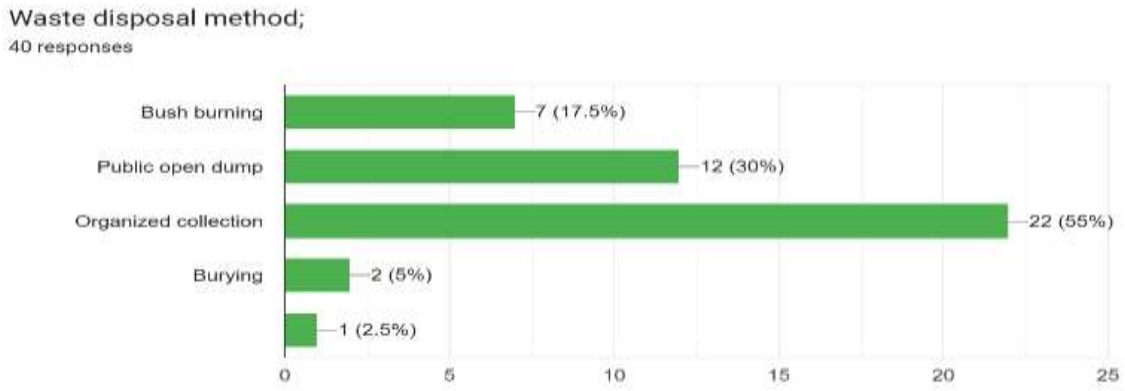


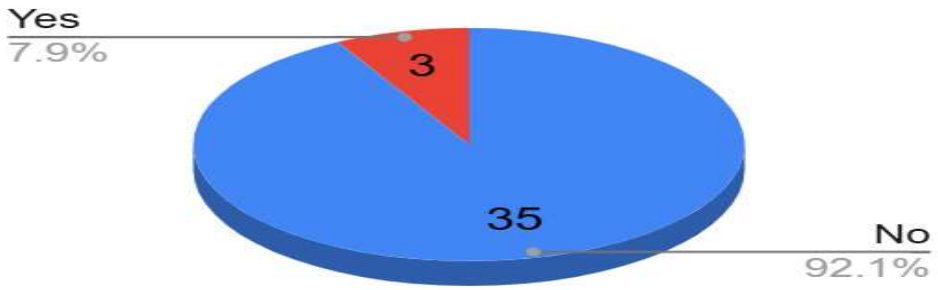
Figure 4.28: Waste Management Practice in the Study Area

Source: Bolben Ltd. Fieldwork Survey, 2026.

Organized waste collection was the most common disposal method, reported by 22 out of 40 respondents (55.0%). However, 12 respondents (30.0%) reported using public open dumps, while bush burning and burying were reported by 17.5% and 5.0% respectively. Although organized collection is in place, informal disposal practices should be reduced because of their environmental and public health risks. The relatively low percentage of organized waste collection indicates limited access to structured waste management services within the community. Overall, the findings highlight the need for improved waste management infrastructure, enhanced environmental awareness, and strengthened institutional systems to promote sustainable and hygienic waste disposal practices in the project area.

Traditional Practices and Cultural Heritage

Traditional Economic Activities Practiced



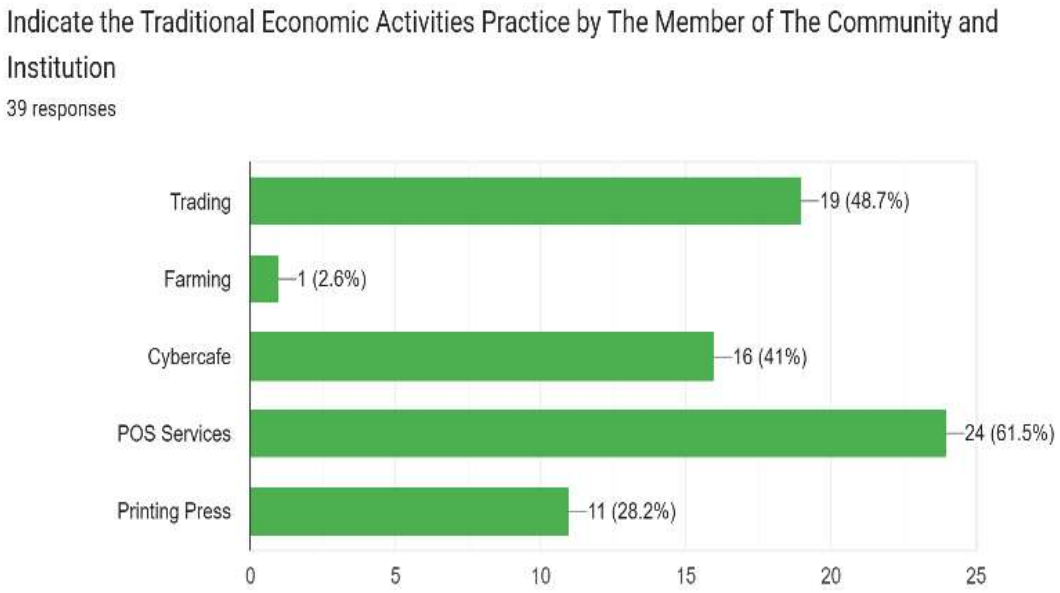


Figure 4.29: Traditional Economic Activities Practiced

Source: Bolben Ltd. Fieldwork Survey, 2026.

Economic activities within the institution community are mainly small-scale commercial and service-based activities. POS services are common, reflecting the demand for cash withdrawal and financial transactions. Trading, cybercafé services, and printing-related businesses also support the day-to-day needs of students, staff, and visitors. Farming is limited, which is consistent with the urban and institutional character of the area. Improved electricity supply is expected to support these activities by reducing disruptions and operating costs.

Valued Resources/Cultural Assets/Archeological Site

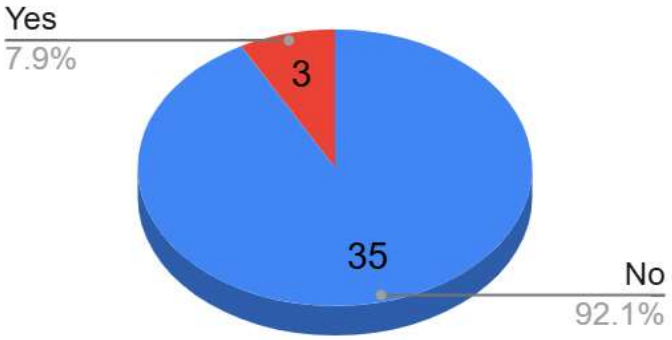


Figure 4.30: Valued Resources/Cultural Assets/Archeological Site Within the Institution/Community

Most respondents stated that the proposed project is not expected to affect valued cultural resources, sacred sites, or archaeological assets. A few respondents, however, expressed concerns. As a precaution, a Chance Find Procedure should be applied during construction to protect any cultural or archaeological resources that may be discovered unexpectedly.

Community Awareness, Perceived Benefits, and Social Associations

Awareness of Proposed Project

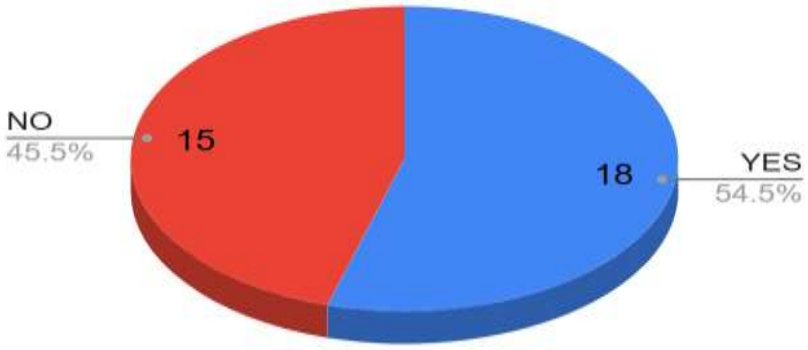


Figure 4.31: Awareness of the Proposed Project

More than half of the respondents were aware of the proposed project. This suggests that earlier consultations and information sharing reached many members of the community. However, because a sizeable number of respondents were still unaware, further sensitization should continue during project implementation.

4.6.7 Consultations/Stakeholder Engagement Activities

Stakeholder consultation and field engagement activities were undertaken as an integral component of the Environmental and Social Impact Assessment (ESIA) for the proposed 2 MW Solar Power Project at the Air Force Institute of Technology (AFIT), Kaduna State. The activities were conducted over two days, from 14 to 15 July 2026, to introduce the proposed Project, obtain institutional and technical information, understand existing electricity supply conditions and future energy requirements, identify environmental and social concerns, assess preliminary Project locations, and commence baseline environmental and socio-economic investigations.

The stakeholder engagement process was integrated with the reconnaissance and baseline field investigations. On 14 July 2026, the ESIA consultant team held consultation meetings with the Provost of Academic Affairs, the Deputy Commandant and the Director of Physical Planning. The consultations were followed by inspection of two preliminary locations within the university campus. On 15 July 2026, the team continued site verification, reviewed planning considerations, identified an alternative site and most suitable site and commenced environmental and socio-economic baseline activities.

See Plate 4.14 to 4.15 for pictorial evidence of Reconnaissance Visit…



Plate 4.14: Reconnaissance Visit Meeting at The Office of The Deputy Commandant.



Plate 4.15: Preliminary Field assessment during Reconnaissance Visit.

The stakeholder categories engaged or represented during the two-day exercise included:

- The Deputy Commandant, The Provost of Academic Affairs and other members of AFIT's top management;
- The Director of Physical Planning and other personnel involved in planning, site access and technical coordination;
- Academic staff, non-academic staff, students and members of adjoining communities who participated in the socio-economic baseline survey;

- Other relevant persons encountered during site verification and field investigations.

The consultations provided information on AFIT's institutional development, academic programs, existing and projected electricity demand, current reliance on the national grid, diesel-powered backup generators and isolated solar installations, and the importance of uninterrupted power supply to the university clinic, engineering laboratories, workshops and other technology-driven academic facilities. The provost clarified that the proposed solar facility is intended to supply electricity to AFIT and not to the wider Nigerian Air Force Base.

The Deputy Commandant requested clarification on the proposed facility's long-term maintenance arrangements. In response, the consultant explained that the Project forms part of the Federal Government's National Electrification Program implemented through the Rural Electrification Agency and sponsored by the African Development Bank, with beneficiary institutions selected in phases. The Deputy Commandant recommended the establishment of internal maintenance or end-user audit teams within beneficiary institutions to support routine inspection, early identification of maintenance needs and improved long-term performance of installed solar systems.

Site reconnaissance identified material safety and suitability constraints. The first preliminary location, situated beneath active high-voltage transmission lines, was considered unsuitable because of operational safety risks, restrictions on future maintenance of the transmission infrastructure and potential environmental implications. A second location was also rejected because its topographical characteristics were unsuitable for the proposed development. Following review of the university Master Plan and further verification, an alternative site of approximately 18 hectares was identified within the Nigerian Air Force Base, from which a 10-hectare area was selected for baseline investigations.



Plate 4.16: Review of the AFIT Master Plan Map during Site Verification

Four sampling points were established within the selected area and baseline investigations commenced for soil, air quality, noise, groundwater and surface water. Environmental and social receptors requiring consideration in the impact assessment were identified. The socio-economic survey was undertaken through questionnaire administration, with 49 questionnaires administered to available academic staff, non-academic staff and available students (as the university was not

in session during the exercise) with 41 retrieved questionnaires taken to the university. The engagement also documented concerns relating to maintenance, waste management, future expansion and the long-term sustainability of the proposed Project.

The principal findings of the stakeholder engagement activities are summarized in Table 4.**55.**

Table 4.55: Minutes of the Stakeholders Meetings.

These minutes document the reconnaissance visit and site-verification engagements held with AFIT management, regulatory representatives, and the ESIA consultant team in relation to the proposed 2 MW Solar Photovoltaic Power Project at the AFIT, Airforce Base, Kawo, Kaduna State.

DAY 1: RECONNAISSANCE VISIT	
Date	Tuesday, 14th July 2026
Time	12:30 p.m.
Project	2 MW Solar Photovoltaic Power Project and Associated Infrastructure under the Nigeria Electrification Program (NEP) Desert to Power Phase II (DTP II), by the Rural Electrification Agency
Venue	Office of the Provost of Academic Affairs AFIT.
Participants	• Provost of Academic Affairs and relevant AFIT management representatives • Deputy Commandant • Director of Physical Planning • Director of Logistics • Works Officer • ESIA consultant team
PROCEEDINGS	

Introduction

The consultant team, led by **Ms. Mariam Mopelola Moshood**, conducted a scheduled reconnaissance visit to the proposed project location at AFIT as a preliminary site-familiarization exercise. The team was welcomed by the Provost of Academic Affairs **Prof. Auwal Kasim** and thereafter proceeded to the office of the Deputy Commandant, **Air Vice Marshall O.C Ubadike**, who represented the Commandant during the meeting.

The consultant team and the AFIT management team were introduced by their respective team leads.

Aim

The aim was to establish a working relationship with the institution's management, introduce the proposed project and the ESIA process, assess the suitability of the proposed site, and obtain AFIT management's support ahead of the formal site-verification and baseline-data-gathering exercises.

Welcome Address/Presentation

The Provost formally welcomed the team and briefed the consultant on AFIT's development since its establishment in 1977, its current academic programs, and its planned future growth.

The Deputy Commandant, giving a welcome address on behalf of the Commandant, thanked the Rural Electrification Agency (REA) and the consultant, BOLBEN LTD, for the initiative. HE further briefed the team on the institution's energy infrastructure and electricity consumption. He explained that AFIT relies on the national grid, diesel-powered backup generators, and isolated solar installations. He also highlighted the institution's increasing electricity demand and the need for reliable power for the clinic, engineering laboratories, workshops, and other technology-driven facilities.

Afterward, the consultant presented an overview of the proposed project, including its objectives and anticipated benefits. The presentation focused on the relevance of the Environmental and Social Impact Assessment (ESIA) to the project, covering the ESIA process, objectives, and the need for AFIT management's support for a hitch-free exercise.

Site Visit

Afterward, the team, accompanied by the Director of Physical Planning **Sqn Ldr B.C Okueyungdbo**, proceeded to the proposed site for identification and inspection.

Observations.

- Upon arrival at the proposed project site, the team observed that three legs of the Kaduna–Jos 330 kV double-circuit transmission line cuts across a substantial portion of the site.
- The transmission-line corridor raised concerns regarding the suitability of the site for the proposed project, particularly in relation to environmental safeguards, public safety, and regulatory compliance.
- Consequently, the proposed site was considered unsuitable for the project.

The teams returned to the meeting venue for a recap and deliberation with AFIT management on the provision of a safer and more suitable alternative site.

Resolutions

- AFIT management assured the consultant team that an alternative site suitable for the proposed project would be provided for the ESIA assessment the following day.
- It was resolved that the initial site would not be progressed for the proposed solar facility because of the existing high-voltage transmission-line.

The consultant team expressed appreciation to AFIT management for its understanding, cooperation, and commitment to providing an alternative site.

DAY 2: SITE VERIFICATION	
Date	Wednesday, 15 July 2026
Time	10 a.m.
Venue	Proposed Project Site
Participants	• AFIT Director of Physical Planning (DPP) • University Surveyor and associated AFIT technical personnel • Representative of the Federal Ministry of Environment (FMEnv) • Representatives of the Kaduna State Ministry of Environment • ESIA consultant team

Introduction

On arrival for the site-verification and baseline-data-collection exercises, the consultant team met with the Director of Physical Planning **Sqn Ldr B.C Okueyungdbo**, as well as the University Surveyor **Gaba Aminu** and associated AFIT technical personnel. The exercise was witnessed by the Federal Ministry of Environment (FMEnv), representative **Mr. Maxwell Linus** and representatives of the Kaduna State Ministry of Environment. The AFIT DPP formally welcomed the consultant and regulatory teams and thereafter led them to the alternative project site for inspection.

Aim

The aim was to verify the alternative project site and its boundaries, gather relevant environmental and socioeconomic baseline information within and around the proposed project location, and further enlighten the institution on the processes, procedures, and importance of the ESIA.

Welcome Address/Presentation

The University Surveyor presented the institution's Master Plan showing the alternative project site which had been approved by the institution's management for the proposed project. and other relevant information. He also delineated the site boundaries to ensure that the baseline-data-collection activities were conducted within the designated area.

An on-site stakeholder meeting was led by the DPP and commenced with formal introductions by all participants. Thereafter, the FMEnv representative presented an overview of ESIA, including its requirements, objectives, aims, and processes. He also stressed the importance of full compliance with the applicable Environmental Impact Assessment requirements and highlighted the environmental and safety implications of constructing beneath existing transmission lines. The Consultant team leader **Ms. Mariam Mopelola Moshood** subsequently explained the scope of the baseline investigations and emphasized the need to identify and evaluate the potential environmental and socioeconomic impacts of the proposed project.

Following the meeting, the teams proceeded to inspect the newly proposed alternative site, which had been identified following the rejection of the initially proposed site. After the site verification, baseline investigations were conducted within and around the project area. The investigations covered soil quality, groundwater and surface-water quality, ambient air quality, noise levels, and socioeconomic conditions.

Observations

- The site is a 10-hectare parcel approximately 660 metres from the former site and adjacent to AFIT. The site was observed to have generally flat terrain, with shrubs and sparsely distributed trees.
- Considering AFIT's extensive existing infrastructure, energy-intensive facilities, expanding academic programs, and planned future developments, the consultant observed that the proposed 2 MW solar power plant may be inadequate to meet the institution's present and projected electricity demand.

Resolutions and Key Action Points

- The alternative site served as the location for the ESIA assessment.
- The project design should incorporate a sustainable approach to the management of solar panels and other electrical and electronic waste.
- The proposed generation capacity should be reviewed against AFIT's present and projected electricity demand, with consideration given to increasing it from 2 MW to approximately 10 MW.

Overall, the stakeholder engagement activities confirmed AFIT's growing electricity demand and the strategic importance of the proposed 2 MW Solar Power Project. Institutional representatives supported the objective of improving electricity reliability while emphasizing the need for appropriate siting, regulatory compliance, long-term maintenance arrangements, battery and waste management, compatibility with future institutional development, consideration of existing agricultural land use and sustained coordination throughout implementation.

The reconnaissance and field investigations resulted in the rejection of two unsuitable preliminary locations, identification of an alternative site, selection of a 10-hectare area for baseline investigations, establishment of four sampling points and commencement of environmental and socio-economic studies. The 10-hectare sampling area should not be treated as the final Project allocation until AFIT and the Nigerian Air Force confirm the exact portion and points to be provided. The information obtained during the consultations provides an important basis for the Project description, baseline assessment, impact assessment, mitigation measures and Environmental and Social Management Plan.

Continued stakeholder engagement should be maintained throughout the Project lifecycle to support timely information disclosure, inclusive participation, reconciliation of the questionnaire count, verification of the reported monthly energy expenditure and other outstanding data, confirmation of land allocation, communication of design and construction arrangements, identification of emerging concerns and effective grievance resolution.

4.6.8 Socio-economic Condition of the Study Area

The Air Force Institute of Technology (AFIT) is a specialized higher institution located within the Nigerian Air Force Base in Kaduna. It serves both military and civilian students and focuses on aerospace engineering, technology, science, management, and related disciplines. AFIT plays an important role in producing technical manpower for the Nigerian Air Force and Nigeria's broader aviation and engineering sectors.

AFIT contributes to the socio-economic profile of Kaduna State through its role in education, employment, research, technical training, and support for local businesses. Its location within the Nigerian Air Force Base also gives the institution a strong military and technical character, with activities that support aviation, engineering, and related manpower development in Nigeria.

During the site visit, the project area was observed to have a range of social amenities and economic activities. Businesses around the NAF Base, including food vendors, transport operators, printing services, POS operators, and small shops, provide day-to-day services to students, staff, military personnel, and visitors.

Adjoining Communities and Social Receptors

The socio-economic Area of Influence extends beyond AFIT's institutional population to adjoining settlements within the Nigerian Air Force Base. Of particular relevance are Angwan Fulani (AFIT Fulani Quarters), located on the upland immediately adjacent to the proposed project site, and Angwan Kano, situated across the seasonal stream valley on the opposite side. These settlements are also identified in the surface-water baseline as part of the Project's immediate environmental and social area of influence. Community residents were therefore considered relevant social receptors during the socio-economic survey and stakeholder engagement process.

Observed livelihood and service activities within the wider project environment include small-scale farming, petty trading, food vending, transport services, printing and related informal commercial activities. These adjoining-community receptors may experience indirect project effects during construction, particularly temporary changes in traffic, dust, noise, access, employment opportunities and worker-community interaction; their baseline conditions and views are therefore relevant to subsequent impact assessment and mitigation planning.

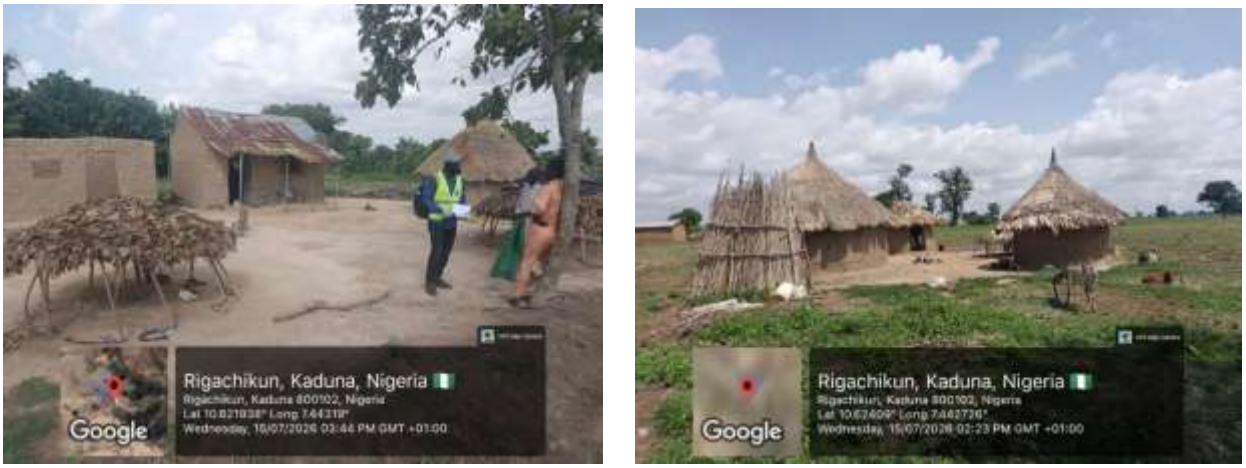


Plate 4.17: View of Angwan Fulani Adjoining Community within the Project Area of Influence

Existing Socio-Economic Conditions Observed

Socio Characteristics	
Social Activities	**Social Amenities/Utilities/Infrastructure**
• Sporting Activities • Recreational activities. • Religious activities (church and mosque services)	Social Amenities • Public toilets and sanitation facilities • Place of worship • Garden and bench seating area • Security posts and emergency response services Utilities • Boreholes and potable water supply • Electricity supply (transformers and generators) • Street lighting Infrastructure • Internal road network • Parking facilities
Economic Characteristics	
• Formal employment of academic, military, and administrative staff. • Food vendors, restaurants, and cafeterias services/activities • Transportation services (tricycles). • Small-scale financial transaction services e.g POS services • Trading and Petty trading activities • ICT and cybercafé services. • Printing, photocopying, and stationery businesses.	



Plate 4.18: AFIT Entrance Gate



Plate 4.19: Public Transportation



Plate 4.20: Mami Market



Plate 4.21: Faculty Building



Plate 4.22: *AFIT Library*



Plate 4.23: AFIT *Mosques*



Plate 4.24: Faculty Workshop



Plate 4.25: Printing Press Building



Plate 4.26: Garden and Bench Sitting Area



Plate 4.27: AFIT Main Auditorium



Plate 4.28: Generator and water tank



Plate 4.29: AFIT Security Office



Plate 4.30: AFIT Clinic



Plate 4.31: Engineering Technical Workshop

4.4.8 Traffic Survey

A traffic survey was undertaken as part of the socio-economic baseline study for this project. The objective of the survey was to identify the existing transportation network, determine prevailing traffic conditions, identify sensitive traffic receptors, and provide baseline information for assessing potential traffic impacts associated with the pre-construction, construction, operation and eventual decommissioning of the project. The traffic adopted a combination of field observations, photographic documentation, and stakeholder consultation. Traffic observations were undertaken around the major vehicular routes serving the Institution, including – NAF Base Main Entrance and Kawo-Mando Express Road;

The observed traffic reflects the urban setting of the AFIT Main Campus and is composed mainly of private cars; taxis; motorcycles; tricycles (Keke); delivery vans; and articulated trucks on adjoining arterial roads. Field observations clearly indicate that traffic volume varies considerably throughout the day. Commercial taxis, tricycles and motorcycles constitute the principal public transport modes serving the campus.

Period	Observed Traffic Condition
Morning (7:00–9:00 am)	High traffic volume associated with staff and Student resumption, commuters and institutional activities
Mid-day (11:00 am–2:00 pm)	Moderate traffic volume with intermittent congestion around the Institution gate and adjoining Kawo-Mando Road
Afternoon (2:00–5:00 pm)	Moderate traffic volume due to closing hours, visitors and commercial activities along the Kawo-Mando Road.
Evening	Moderate traffic with reduced institutional traffic but sustained public traffic along adjoining roads

Based on the field observations and the existing transportation infrastructure, the surrounding road network possesses adequate capacity to accommodate the temporary increase in traffic associated with the proposed 2MW Solar Hybrid Power Project. The major impacts of the project, including increase in traffic, will occur during the construction phase and are expected to be short-term, localized and reversible.

CHAPTER FIVE

ASSOCIATED AND POTENTIAL IMPACTS

5.0 Introduction

This chapter presents the potential environmental and social (E&S) impacts and risks associated with the proposed 2MW solar-hybrid power plant and associated infrastructure at the Air Force Institute of Technology (AFIT) Kawo, Kaduna State, under the Federal Government's Energizing Education Program (EEP), a component of the Nigeria Electrification Project (NEP). It also includes the methodology employed to assess the significance of the E&S impacts and risks.

5.1 Impact Assessment Overview

The potential for an E&S impact exists where an environmental aspect has been identified i.e. where a project activity has been determined to have the potential to interact with the biophysical and socio-economic environment. The significance of each impact is then determined. Figure 5.1 illustrates the general overview of the impact assessment process employed for this ESIA.

The primary objectives of the impact assessment process are to:

- Establish the significance of identified potential impacts that may occur as a result of the proposed Project activities;
- Differentiate between those impacts that are insignificant and those that are significant; and
- Apply mitigation hierarchy measures for the identified significant impacts and assess residual impacts, including periodic monitoring of the effectiveness of the proffered mitigation measures through the entire life cycle of the Project.

The assessment of impact significance is both in qualitative and quantitative terms. Qualitatively, the impact significance is ranked on four (4) widely accepted levels: **Major**, **Moderate**, **Minor** and **Negligible.**

The impact assessment covers the entire life cycle of the Project. i.e.: pre- construction; construction; commissioning; operation; and decommissioning. However, environmental and social issues including mitigation and management plans related to decommissioning activities are discussed in ***Chapter 8.***

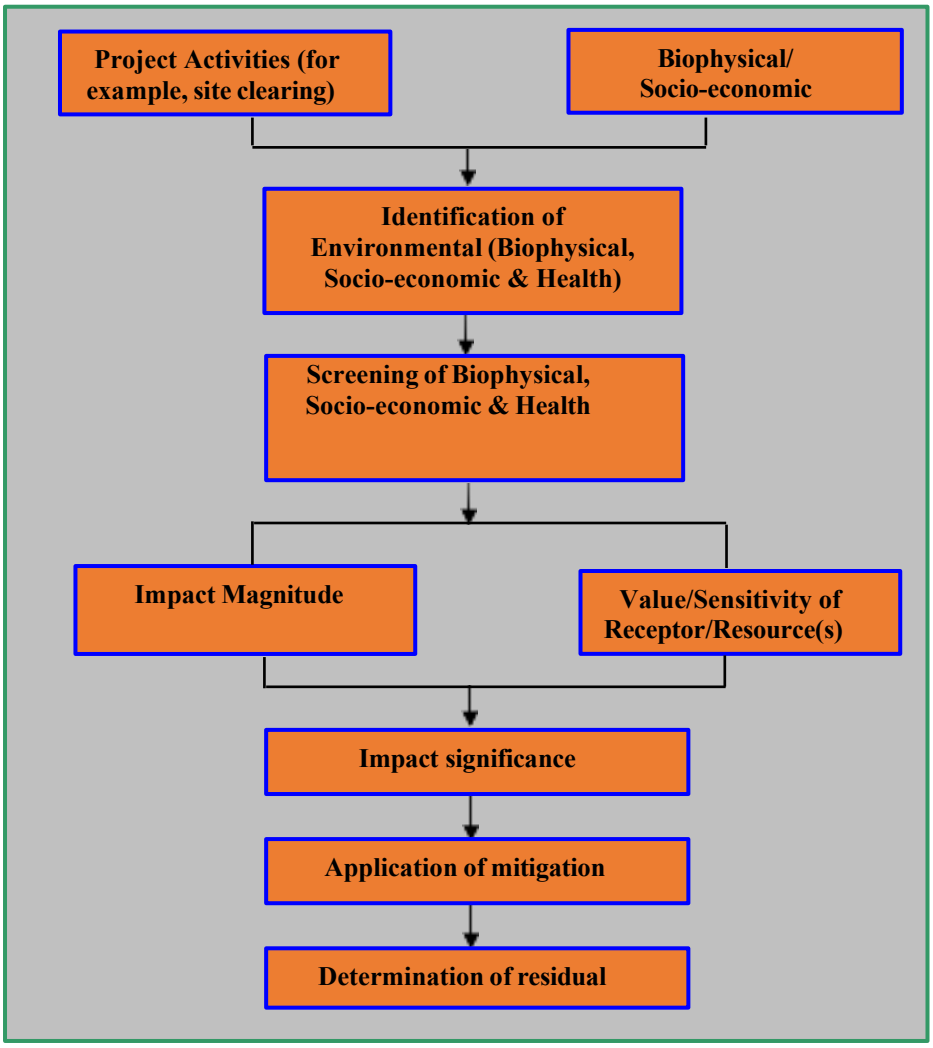


Figure 5.1: Overview of the Impact Assessment Process

5.2 Identification of Environmental and Socio-economic Aspects and Impacts

5.2.1 Defining Environmental and Socio-economic Aspects and Impacts

The International Organization for Standardization's Environmental Management Systems (EMS), ISO 14001, defines an environmental aspect as: *"An element of an organization's activities, products or services that can interact with the environment. while an* environmental impact is defined as: *"Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services."*

To identify environmental and social aspects of the Project, the proposed Project activities were considered in terms of their direct or indirect potential to:

- Interact with the existing natural environment including its physical and biological elements;
- Interact with the existing socio-economic environment; and
- Breach relevant policy, legal and administrative frameworks including national legislation, relevant international legislation/conventions, standards and guidelines,

and corporate environmental policy and management systems.

Activities assessed covered planned and non-planned events.

Table 5.1 illustrates the links between project activity, environmental aspect and potential impact.

Table 5.1: Example of a Link between Activities, Environmental Aspects and Impacts

Project Activity	Environmental Aspect	Potential Impact
Site clearing and grading	Removal of vegetation	Loss of biodiversity/sensitive receptors
Installation of PV panels	Soil excavation	Soil erosion and degradation
	Noise generation	Disturbance to surrounding environment and/or sensitive receptors

5.2.2 Potential Impact Characteristics

The following characteristics were also used to define potential impacts that may be associated with the proposed Project:

- *Negative:* An impact that is considered to represent an adverse change from the baseline or to introduce a new undesirable factor.
- *Positive:* An impact that is considered to represent an improvement to the baseline or to introduce a new desirable factor.
- *Direct*: Impacts that result from the direct interaction between a planned project activity and the receiving bio-physical and socio-cultural environment.
- *Indirect:* Impacts that result from other activities that are encouraged to happen as a consequence of the project.
- *Temporary:* Temporary impacts are predicted to be of short duration, reversible and intermittent/occasional in nature
- *Short-term:* Short term impacts are predicted to last only for a limited period but will cease on completion of the activity, or as a result of mitigation measures and natural recovery
- *Long-term:* Impacts that will continue for the life of the project, but cease when the project stops operating.
- *Permanent:* Potential impacts that may occur during the development of the project and cause a permanent change in the affected receptor or resource that endures substantially beyond the project lifetime
- *On-site:* Impact that is limited to the project site.
- *Local:* Impacts that affect locally important environmental resources or are restricted to a single (local) administrative area or a single community.
- *Regional:* Impacts that affect regionally important environmental resources or are experienced at a regional scale as determined by administrative boundaries.
- *National:* Impacts that affect nationally important environmental resources; affect an area that is nationally protected; or have macro-economic consequences
- *Reversible:* An impact that the environment can return to its natural state
- *Irreversible:* An impact that the environment cannot return to its original state, e.g. the extinction of an animal or plant species
- *Cumulative/Synergistic*: Potential impacts that may result from incremental changes

caused by other past, present or reasonably foreseeable actions together with the project. This also includes synergy with other projects/infrastructure in the project area

- *Residual:* Both environmental and social impacts that will remain after the application of mitigation measures to project impacts during each of the project phases.

5.2.3 Screening and Scoping for Potential Impacts

A modified version of the Leopold Interaction-matrix technique was employed to screen and scope for the potential impacts of the proposed Project on the environment. The basis for the screening was derived from the following:

- Knowledge of the Project activities as summarized in Table 5.2.
- Detailed information on the environmental and socio-economic setting of the Project's area of influence as documented in Chapter 4. The potential environmental and social receptors/resources that could be affected by the proposed Project are summarized in Table 5.3.
- Consultation with relevant stakeholders including potentially affected community
- Review of other ESIA reports on similar projects/environments.
- Series of experts group discussions, meetings and experience on similar projects.

Table 5.2: Summary of the Proposed Project Activities

S/N	Project Phase	Associated Activities
1.	Pre-Construction	Site selection
		Site clearing and preparation
		Mobilization of construction equipment and materials to site
2.	Construction/ Installation	Civil work activities including excavation, trenching, cable laying, foundation, construction of building (e.g. training centre)
		Installation of power plant facilities such as PV panels, mounting structures, inverters, power storage batteries; upgrade of existing distribution infrastructure; installation of streetlights
		Waste generation and disposal
3.	Commissioning	Testing of power plant and associated infrastructure
4.	Operation	Power generation (through PV panels) and distribution; provision of training on renewable energy
		Routine maintenance including occasional cleaning of PV panels; waste generation

Note: Activities related to decommissioning are discussed in Chapter 8

Table 5.3: Resource/Receptors and Impacts Indicators Considered

Environmental Receptor/Medium	Comment	Impact Indicators
Physical		
Air	Ambient air quality within the Project's area of influence.	Increase in concentration of gaseous and particulate pollutants.
Noise	Ambient noise level within the Project's area of influence.	Increase in ambient noise level; day and night-time disturbance; communication impairment, etc.
Soil	Soil environment the Project's area of influence.	Changes in physical, chemical and biological properties of the soil; loss of soil ecology and fertility; soil erosion, etc.
Groundwater/ aquifers	Underground water resources in the Project's area of influence.	Decrease in underground water/aquifer reservoir level; groundwater contamination.
Landscape/ topography	The geomorphological land forms and terrain of the Project site and its surrounding environment.	Alteration in drainage pattern; changes in landscape.
Biological		
Terrestrial flora and habitats	Plant species (vegetation) in the Project's area of influence.	Loss of terrestrial flora; introduction of new species.
Terrestrial fauna	Terrestrial fauna in the Project's area of influence.	Loss of terrestrial fauna; involuntary migration.
Socio-economic Environment		
Land use	Existing land use within the Project site and its surrounding environment.	Loss of existing land use.
Visual prominence	The aesthetic quality of the proposed Project on the surrounding visual catchment.	The compatibility of the Project with the character of the locality; visual nuisance through reflection of panels.
Demography	Demography of community in the Project's area of influence.	Changes in demography, gender ratio, age distribution, socio-economic structure, etc. of the local community
Utilities	The existing utilities (e.g. power supply, water, sewer services, etc.) in the Project's area of influence.	Changes in existing utilities; potential damage to public utilities.
Infrastructure	The existing infrastructure such as road, waste handling facilities, etc. within the Project's area of influence.	Potential damage to road infrastructure; road traffic and accidents; increased pressure on waste management facilities.
Employment/income	The employment situation in the Project's area of influence.	Opportunities for local employment; changes in income level.

Environmental Receptor/Medium	Comment	Impact Indicators
Gender	Gender and disproportionate gender impacts	Potential for gender-based violence (GBV); marginalization of women; gender pay gaps; discrimination, etc.
Other (Health and Safety)		
Construction workers	Health and safety of construction workers.	Accident, injury, fatality, exposure to nuisance (dust, noise), fire, etc.
Workplace health and safety	Health and safety of employees involved in the operational phase of the Project operation.	Accident, injury, fire, explosion, etc.
General public	Health and safety of the general public	Accident, fire, explosion, etc.

Identified Project activities, biophysical and socio-economic receptors were integrated into a matrix. The Project activities are on the y-axis while the biophysical and socio-economic receptors are on the x-axis. The matrix was completed for each of the Project elements. The Leopold's Interaction matrix was subsequently assessed to identify every possible case of activity-receptor interaction. Where it was considered that an activity-receptor interaction was possible, the cell was marked denoting an identified environmental aspect (denoted as "X" in Table 5.4).

Table 5.4: Activity-Receptor Interaction for Impact Screening

Summary of Project Activities at various Phases	Receptors																
	Physical						Biological		Socio-economic						Others (Health and Safety)		
	Air Quality	Ambient Noise	Soil	Groundwater	Surface Water	Landscape/	Terrestrial Flora	Terrestrial Fauna	Land Use	Population	Utilities	Infrastructure	Employment/	Gender	Construction	Workplace	General Public
Pre-construction Phase																	
Site selection									X								
Site clearing and preparation	X	X	X			X	X	X					X		X		
Mobilization of construction equipment and materials to site	X	X										X	X				X
Construction Phase																	
Civil work activities including excavation, trenching, cable laying, foundation, construction of building (e.g. training centre)	X	X	X	X	X					X			X	X	X		X
Installation of power plant facilities, upgrade of existing distribution infrastructure, installation of streetlights	X	X	X											X	X		
Waste generation and disposal			X	X								X	X		X		X
Commissioning Phase																	
Testing of power plant and associated infrastructure		X								X		X			X		X
Operational Phase																	

Summary of Project Activities at various Phases	**Receptors**																
	Physical						**Biological**		**Socio-economic**						**Others (Health and Safety)**		
	Air Quality	**Ambient Noise**	**Soil**	**Groundwater**	**Surface Water**	**Landscape/**	**Terrestrial Flora**	**Terrestrial Fauna**	**Land Use**	**Population**	**Utilities**	**Infrastructure**	**Employment/**	**Gender**	**Construction**	**Workplace**	**General Public**
Power generation and distribution and provision of training on renewable energy		X											X	X		X	X
Routine maintenance; waste generation and disposal	X		X	X		X					X	X	X	X		X	X

Note: Decommissioning is separately covered in Chapter 8

5.2.4 Determination of Impact Significance

Once all environmental aspects (and interactions between a receptor/resource and Project activity) were identified, the levels of impacts that may result from the proposed Project activities were assessed. Three (3) stages were utilized to establish significance of impacts as follows:

- **Impact Magnitude** which is a function of the combination of the following impact characteristics: extent, duration, scale and frequency;

Value/Sensitivity/Fragility and importance of the relevant Receptor;

- **Identification of the impact significance,** which is the "product" of a combination of the above two (2) key variables.

Impact Magnitude

The magnitude designations employed for potential negative impacts are: **Negligible**; **Low**; **Medium**; and **High**. In the case of a positive impact, it is considered sufficient for the purpose of the impact assessment to indicate that the Project is expected to result in a positive impact, thus no magnitude designation is assigned.

The magnitude of an impact takes into account the various dimensions of a particular impact in order to make a determination as to where the impact falls on the spectrum from Negligible to High. These criteria are discussed further as follows:

Determining Magnitude for Biophysical Impacts

For biophysical impacts, the quantitative definitions for the spatial and temporal dimension of the magnitude of impacts used are summarized in the following paragraphs:

A **High Magnitude Impact** is considered to affect an entire area, system (physical), or species (biological) and at sufficient magnitude to cause a significant measureable numerical increase in measured concentrations when compared with national or international limits specific to the receptors) or a decline in species abundance beyond which natural process would not return that population or species, to its former level within several generations.

A **Medium Magnitude Impact** affects a portion of an area, system, aspect (physical), population or species (biological) and at sufficient magnitude to cause a measurable numerical increase in measured concentrations or levels (when compared with national or international limits and standards specific to the receptors) and may bring about a change in species abundance, but does not threaten the integrity of that population or any population dependent on it.

A **Low Magnitude Impact** affects a specific area, system, aspect (physical), group of localized individuals within a population (biological) and at sufficient magnitude to result in a small increase in measured concentrations or levels (when compared with national or international limits and standards specific to the receptors) over a short time period, but does not affect other trophic levels or the population itself), and localized area.

A Negligible Magnitude Impact: Some impacts will result in changes to the environment that may be immeasurable, undetectable or within the range of normal natural variation. Such changes can be regarded as essentially having no impact, and are characterized as having a very low or negligible magnitude.

Determining Magnitude for Socio-economic Impacts

For socio-economic impacts, the magnitude considers the perspective of those affected by taking into account the likely perceived importance of the impact, the ability of people to manage and adapt to change and the extent to which a human receptor gains or loses access to, or control over socio-economic resources resulting in a positive or negative effect on their well-being. The quantitative elements are included into the assessment through the designation and consideration of scale and extent of the impact. Table 5.5 below presents the impact magnitude criteria for socio-economic and health impacts.

Table 5.5: Impact Magnitude Criteria for Socio-economic Impacts

Category	Ranking	Definition
High	4	▪ Major impacts on human health (e.g. serious injury). ▪ Significant impact on the livelihoods of individuals (i.e. access to income source restricted over lengthy period of time). ▪ Serious impact on access to community facilities and utilities ▪ Breach of economy social policy and/or regulation.
Medium	3	▪ Modest impact on human health and well-being. ▪ Moderate impact on individual livelihoods (e.g. restricted access to income source). ▪ Medium impact on access to community facilities and utilities (e.g. access to utilities restricted for long periods (weeks) of time). ▪ Potential breach of company social policy and/or legislation.
Low	2	▪ Limited impact on human health and well-being (e.g. occasional dust, odour, traffic noise). ▪ Some impact on the livelihoods of individuals (e.g. isolated incidents related to ethnic tensions and some restrictions on access to income source). ▪ Some impact on access to community facilities and utilities (e.g. access to cultural centers restricted to a limited extent, i.e. (days).
Negligible	1	▪ Possible nuisance to human health and well-being (e.g. occasional unpleasant odours) ▪ Inconvenience experienced in accessing community facilities and utilities (e.g. electricity supply disruption for short (hours) period of time). ▪ No impact on livelihood, community facilities and human health.
Positive	+	▪ Beneficial improvement to human health. ▪ Benefits to individual livelihoods (e.g. additional employment opportunities). ▪ Improvements to community facilities/utilities. ▪ Increased economy (e.g. local procurement, sourcing of supplies).

Determining Receptor Sensitivity

In addition to characterizing the magnitude of impact, the other principal variable necessary to assign significance for a given impact is the value, and sensitivity/fragility of the receptor. This refers to economic, social, and/or environmental/ecological importance of the receptor, including reliance on the receptor by people for sustenance, livelihood, or economic activity, and to the importance of direct impacts to persons associated with the resource.

The receptors-sensitivity designations employed in this impact assessment process are **Low**, **Medium** and **High** which are universally acceptable.

The sensitivity/fragility/value/importance criteria for biophysical and socio- economic receptors are defined in Table 5.6.

Table 5.6: Bio-physical and Socio-economic Receptor-Sensitivity/ Fragility/ Value Criteria

Category	Ranking	Definition
Physical (for example, air quality)		
High	3	All ambient conditions/concentrations exceed guideline limits and are indicative of the resource being impacted or polluted. There is no (or very little) assimilation capacity for increased concentrations/ change in conditions.
Medium	2	Some ambient conditions/concentrations exceed guideline limits while others fall within the limits. There is some small assimilation capacity for increased concentrations/ change in conditions. Resource use does affect other users
Low	1	All ambient conditions/concentrations are significantly lower than guideline limits and there is capacity for assimilation for additional concentrations/ change in conditions. Resource use does not significantly affect other users.
Biological (for example, terrestrial ecology)		
High	3	Specifically protected under Nigerian legislation and/or international conventions such as International Union for Conservation of Nature (IUCN); considered to be of critical importance to the local use; and totally dependent on for livelihood or means of survival.
Physical (for example, air quality)		
Medium	2	Not protected or listed but may be a species common globally but rare in Nigeria with little resilience to ecosystem changes, important to ecosystem functions, or one under threat or population decline; considered to be of moderate importance to the local use; and partially dependent on for livelihood or means of survival.
Low	1	Not protected or listed as common / abundant; or not critical to other ecosystem functions; considered to be of minor importance to the local use; and local communities do not depend on the resources for livelihood.
Socio-economic and Health		
High	3	Those affected will not be able to adapt to changes and continue to maintain pre-impact status.
Medium	2	Able to adapt with some difficulty and maintain pre-impact status but only with a degree of support.
Low	1	Those affected are able to adapt with relative ease and maintain pre-impact status.

Significance

The significance of the impact is determined by calculating the "product" of impact magnitude and severity/fragility/value/importance of the relevant receptor(s). Figure 5.2 illustrates the process for combining the impact magnitude with the receptor sensitivity.

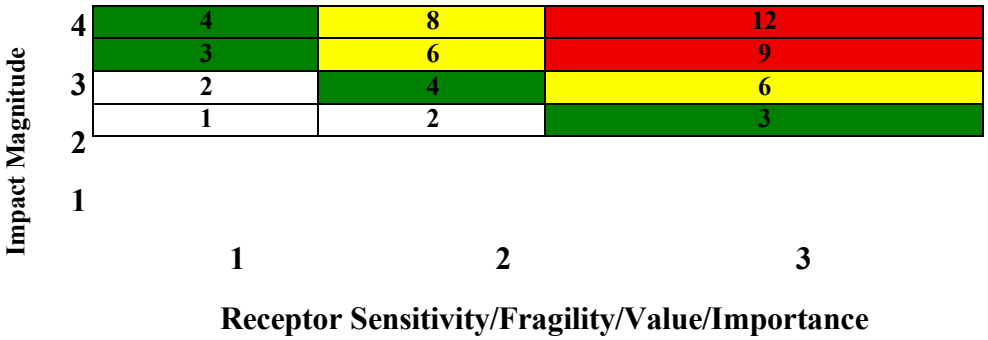


Figure 5.2: Impact Magnitude-Receptor Sensitivity Product Result

Based on its impact magnitude-receptor sensitivity/fragility/value score, each impact was again ranked into four (4) categories of significance as illustrated in Table 5.7.

Table 5.7: Environmental Impact Significance Rankings

Ranking (Impact Magnitude x Sensitivity of Receptor)	Significance
9 – 12	Major
6 – 8	Moderate
3 – 5	Minor
1 – 2	Negligible

Negligible Significant impacts are where a resource or receptor will not be affected in any way by a particular activity or the predicted effect is deemed to be 'negligible' or 'imperceptible' or is indistinguishable from natural background variations.

An impact of minor significance is one where an effect will be experienced, but the impact severity is sufficiently low (with or without mitigation) and well within accepted standards, and/or the receptor is of low sensitivity/value.

An impact of moderate significance is one within accepted limits and standards. Moderate impacts may cover a broad range, from a threshold below which the impact is minor, up to a level that might be just short of breaching a legal limit. The emphasis for moderate impacts is therefore on demonstrating that the impact has been reduced to a level that is as low as reasonably practicable (ALARP).

An impact of major significant is one where an accepted limit or standards may be exceeded, or high magnitude impact occurs to highly valued/sensitive receptors/resources.

Determining the Significance of Potentials Impacts of the Project

To assist in calculating the overall significance of each of the identified potential impacts, expert discussions were constituted. They employed extensive use of screening matrices and predefined criteria for impact magnitude and sensitivity/fragility/value/importance of resources/receptors. The significance was then developed as seen in Table 5.8.

Table 5.8: Leopold's Activity-Receptor Interaction Matrix (Impact Significance Matrix)

Summary of Project Activities at various Phases	Receptors																
	Physical						Biological		Socio-economic						Others (Health and Safety)		
	Air Quality	Ambient Noise	Soil	Groundwater	Surface Water	Landscape/	Terrestrial Flora	Terrestrial Fauna	Land Use	Population	Utilities	Infrastructure	Employment/	Gender issues	Construction workers	Workplace health and	General Public
Pre-construction Phase																	
Site selection									3(2)								
Site clearing and preparation	2(2)	2(2)	2(2)			2(1)	3(1)	3(1)					+		2(2)		
Mobilization of construction equipment and materials to site	2(2)	2(2)										2(2)	+				2(2)
Construction Phase																	
Civil work activities including excavation, trenching, cable laying, foundation, construction of building (e.g. training centre)	2(2)	2(2)	3(1)	2(2)	2(2)					3(2)			++	2(3)	2(3)		2(3)
Installation of power plant facilities, power storage batteries, upgrade of existing distribution infrastructure, installation of streetlights	2(2)	2(2)	3(1)											2(3)	2(3)		
Waste generation and disposal			2(2)	2(2)								2(1)	+		2(2)		2(2)
Commissioning Phase																	
Testing of power plant and associated infrastructure		2(1)								1(1)		1(1)			2(3)		2(2)
Operational Phase																	
Power generation and distribution and provision of training on renewable energy		2(1)											++	2(3)		2(3)	2(3)

Summary of Project Activities at various Phases	Receptors																
	Physical						Biological		Socio-economic						Others (Health and Safety)		
	Air Quality	Ambient Noise	Soil	Groundwater	Surface Water	Landscape/	Terrestrial Flora	Terrestrial Fauna	Land Use	Population	Utilities	Infrastructure	Employment/	Gender issues	Construction workers	Workplace health and	General Public
Routine maintenance; waste generation and disposal	2(2)		2(2)	2(2)		2(2)					2(1)	1(2)	+	2(1)		2(2)	2(2)

Note: Decommissioning is separately covered in Chapter 8

The value assigned to each cell in the matrix is in the form "x (y)": where "x" denotes the impact magnitude and "y" the sensitivity/fragility/importance of receptor Impact magnitude ranking: 1 = Negligible; 2 = Low; 3 = Medium; 4 = High., Impact sensitivity raking: 1 = Low; 2 = Medium; 3 = High.

5.2.5 Impact Discussion

Potential Positive Impacts

The proposed Project seeks to provide independent and reliable power supply to Air Force Institute of Technology (AFIT), Kaduna through a renewable energy source and thus, enhance learning and institutional operations. It also forms part of the measures in ensuring that Nigeria achieves its carbon emission reduction targets (20% - 30% carbon emission reduction by the year 2030) as contained in Nigeria's Nationally Determined Contributions (NDC) on climate change. In line with the Federal Government's plans for Power Sector reform, the Project will assist to promote stronger relationship and collaboration between the Federal Government of Nigeria (FGN), Nigerian Universities, REA, and other relevant regulatory bodies.

In addition, the Project will improve social economic activities within the Institution and help to enhance internally generated revenue. Furthermore, there are employment opportunities associated with the proposed Project for skilled, semi- skilled and unskilled workforce. The employment opportunities will lead to acquisition of new skills and introduction of all manners of income generating spill- over effects. For example, during the construction phase, about 1,000 workers would be engaged. The larger portion (60%) of the workforce (especially semi- skilled and unskilled craftsmen) would be drawn from the Project area.

Other potential benefits of the proposed Project include increase in local and regional economy through award of contracts and purchase of supplies for Project development as well as waste management.

Potential Negative Impacts

The potential negative impacts associated with the proposed Project are discussed under the following headings:

- Potential impact of the proposed 2MW solar-hybrid power plant and associated infrastructure
- Potential cumulative impacts

It is important to note that the significance of potential environmental and social impacts discussed in this section is without mitigation measures except those already built into the Project design. Implementation of additional mitigation measures (presented in Chapter Six of this report) are expected to further reduce the impact rating as low as reasonably practicable.

Potential Impacts of the proposed Project

i. Pre-Construction Phase Activities

The pre-construction phase of the proposed Project includes the following activities:

- Site selection
- Site clearing and preparation
- Mobilization of equipment and materials to site

Site Selection

The proposed Project will be sited on approximately 10.02Ha of land within the existing land property owned by AFIT, Kaduna. No additional land take, either from a private or public property, will be expropriated for the Project.

The Project site is characterized by vegetation which includes shrubs, grasses, and trees. However, a large portion (approximately 70 %) of the site is used for subsistence farming by some locals and staff living within the Institution campus (the exact number of persons involved could not be ascertained at the time of site visit).

The selection of the site for the proposed Project would affect the existing farming activities onsite. The impact magnitude is considered to be low given that about 25% of the entire 10.02 hectares of land would only be used for Project development. Also, the sensitivity of the receptor is regarded as medium. In addition, the Project site is used only for subsistence farming. The discussions with the Institution representative from the Physical Planning Unit also revealed that the affected persons will be allowed to harvest their crops before commencement of construction activities. Furthermore, alternative land within the Institution campus shall be provided for the affected persons to continue their farming activities. The impact significance of site selection for the proposed Project on the existing land use is rated **moderate**.

Site Clearing and Preparation

The Project site will be cleared of vegetation prior to construction activities. The site clearing activities would likely involve the use of earth moving equipment such as tractor. The potential impacts associated with the site clearing activities are discussed as follows:

Potential Impact on Terrestrial Flora and Fauna

Site clearing activities associated with the proposed Project will lead to loss of terrestrial flora on the Project site. The potential impact on the terrestrial flora is considered to be negative, direct, site specific and largely irreversible. The impact magnitude is considered to be medium considering that not all the land area (3.0ha) will be cleared for the Project. However, the sensitivity/importance of the receptor is regarded as low since the Project site is a modified habitat, and none of the plant species identified within the Project site during the baseline survey was found to be endangered or threatened based on the International Union for Conservation of Nature (IUCN)-2018 classification scheme. Also, the local community has no direct or indirect ecosystem services that they benefit from the site. Furthermore, there are no protected/conservation areas within the site. The significance of the potential impact of site clearing on the existing terrestrial flora species of the Project site is therefore regarded as **minor.**

While the plant species are unable to avoid the point of impact, most fauna species may be able to migrate away from unfavourable areas. Animals are generally mobile and, in most cases, can move away from a potential threat. The tolerance levels of some animal species are of such a nature that surrounding areas will suffice in habitat requirements of species forced to move from areas of impact.

With regard to the clearing of the Project site for construction purpose, the potential impact on terrestrial fauna species may include loss of individual or localized population of fauna species or disturbance to avifauna species. This is unlikely to lead to a change in conservation status of the species since none of the fauna species (including avi-fauna) encountered or reported in the Project site belongs to the IUCN classification of threatened

animal species which include those classified as critically endangered, endangered or vulnerable. The major fauna species observed on the site were mostly the birds nesting on some of the trees within the site. However, the site is not a designated bird nesting area. The sensitivity of the fauna species recorded on the Project site is thus regarded as low. The impact magnitude is considered to be medium given that the site clearing activities would not cover all of the approximately 3.0 ha of land allocated for the Project. The impact significance is thus considered **minor.**

Potential Impact on Soil

The proposed site clearing and preparation activities could potentially impact the soil environment of the Project site. The potential effects on soil include degradation due to site preparation e.g. compaction of soil as a result of the movement of earth moving equipment. Soil degradation is the removal, alteration, or damage to soil and associated soil forming processes, usually related to human activities. The stripping of vegetation or disturbance to the natural ground level over disturbance areas will negatively affect soil formation, moisture levels, soil density, soil chemistry, and biological activity. Uncontrolled site clearance of vegetation could lead to direct surface soil exposure and hence erosion of soil which could be significant.

The impact magnitude is considered as medium as the extent of soil erosion could be high, especially if the site clearing activities are carried out in the wet season. However, based on the results of laboratory analysis conducted on soil samples from the Project area, the Project site is not considered to be significantly prone to land- based erosion.

ii. Mobilization of Construction Equipment and Materials to Site

Potential Impact on Air Quality and Ambient Noise

Construction equipment and materials will be moved to the Project site prior to commencement of main construction activities. The potential biophysical impacts associated with the mobilization activities include decrease in ambient air quality of the Project area as a result of emissions from vehicles that will convey materials and equipment to site.

It is anticipated that the potential impacts will be similar to those experienced during site clearing activities. The capacity for assimilation of vehicular emissions and dust associated with the mobilization activities in the Project's area of influence is considered to be high. The overall impact significance of mobilization activities on the ambient air quality and noise of the Project area is rated **minor**.

Potential Impact on Infrastructure (Road)

Regarding community health and safety, the mobilization activities during the pre-construction phase of the Project could increase the traffic volume in the Project area (and potential for road accident) as a result of movement of vehicles in and out of the Project site. The social aspects of these activities could lead to accident, traffic congestion and annoyance from other road users in the area. The magnitude of the impact is considered low since the mobilization activities would be less than 1 week. The sensitivity of the receptors is adjudged as medium given that the existing vehicular movement in the Institution's environment is high. The prominent means of transportation are cars, tricycles, and motorcycles while buses/trucks are rare. The impact significance is considered to be **minor**.

Potential Impact on Workers Safety

Mobilization of construction materials will involve off-loading of heavy consumables such as cement, gravel, etc. Injuries and accidents may occur especially when those involved are unskilled. It is expected that the potential impacts will be similar to those experienced during site clearing and preparation activities. The impact significance is considered to be **minor**.

Summary of Potential Negative Impacts Associated with Pre-Construction Phase

Table 5.9 summarizes the potential impacts associated with the pre-construction phase of the proposed Project.

Table 5.9: Summary of Potential Negative Impacts Associated with the Pre-Construction Phase of the proposed Project

Activity	Receptor	Associated Impact	Significance
Site Selection	Existing farmland on site	• The farmlands belong to the university and there is no displacement due to land selection	Negligible
Site clearing and preparation	Terrestrial flora and fauna	• Vegetation loss • Direct impacts on vegetation and soil-dwelling organisms; indirect impacts on fauna species in the immediate surroundings of the Project site	Minor
	Soil	• Loss of top soil • Soil compaction and degradation • Increased erosion potential • Reduction in structural stability and percolative ability of soil	Minor
	Air Quality and Noise	• Air quality impacts due to emission from site clearing equipment • Increase in ambient noise levels	Minor
	Workers Safety	• Injuries and accidents to workers during site clearing and preparation.	Minor
Mobilization of construction equipment and materials to site	Air Quality and Noise	• Air quality impacts from vehicular emissions (TSP, NOx, CO, SOx) • Increase in noise levels	Minor
	Infrastructure (road)	• Increase in vehicular movement and traffic including potential for road accident	Minor
	Workers Safety	• Injuries and accidents to workers during loading and offloading of construction materials.	Minor

iii. Construction Phase

The construction phase of the proposed Project will include activities such as civil and electrical works (excavation, trenching, concrete mixing, etc.), installation of PV panels

and associated components; construction of training centre; installation of streetlights, upgrade of existing electricity distribution infrastructure; and waste waste generation and disposal.

The potential environmental and social impacts associated with the construction phase of the proposed Project are assessed and discussed as follows:

Potential Impact on Surface water

No surface water body occurs within the proposed Project footprint. Although a seasonal surface water body located at a considerable distance from the proposed development sites and is not hydraulically connected to the Project area. Consequently, construction and operational activities are not expected to directly affect the surface water body. Potential impacts are therefore considered unlikely under normal operating conditions. Nevertheless, standard good construction practices, including proper waste management, fuel and chemical handling, and erosion and sediment control measures, will be implemented to prevent any accidental off-site migration of pollutants. Based on the baseline water quality assessment, which showed no detectable hydrocarbon contamination or elevated heavy metal concentrations, the potential impact on surface water is assessed as negligible, indirect, highly localized, and reversible, with an overall impact significance of **negligible**.

Potential Impact on Terrestrial Flora and Fauna

The construction activities may potentially cause disturbance to flora and fauna species as a result of increase in human activity, noise level, creation of areas of bare soil, etc. which may alter the composition and diversity of plant species around the Project site and drive many fauna species away from the area. In addition, the potential for plant species invasion is likely to increase as a result of increase in areas of bare soil around the Project site.

Also the disturbance associated with noise and movement of construction equipment and personnel at the Project site may deter bird species from the area and disrupt the breeding of avifauna. It may also lead to increased risk to species such as snakes, rodents and mammals. The sensitivity of the receptor is adjudged to be low. The Project area is not known as a migratory route for avifauna species based on desktop reviews and field observation. The impact significance is regarded as **minor**.

Potential Impact on Hydrogeology and Groundwater Quality

The construction activities could lead to potential impacts on hydrogeology of the Project area. These include increased sediment load in the drainage channels as a result of erosion; increased storm water runoff from a decrease in infiltration; and increased runoff from hard standing areas.

Groundwater may be impacted as a result of infiltration of contaminants associated with spills or leaks of fuels, oils and lubricants from construction vehicles and/or storage containers. Currently, there are no boreholes within the Project site and the nearest borehole to the Project is over 300m away. The results of laboratory analysis conducted on groundwater samples from existing boreholes in the Project area did not reflect any heavy metal and hydrocarbon pollution. It is not anticipated that construction activities will have any direct impacts on the underground aquifer in the project area. Therefore, the potential for groundwater contamination as result of construction activities is rated **minor**

The potential impact on the existing underground aquifer (water reserve) of the Project area as a result of water abstraction for construction activities such as concrete mixing and

washing of construction equipment is considered to be **negligible** since the use of water for construction activities would be minimal. There are several boreholes within the University campus as noted during the site visit. The recharge of the existing boreholes in the Project area is largely due to direct precipitation. During the rainy season, the water reserve of the aquifer in the study area increases; thus, hand dug wells and boreholes yields improve significantly.

Potential impact on Gender

Construction activities in Nigeria are typically dominated by males which presents a major challenge for equal opportunities for women. Generally, the Nigerian construction sector has a particularly low participation rate for women, both in industry and academia. Key Informant Interviews (KII) and Focus Group Discussions (FGD) conducted within the local community revealed that although women are allowed to work and trade freely; they are underrepresented in leadership positions.

During construction activities, women may experience discrimination as most employment and training opportunities may be provided to men, while women will be left with menial jobs. This may result in marginalization due to lack of adequate training, thereby reinforcing gender stereotypes and gender pay gaps. Furthermore, there is the possibility of gender-based violence cases (GBV) against women employed to work at the Project site. However, FGD with the women in the local community revealed that GBV incidents are not frequent within the community. AFIT, Kaduna management expressed their commitment to providing a safe and conducive environment for all women within the institution. Nevertheless, the sensitivity of gender impacts is rated high due to cultural and religious doctrine that is deeply rooted in the belief and customs of an average Northerner therefore, the impact significance is regarded as **moderate**.

Potential Impact on Socio-economic and Health

Impacts associated with the construction phase of a project are usually of a short to medium term in nature, but could have long term effects on the surrounding environment. During construction, the proposed Project has the potential to affect the nearby community.

With regard to the presence of construction workers on site, the manner in which the workers conduct themselves can affect the local community in terms of disruption of existing family structures due to influx of migrant workers. The potential behaviour of construction workers, most especially male construction workers, may lead to an increase in levels of crime and drug and alcohol abuse, and an increase in incidence of casual sexual relations, which may result in increase in sexually transmitted disease (such as HIV/AIDS infections) and unwanted pregnancies. Additional pressure may also be placed on existing social infrastructure. Considering that the proposed number of workers (approximately 1,000) for the construction phase of the Project is relatively high, the potential risk to local family structures is regarded as high. Given that the majority of the construction workers, especially unskilled labour force would be drawn from the local community, the impact significance is considered to be **moderate**.

Potential Impact on Infrastructure (Road)

Regarding road infrastructure, the movement of construction vehicles in and out of the Project site during construction has the potential to increase road traffic and accidents. The impact magnitude is considered as low due to the minimal (about 2-3 daily) number of Project vehicles and trucks to be used during the construction phase. The impact sensitivity is rated medium. Therefore, the impact significance is considered **minor**.

Potential Impact on Construction Workers Safety

Construction sites are potentially hazardous place. Occupational accidents may occur especially when those involved are unskilled. Such occupational accidents may result in loss of man-hours which may ultimately affect the schedule date of completion of the Project development especially if the man-hour losses are high. Potential impacts to construction workers include increase in noise level and air emissions from construction activities, injuries, electrical shocks, accident, and denial of rights. The impact significance is considered **moderate**.

iv. Waste Generation and Disposal

Potential Impact on Soil

Construction activities are associated with waste generation. The potential wastes to be generated during the construction phase of the Project include scrap metals, electrical cables, spent oils, damaged batteries, wood/planks, paper waste, food remnants, leftover sand and gravel, etc. The waste streams if not properly handled, could contaminate the soil environment within the Project site and its surrounding environment. The impact sensitivity of the soil environment of the Project area is low judging by the results of laboratory analysis conducted on the soil samples. The impact significance is considered to be **minor**.

Potential Impact on Groundwater

Groundwater may be impacted as a result of infiltration of contaminants associated with liquid wastes especially from damaged batteries and spent oils. The impact magnitude is considered low; the nearest existing groundwater source to the Project site is over 300m away. The results of laboratory analysis conducted on groundwater samples from existing boreholes in the Project area did not reflect any heavy metal and hydrocarbon pollution. The potential for groundwater contamination as result of waste disposal is rated **minor**.

Potential Impact on Infrastructure (Waste Management Facility)

Construction waste can potentially have impact on the existing waste management facility of the Project area. Domestic wastes in AFIT, Kaduna are collected by Kaduna State Environmental Protection Authority (KEPA) accredited waste collectors. However, construction wastes such as scrap electrical components, batteries, damaged/defective panels and electrical cables (e-waste) cannot be disposed of in such manner. These wastes shall be returned to the manufacturers based on a take-back scheme or recycled as appropriate. The quantity of domestic wastes designated for the dumping site will thus be low. The impact of the waste on the waste management facility of the Project area is considered **negligible**.

Summary of Potential Negative Impacts Associated with Construction Phase

Table 5.10 summarizes the potential negative impacts associated with the construction phase of the proposed Project.

Table 5.10: Summary of Potential Negative Impacts Associated with the Construction Phase of the proposed Project

Activity	Receptor	Associated Impact	Significance
Civil and Electrical Works/ Installation Activities	Air Quality	• Air quality impacts due to emission from construction equipment (SPM, NOx, CO, SOx) • Increase in dust from cleared land and windblown stockpiles	Minor

Activity	Receptor	Associated Impact	Significance
	Ambient Nosie	• Increase in noise level due to construction activities	Moderate
	Soil	• Increased erosion potential as a result of construction activities such as excavation • Reduction in structural stability and percolative ability of soil resulting from compaction during civil works and installation activities	Minor
	Terrestrial Flora and Fauna	• Loss of plant species as a result of introduction of alien plants which may prevent the natural recovery of the natural vegetation on the site and power evacuation route. • Loss of fauna as a result of increased human activity and associated noise.	Minor
	Hydrogeology and	• Decrease in groundwater aquifer as a result of groundwater abstraction for construction activities e.g. concrete mixing, equipment washing, etc. • Groundwater contamination	Minor
	Groundwater		
	Surface water	• Surface water contamination	Minor
	Gender	• Discrimination of Women during employment • GBV	Moderate
	Socio-economic and health	• Influx of migrant workers, increase in sexual transmitted diseases.	Moderate
	Infrastructure (road)	• Road damage, traffic and safety impacts.	Minor
	Construction workers safety	• Injury to construction workers during construction activities.	Moderate
Waste Generation and Disposal	Soil	• Decrease in soil quality	Minor
	Groundwater	• Groundwater contamination	Minor
	Infrastructure (waste management facility)	• Disposal of construction wastes to existing waste management facility in the Project area.	Negligible

v. Commissioning Phase

Once the construction phase of the proposed Project is completed, the power plant and associated infrastructure will be tested to ensure that they have been installed according to the pre-design and operational requirements. During the commissioning, there could be increase in noise level due to humming noise emission from the plant components (inverters and batteries), vehicular movement (transportation of commissioning officials), crowd noise, and other ceremonial activities. The ambient noise levels recorded in the area during baseline data gathering were generally below the FMEnv and World Bank recommended limits. Also, considering that the commissioning activities would be short-termed and localized, the impact significance is rated **minor**.

Also, there is potential for occupational hazards during the facility testing as a result of any wrong electrical connection. The impact significance is considered to be **moderate** on the workers' health and safety.

The commissioning phase will lead to an influx of guest and officials which will have an impact on the existing population and infrastructure (road) of the Project area. Due to the short duration of the commissioning activities, the impacts are considered to be **negligible**.

Table 5.11 summarizes the potential negative impacts associated with the commissioning phase of the proposed Project.

Table 5.11: Summary of Potential Impact Associated with the Commissioning Phase of the proposed Project

Activity	Receptor	Associated Impact	Significance
Plant testing	Ambient noise	• Increase in ambient noise level	Minor
	Workers	• Occupational health and safety hazards (e.g. injuries, electrocution, etc.) as a result of any wrong electrical connection.	Moderate
	Population influx	• Increase in population during Commissioning	Negligible
	Infrastructure (road)	• Road traffic and risk of accidents	Negligible

vi. Routine Maintenance, Waste Generation and Disposal

Potential Impact on Soil

Routine maintenance of the Project facilities has the potentially for waste generation. Such wastes if not handled properly could lead to soil contamination. The major waste stream will be e-waste generated from spent/damaged components of the Project such as batteries, inverters and PV panels. These wastes will be stored within the Project site according to the manufacturer's instructions. All components to be used for the Project will have buy back agreements with the manufacturers as specified in the Extended Producer Responsibility Program (EPRP). The impact significance is considered to be **minor**.

Potential Impact on Groundwater

Potential impacts may include decrease in amount of groundwater reservoir as a result of water abstraction for cleaning of the PV panels. Cleaning of the PV panels is envisaged to be carried out about three (3) times during the raining reason and this would be more than three times during the dry season.

Based on previous experience, each panel would require approximately 5 litres of water per cleaning cycle. With an estimated number of 6,600 panels for 2MW generation, it is envisaged that the proposed Project would consume approximately 16,500 litres of water per cleaning cycle. The water required for the cleaning purpose would be obtained from the existing boreholes within the Institution campus. Based on observations noted during the field survey and the estimated quantity of water required for occasional cleaning of the PV panels, water abstraction for the Project is not envisaged to have serious effect on the existing groundwater aquifer of the Project area as well as the local water use. Thus, the impact significance is considered **minor**.

Potential Impact on Occupational Health, and Safety of Workers

During routine maintenance, workers may be exposed to occupational health and safety issues (e.g. electrical and field exposure, shock hazards and mechanical injuries). The impact significance is considered to be **minor** primarily due to the low number of staff (approximately) required for maintenance activities and low frequency of maintenance.

Summary of Potential Negative Impacts Associated with Operation Phase

Table 5.12 below summarizes the potential negative impacts associated with the operational phase of the proposed Project.

Table 5.12: Summary of Potential Negative Impacts Associated with Operational Phase of the proposed Project

Activity	Receptor	Associated Impact	Significance
Power Generation and distribution	Gender	• Discrimination of women during employment • GBV (sexual harassment, assault and poor working condition)	Moderate
	Socio-economic (visual prominence)	• Landscape alterations resulting in unpleasant changes in the visual character of the area	Minor
	Socio-economic (health issues)	• Community health and safety impact due to electromagnetic field (EMF) radiation from the Solar-hybrid power plant	Negligible
	Health, safety and welfare of staff during Plant operation	• Electric shock, injuries to personnel associated with the Power Plant operations, • Work related issues such as discrimination, denial of rights, unfair treatment, poor working Conditions	Moderate
Routine Maintenance, Waste Generation and Disposal	Soil	• Soil contamination from spent batteries and inverters	Minor
	Groundwater	• Groundwater abstraction from cleaning of PV panels	Minor
		• Groundwater and soil contamination	Negligible
	Health, safety and welfare of staff during maintenance	• Electric shock, injuries to personnel during maintenance	Minor

vii. Potential Cumulative Impacts

Cumulative impacts are those impacts resulting from the combined effects of past, present or reasonably foreseeable actions owing to the project aspects and activities outside the project (GSI, 2003). The concept of cumulative effects is an important one. It holds that, while impacts may be small individually, the overall impact of all environmental changes affecting the receptors taken together can be significant. When a resource is nearing its tolerance threshold, a small change can push it over.

The major existing activities around the Project area are farmlands and the university switchyard. Given the nature of the activities associated with the proposed Project and the existing activities around the project area, the potential cumulative impacts of the Project on road traffic, ambient noise levels and groundwater availability is considered **low**.

5.3 Risk and Hazard Assessment

Overview

Risk assessment is the determination of quantitative or qualitative estimate of *risk* related to a concrete situation and a recognized threat (also called hazard). The assessment of the risks and hazards associated with the proposed Project involves the following steps:

- Identification of hazards/risks
- Likelihood of occurrence
- Consequence/severity of the hazards

The risk assessment matrix is then developed as presented in Figure 5.3.

0 – 5 = Low Risk 6 – 10 = Moderate Risk 11 – 15 = High Risk 16 – 25 = extremely high unacceptable risk		Severity of the potential injury/damage				
		Insignificant damage to Property, Equipment or Minor Injury 1	Non-Reportable Injury, minor loss of Process or slight damage to Property 2	Reportable Injury moderate loss of Process or limited damage to Property 3	Major Injury, Single Fatality critical loss of Process/damage to Property 4	Multiple Fatalities Catastrophic Loss of Business 5
Likelihood of the hazard happening	Almost Certain 5	5	10	15	20	25
	Will probably occur 4	4	8	12	16	20
	Possible occur 3	3	6	9	12	15
	Remote possibility 2	2	4	6	8	10
	Extremely Unlikely 1	1	2	3	4	5

Figure 5.3: Risk Assessment Matrix

5.3.1 Project Specific Risks and Hazards

The potential risks and hazards associated with the proposed Project are described below:

Fire and Explosion

The major risk associated with the operational phase of the Project is fire and explosion. PV systems are subject to electrical faults like any other electrical installation such as short circuits, ground faults and reverse currents. These faults and other failures of the system, including cable insulation breakdowns, rupture of a module, and faulty connections, can result in hot spots that can ignite combustible material in their vicinity. Wrongly installed or defect DC/AC inverters have been the reason of several photovoltaic fires as well.

Fire could possibly occur during operation of the power plant. Overcharging, high temperatures and physical stress to Lithium-ion battery cells can cause thermal runaway, which commonly leads to the destruction of the battery, fire and even explosions. In addition, deep discharging can also cause battery fires. Any outbreak of uncontrolled fire in the area can escalate to dangerous dimensions which could be critical. The hazard is classified as **high risk**.

Electrocution

Electrocution from direct contact with high-voltage electricity or from contact with tools, vehicles, ladders, or other devices that are in contact with high-voltage electricity could occur during the Plant operation. The likelihood of the hazard happening is remotely

possible and its severity if occurs may result into marginal consequence. The hazard is classified as **moderate risk**.

Occupational Hazards

Workers may be exposed to occupational hazards when working at elevation during construction. Also, there could be electrical hazards to workers. Common electrical accidents result in shocks and/or burns, muscle contractions, and traumatic injuries associated with falls after the shock. The likelihood of the hazards occurring is considered to be possible while its severity is considered to be marginal. The hazard is classified as **moderate risk**.

Summary

In summary, the key potential impacts and risks associated with the proposed Project have been evaluated in this chapter. From such, the significance of the identified negative impacts/risks will be minimized to as low as reasonably practicable with the implementation of appropriate mitigation measures presented in the next chapter of this report. Enhancement measures for the identified positive impacts are also contained in the chapter.

CHAPTER SIX

MITIGATION MEASURES

6.0 Introduction

Following the detailed description of the associated and potential impacts of the proposed Project in Chapter 5, the recommended mitigation measures for the identified negative impacts are presented in this chapter as well as the enhancement measures for the potential positive impacts. The implementation of the mitigation measures shall be overseen by the Rural Electrification Agency's Project Management Unit (REA-PMU).

6.1 Mitigation Measures Approach

Mitigation refers to measures or interventions necessary to avoid, minimize, reduce or offset adverse impacts. Approach for selecting appropriate mitigation measures followed the framework stated by AfDB:

- Anticipate and avoid risks and impacts
- Where avoidance is not possible, minimize or reduce risks and impacts to acceptable levels
- Once risks and impacts have been minimized or reduced, mitigate
- Where significant residual impacts remain, compensate or offset them, where technically and financially feasible

In proffering mitigation measures for the various negative impacts identified in the previous chapter, preference was given to avoidance or prevention of adverse impacts and where not feasible, measures which are practicable and cost-effective using best available technology were suggested to reduce and/or minimize the impacts while rehabilitation, restoration or compensation was considered as the last resort.

6.2 Mitigation Measures for the Identified Significant Negative Impacts

The recommended mitigation measures for the identified negative impacts associated with the proposed Project. The unmitigated potential negative impacts ranked as negligible are not included in the table. The recommended mitigation measures are considered adequate to address the adverse impacts identified in Chapter 5 of this report. There are no potential long-term impacts associated with the Project that cannot be mitigated to acceptable levels of residual impact. The residual impacts of the proposed Project, following the implementation of the proffered mitigation measures highlighted in Table 6.1, are of negligible to minor significance.

6.3 Mitigation Measures for the Identified Project Risks and Hazards

The mitigation measures for the identified Project risks and hazards are highlighted below:

Fire and Explosion

- Only PV modules which comply with international and local standards for electrical performance and safety shall be used.
- Only solar cables suitable for outdoor applications and severe weather conditions shall be used
- Inverters shall not be mounted on combustible walls such as wood panels or combustible sandwich panels
- Inverters shall be easily accessible and protected from severe weather conditions.
- The local fire department shall be informed of and familiarized with the

photovoltaic installation.
- PV systems shall only be installed by qualified contractors.
- PV systems shall be inspected regularly by qualified professionals.
- PV systems shall be regularly checked for damage from rodents and other pests, which could compromise wiring or insulation.
- Batteries installed for the power plant shall be monitored regularly to prevent overcharging and deep discharging during operations
- Protection devices (e.g. Current interrupt devices (CIDs), positive temperature coefficient (PTC) thermistors, current-limiting fuses, diodes, battery management systems (BMSs), etc.) shall be installed to protect the batteries
- The batteries shall be housed in well ventilated, dust free containers under optimal conditions.
- Emergency response plan shall be developed and implemented.
- Fire extinguishers, fire notices, warning signs) shall be installed at different locations within the Plant site.

Electrocution
- Use of signs, barriers and public outreach to prevent public contact with distribution cables shall be employed.
- Grounding conducting objects (e.g. fences or other metallic structures) shall be installed where required to prevent shock.

Occupational Hazards
- Provision of an adequate work-positioning device system for workers shall be ensured.
- Hoisting and lifting equipment shall be rated and maintained and operators trained in their use.
- Appropriate Personal Protective Equipment shall be worn.
- Electrical installation shall be carried out by trained personnel in line with the approved procedures.

6.4 Enhancement Measures for Identified Positive Impacts

6.4.1 Reduction in Carbon Emissions

The Project will enhance Nigeria's intention of reducing its carbon emissions by 20% in the year 2030 as contained in its NDC on climate change. To enhance this impact, the following measures shall be implemented:

- In cases where the power generated (2 MW) is insufficient to meet the power demands of the University in the next 10 to 20 years, power shall be distributed to high priority areas so as to reduce/eliminate the use of diesel- powered generators. In addition, the Project will be designed and constructed to allow for further expansion in power generation and distribution capacity to meet the University's demands.

- The University shall implement energy conservation measures such as encouraging switching off appliances, use of energy-saving bulbs, purchase of low-energy appliances such as printers, computers, refrigerators, etc.

6.4.2 Enhancement of Learning

The Project will help to overcome the barrier on research and learning posed by epileptic power supply to the Institution. To enhance this impact, the following measures shall be implemented:

- Power distribution priority shall be given to all classrooms, lecture theatres, research centers, libraries, laboratories, and other academic buildings especially during learning hours.
- Research centres, laboratories, and libraries shall have 24-hour power supply.

6.4.3 Direct Employment and Training

The Project will give rise to direct employment opportunities across different skill levels, from unskilled to highly skilled labour. It is estimated that during construction phase, at least 100 job opportunities would be created. Training for local people from skilled technicians shall also be carried out. The following measures shall be implemented to ensure that direct employment and training opportunities are maximized:

- A Labour and Employment Management Plan (LEMP) shall be developed prior to construction, detailing percentages and numbers of the workforce to be sourced from the local area and various demographics as well as influx management. The plan shall follow local and international employment guidelines.
- The EPC contractor shall provide notification to different groups in the community on specific jobs and skills required for the project, prior to the commencement of construction. Subsequently, the group leaders shall notify the local population prior to the commencement of construction of job opportunities and relevant skills/qualifications required to be employable on the Project.
- A Gender Management Plan (GMP) shall be developed and implemented to ensure that the Project does not increase women's burden and that women not only contribute, but also benefit from it.
- The EPC contractor shall initiate training and skills development programmes prior to the commencement of construction, as a means of ensuring that members of the local workforce are up-skilled and can be employed on the Project.

During the operational phase of the Project, job opportunities will also be created. About 15 people will be employed. This will be a mixture of skilled labour (such as electrical and mechanical technicians) and unskilled labour (such as PV module cleaners and security personnel). Periodic capacity building will be offered to the workforce.

6.4.4 Procurement and Indirect Employment

The construction and operation of the proposed Project will create opportunities for the supply of goods and services to the Project and in turn, indirect employment will be created in the supply chain. Other opportunities for local companies to provide catering, waste / recycling and landscaping facilities, etc. will also be created. Local and regional procurement targets shall be included in the Project's LEMP to enhance this potential opportunity.

Table 6.1: Mitigation Measures for the Potential Negative Impacts of the proposed Project

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
Pre-construction Phase					
Site clearing and preparation	Terrestrial flora and fauna	• Vegetation loss • Direct impacts on vegetation and soil- dwelling organisms; indirect impacts on fauna species in the immediate surroundings of the Project site	Minor	▪ Vegetation clearing shall be limited to the areas within the site needed for the Project. ▪ The extent of vegetation to be cleared shall be clearly identified and appropriately demarcated. Clearing exceeding the approved working corridor shall be prohibited. ▪ Bush burning shall be avoided. ▪ Use of herbicides for site clearing shall be avoided. ▪ Any cleared areas which are not used will be re-vegetated using plants or seeds of locally occurring species.	Negligible
	Soil	• Effects on top soil and soil compaction associated with site clearing • Increased erosion potential • Reduction in structural stability and percolative ability of soil	Moderate	▪ Removal of vegetation shall be restricted to the areas required for the Project. ▪ Disturbed areas will be rehabilitated as soon as possible to prevent erosion. ▪ The extent of vegetation to be cleared shall be clearly identified and appropriately demarcated. Clearing exceeding the approved working corridor shall be prohibited. ▪ Use of silt traps or similar systems to reduce discharge of silt shall be	Minor

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				ensured.	
	Air quality and noise	• Air quality impacts due to emission from site clearing equipment • Increase in ambient noise levels	Minor	▪ Site clearing equipment / machinery shall be operated and maintained under optimum fuel-efficient conditions. ▪ Noise suppression equipment shall be fitted on machinery. ▪ Site clearing equipment shall be turned off when not in use. ▪ Equipment/machinery with lower sound power levels shall be selected and used for site clearing.	Negligible
	Workers Safety	• Injuries and accidents to workers during site clearing and preparation.	Minor	▪ Site clearing shall be limited to the day time as much as possible. ▪ Unregistered labourers and touts shall not be engaged for off-loading materials ▪ Provision of adequate personal protective equipment (PPE) such as nose masks shall be ensured. All employees will be required to wear the appropriate PPE	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				whilst performing their duties.	
Mobilization of personnel, materials and equipment to site	Air quality and noise	• Air quality impacts from vehicular emissions • Increase in ambient noise levels	Minor	▪ Construction vehicles with efficient engine performance and with minimal noise and air emissions shall be selected and used. This can be achieved through regular servicing and maintenance. ▪ All materials with potential to result in dust emissions shall be covered during transport. ▪ Onsite vehicle speed on unhardened roads and surfaces shall be limited to about 15 – 20km/h so as to reduce dust generation.	Negligible
	Infrastructure (road)	• Increase in vehicular movement and traffic around the project site; • Potential for road accident.	Minor	▪ A traffic management plan (TMP) shall be developed by the EPC Contractor and implemented. ▪ Appropriate signage and safety measures (barrier, formalized crossing points) to reduce the risk of accidents in the Project area shall be provided. ▪ The local community shall be sensitized about the Project activities and the need to comply with the traffic management plan put in place.	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				▪ Project related vehicles shall be regularly serviced and maintained. ▪ Drivers' competency shall be assessed and where required, appropriate training shall be provided. This will include training on safe driving measures such as adherence to speed limits (of less than 10 km/h) in the Project area. ▪ A procedure for recording traffic incidents/accidents associated with the Project shall be developed and implemented. This will include date/time, location, reason for accident, corrective measures, etc.	
Construction Phase					
Civil and Electrical Works/ Installation Activities	Soil	• Increased erosion potential as a result of construction activities such as excavation • Reduction in structural stability and percolative ability of soil resulting from compaction during civil works and installation activities	Minor	▪ Excavation works shall not be executed under aggressive weather conditions. ▪ Stockpiles shall be appropriately covered to reduce soil loss as a result of wind or water erosion. ▪ Disturbed areas shall be rehabilitated with erosion control plants (using native plant species) as soon as possible to prevent erosion. ▪ Work areas shall be clearly defined and where necessary demarcated to avoid unnecessary disturbance of areas outside the development footprint.	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
	Air Quality	• Air quality impacts due to emission from construction equipment • Increase in dust from cleared land and windblown Stockpiles	Minor	▪ Regular maintenance and servicing of construction equipment /machinery shall be ensured. ▪ Only modern and well maintained equipment and machinery shall be used for construction activities. ▪ Routine water sprinkling shall be carried out to minimize dust generation during construction.	Negligible
	Ambient Noise	• Increase in noise level due to Construction	Moderate	▪ Construction activities shall be limited to day-time (08.00hr to 17.00hr during weekdays; and weekends 09.00hr- 13.00hr). In the event that noisy activities are undertaken	Minor
		activities; • Disturbance to neighbouring community and local ecology		outside of the specified working hours, all noise receptors in the Project area shall be informed of such activities in advance. ▪ Construction machinery shall be turned off when not in use. ▪ Machinery/equipment to be used for construction work shall meet industry best standard in relation to noise attenuation. ▪ Construction equipment shall be properly maintained and serviced. ▪ Major construction activities shall be limited to a particular area within the	

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				site. ▪ Construction-related vehicles shall be limited to access areas. ▪ Noise complaints related to the construction activities shall be assessed and appropriately addressed. ▪ Noise monitoring at locations with persistent noise complaints shall be maintained.	
	Infrastructure (road)	• Road damage, traffic and safety impacts.	Minor	▪ A TMP shall be developed by the EPC Contractor and implemented. ▪ Speed limits for all construction-related vehicles shall be established and enforced. ▪ Construction related vehicles shall be regularly serviced and maintained. ▪ Appropriate barriers and signage shall be provided to demarcate areas in which construction traffic is active. ▪ Drivers' competency shall be assessed and where required training shall be provided. ▪ A procedure for recording all construction related traffic incidents/accidents shall be developed and implemented. This will include date/time, location, reason for accident, corrective measures, etc. ▪ The NEP Grievance Redress	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				Mechanism (GRM) shall be implemented for receiving complaints arising from damage to infrastructure and private property during construction activities shall be developed. The EPC contractor shall receive the complaints and repair damages as quickly as possible.	
	Groundwater and surface water	• Groundwater and surface water contamination	Minor	▪ Training shall be provided for workers on safe storage and handling practices and rapid spill response and clean-up techniques during induction. ▪ Spill control and response plans to respond to spills and leaks shall be implemented. ▪ Waste receptacles shall be provided within a secured area within the project site for collection of solid waste. ▪ General wastes that cannot be reused shall be periodically evacuated by the government accredited waste contractor	Negligible
	Terrestrial Flora and Fauna	• Loss of fauna as a result of increased human activity and associated noise.	Minor	▪ Construction workers shall be provided with appropriate training on ecological awareness, as appropriate to their work activities. ▪ All construction equipment shall be cleaned (mud and soil removed) at	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				source before being brought to site to minimise introduction of alien species. ▪ If sand or other natural materials for building are required and brought onto site, the stored heaps will be monitored for the growth and germination of alien species and will be regularly cleared during construction. ▪ Regular monitoring will be undertaken to ensure that alien plants are not increasing as a result of the disturbance that has taken place. ▪ In order to reduce collision of vehicles with fauna, a 10 km/hr speed limit by construction-related vehicles shall be enforced in the Project area.	
	Gender	• Discrimination during employment and training opportunities • GBV (sexual harassment, intimate partner violence, poor working)	Moderate	▪ Equal treatment of workers shall be ensured. ▪ The GBV Action Plan for EEP shall be implemented for the Project ▪ All workers on the project shall be required sign a code of conduct to prohibit any form of Gender Based Violence/Sexual Exploitation and Abuse (GBV/ SEA) ▪ GBV sensitive channels for reporting in GRM shall be implemented for the Project	Minor

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				▪ The EPC Contractor shall be required to hire a Gender/GBV officer. ▪ Collaboration with appropriate government institutions or GBV service providers on potential GBV case management shall be ensured. ▪ All workers shall be required to undergo regular training and refreshers on GBV ▪ The EPC Contractor shall provide separate facilities for men and women and add GBV-free signage at the project site. ▪ All gender-based violence incidents shall be reported and dealt with as per the law.	

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
	Construction workers safety	• Injury to construction workers during construction activities.	Moderate	▪ Health and Safety Plan shall be developed and implemented. The plan shall provide for recording, reporting, and investigating accidents and near misses, and developing measures to prevent recurrence. ▪ Construction workers shall be sensitized and monitored on the need to be safety conscious. ▪ Daily toolbox talks prior to commencement of work activities shall be carried out. ▪ Construction activities shall be limited to daytime as much as possible. ▪ Onsite safety officer shall be engaged to monitor the compliance of workers to safety rules. ▪ Proper safety signs and signage shall be placed at strategic locations within the site. ▪ PPE such as safety boot, coverall, eye google, safety helmets, reflective vests, etc. shall be provided to construction workers and the level of PPE compliance shall be monitored. ▪ Safety training focused on safe working practices, information on specific hazards, first aid and fire-fighting shall be included in the induction programme	Minor

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				for workers. ▪ A mechanism procedure for receiving and addressing the concerns of workers shall be put in place and implemented. ▪ The site shall be secured with perimeter fencing and/or security. ▪ Sanitary amenities and potable water shall be provided.	

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
	Socio-economic and health	• Influx of people, increase in sexual transmitted diseases.	Moderate	▪ Construction workers (e.g. semi-skilled and unskilled craftsmen) shall be drawn from the local community as much as possible. ▪ No person under the age of 18 shall be engaged to work on the project. The EPC Contractor shall ensure that children and minors are not employed directly or indirectly on the project ▪ Any child dropout should be reported to the relevant government agency ▪ The local community shall be informed of the Project activities prior to commencement of work. ▪ An induction and sensitization programme, including a Code of Conduct, for all construction workers shall be carried out prior to construction activities. This will increase sensitivity to local norms and customs, provide awareness to construction workers of appropriate and acceptable behaviours, and will govern worker interactions with the local community. ▪ Awareness education about	Minor

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				GBV/SEA/HIV/AIDS and other sexually transmitted diseases shall be created among the workforce and extended to the local community. ▪ The CoC shall include provisions to prohibit any form of Gender Based Violence/Sexual Exploitation and Abuse by workers within the local community. ▪ Public access shall be restricted to construction area via security fencing and appropriate signage. ▪ Substance abuse prevention and management programs shall be implemented for workers. ▪ Sanctions (e.g., suspension and dismissal) shall be introduced for workers involved in criminal activities ▪ Procedure for receiving and addressing community concerns shall be developed and implemented.	
Waste Disposal and Generation	Infrastructure (waste management facility)	• E-waste generation • Disposal of construction wastes to existing waste management facility in the Project area.	Minor	▪ A Waste Management Plan shall be developed and implemented ▪ Training shall be provided for workers on safe storage, use and handling of e-waste on site. ▪ E-wastes generated shall be stored in appropriate locations prior to recycling and/or disposal	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				▪ Waste receptacles shall be provided within a secured area for collection of solid waste. ▪ Construction vehicles and equipment shall be serviced regularly.	
	Soil	• Soil contamination from solid and liquid construction waste streams.	Minor	▪ Hazardous substances and materials (e.g. fuel, lubricating oil, etc.) shall be stored in appropriate locations with impervious hardstanding and adequate secondary containment. ▪ Portable spill containment and clean-up kits shall be available onsite. ▪ Construction workers shall be provided with adequate training on use, storage and handling of hazardous substances.	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
	Groundwater	• Groundwater contamination of liquid construction waste streams.	Minor	▪ Training shall be provided for workers on safe storage, use and handling of hazardous materials (e.g. fuel, lubricating oil) on site. ▪ Hazardous substances and materials (e.g. fuel, lubricating oil, etc.) shall be stored in appropriate locations with impervious hardstanding and adequate secondary containment. ▪ Portable spill containment and clean-up kits shall be available onsite. ▪ Waste management plan (WMP) shall be developed by the EPC Contractor and implemented. ▪ Waste bins shall be provided at designated locations on site for temporary storage of different waste streams. ▪ Construction waste, as much as practicable, shall be reused or recycled. ▪ Waste that cannot be reused or recycled shall be disposed of at an approved dumpsite.	Negligible
Commissioning Phase					

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
Plant Testing	Ambient noise	• Increase in ambient noise level	Minor	▪ The Power Plant components shall be installed in line with the pre-established standards and as per manufacturer recommendations. ▪ Strict compliance to the Standard Operating Procedures shall be ensured. ▪ The inverters and batteries to be used for the Project shall meet industry best standard in relation to noise attenuation.	Negligible
	Workers	• Occupational health and safety hazards (e.g. injuries, electrocution, etc.) as a result of any wrong electrical connection.	Moderate	▪ Plant testing shall be carried out by experienced personnel. ▪ Adequate PPE shall be worn. ▪ The Project components shall be installed in line with the pre-established standards and as per manufacturer recommendations. ▪ The EPC contractor shall develop the Standard Operating Procedures (SOPs) for the operational phase of the project ▪ Strict compliance to the (SOPs) shall be ensured. ▪ Prior to the Plant commissioning, appropriate emergency equipment (such as first aid box, fire extinguishers) shall be provided onsite. ▪ Plant testing shall be restricted to the	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				daytime. ▪ The site shall be secured with perimeter fencing and/or security ▪ Sanitary amenities and potable water shall be provided	
Operational Phase					
Power Generation and Evacuation	Socio-economic (visual prominence)	• Landscape alterations resulting in unpleasant changes in the visual character of the area	Minor	▪ All lighting will be kept to a minimum within the requirements of safety and efficiency. Where such lighting is deemed necessary, low-level lighting, which is shielded and directed downward, to reduce light spillage will be used. ▪ Site fencing if required shall be implemented.	Negligible
	Health, safety and welfare of staff during Plant operation	• Electric shock, injuries to personnel associated with the Power Plant operations, • Work related issues such as discrimination, denial of rights, unfair treatment, poor working conditions	Moderate	▪ Appropriate PPE shall be provided for workers. ▪ Training shall be provided to employees on emergency preparedness and responses. ▪ Provision of medical insurance scheme for employees shall be ensured. ▪ Appropriate safety signage shall be placed at strategic locations within the site. ▪ Strict compliance to the SOPs/ code of conduct shall be ensured. ▪ A grievance mechanism procedure for receiving and addressing the concerns	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				of employee shall be put in place and implemented.	
	Gender	• Discrimination during employment and training opportunities • GBV (sexual harassment, intimate partner violence, poor working)	Minor	▪ Equal treatment of workers shall be ensured. ▪ Continuous implementation of the GBV Action Plan for EEP shall be sustained for the Project ▪ All workers on the project shall be required sign a code of conduct to prohibit any form of Gender Based Violence/Sexual Exploitation and Abuse (GBV/ SEA) ▪ GBV sensitive channels for reporting in GRM shall be implemented for the Project ▪ The O&M Contractor shall be required to hire a Gender/GBV officer. ▪ Collaboration with appropriate government institutions or GBV service providers on potential GBV case management shall be sustained. ▪ All workers shall be required to undergo regular training and refreshers	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
				on GBV ▪ The O&M Contractor shall provide separate facilities for men and women and add GBV-free signage at the project site. ▪ All gender-based violence incidents shall be reported and dealt with as per the law.	
Routine Maintenance, Waste Generation and Disposal	Soil	• Soil contamination from spent batteries and inverters	Minor	▪ General housekeeping to ensure the site is not overgrown with grasses shall be maintained ▪ Waste bins shall be provided at designated locations on site for temporary storage of different waste streams. ▪ General waste that cannot be reused or recycled shall be disposed of at an approved dumpsite. ▪ WMP shall be implemented. ▪ Burning of waste shall be prohibited. ▪ Damaged/expired Lithium-ion batteries, solar panels, inverters and electric components shall be returned to the manufacturer based on the Extended Producer Warranty (EPR) model. Prior to returning them to the manufacturers, they will be stored on impermeable surfaces within the site.	Negligible

Project Activities	Receptors	Summary of Potential Impacts	Potential Impact Significance (without mitigation)	Mitigation Measures	Residual Impact (after implementation of mitigation measures)
	Health, safety and welfare of staff during Maintenance	• Electric shock, injuries to personnel during maintenance	Minor	▪ Appropriate PPE shall be provided for workers. ▪ Maintenance workers shall imbibe the workplace safety rules via proper sensitization procedures. ▪ Strict compliance to the SOPs shall be ensured.	Negligible
	Groundwater	• Groundwater abstraction from cleaning of PV panels	Minor	▪ Water management plan shall be implemented ▪ Manual cleaning of the PV panels with water shall be regulated as much as practicable. The frequency of cleaning of PV panels with water is dependent on the rainfall pattern in the project area. During rainy season, cleaning is estimated to occur not more than thrice; however during dry season the interval shall depend on the rate of dust accumulation. ▪ Periodic monitoring of groundwater resources in the Project's area of influence shall be implemented.	Negligible

CHAPTER SEVEN

ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

7.0 Introduction

The potential and associated impacts of the proposed 2MW solar-hybrid power plant and associated infrastructure at Air Force Institute of Technology (AFIT), Kawo, Kaduna State, as part of the Federal Government's Energizing Education Programme, have been analyzed and documented in Chapter 5 of this report. The results show that if the recommended mitigation measures (presented in Chapter 6) are implemented, the identified impacts of the Project are not severe and can be reduced to as low as reasonably practicable. It is thus important that those recommended mitigation measures be translated into practical management actions, which can be adequately resourced and integrated into the Project phases.

Hence, this chapter presents the management measures and actions required to address the potential environmental and social impacts of the proposed Project. It also includes monitoring program as well as performance indicators, responsible parties, timeframe and cost estimates for the implementation of recommended measures to address the associated impacts of the project throughout its life cycle. In addition, the framework for the contents of additional management plans to be developed and implemented as part of this ESMP is provided.

7.1 Objectives of the ESMP

The ESMP is essential for successfully implementing the Project's environmental and social performance throughout the life of the Project. Having this framework in place ensures a systematic approach to bringing environmental and social considerations into decision-making and day-to-day operations. It establishes a framework for tracking, evaluating and communicating environmental and social performance and helps ensure that environmental risks and liabilities are identified, minimized and managed including roles, responsibilities, and budget.

The ESMP will be a living document and will continue to develop during the design and construction phases to enable continuous improvement of the Project's environmental performance.

The specific objectives of the ESMP are to:

- Promote environmental and social management and communicate the aims and goals of the ESMP;
- Ensure that all workers, subcontractors and others involved in the Project meet legal and regulatory requirements with regard to environmental management;
- Incorporate environmental and social management into Project design and operating procedures;
- Serve as an action plan for environmental and social management for the Project;
- Provide a framework for implementing Project environmental and social commitments (i.e. mitigation measures identified in the ESIA);
- Prepare and maintain records of Project environmental and social performance (i.e. monitoring, audits and non-compliance tracking).

7.2 Environmental and Social Management Measures

Tables 7.1 to 7.5 present the recommended environmental and social management measures required to mitigate the identified impacts of the Project development and operation. Environmental and social measures for the decommissioning are documented in Chapter 8.

Table 7.1a: Environmental Management Measures for Pre-construction Phase of the proposed Project

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Site Clearing and Preparation							
Vegetation loss; direct impacts on vegetation and soil-dwelling organisms; indirect impacts on fauna species	Vegetation clearing shall be limited to the areas within the site needed for the Project. Use of herbicides for clearing shall be avoided. Site clearing and preparation shall be done mechanically.	Inspection	Daily	Adherence to measures	EPC Contractor	REA (PMU) AFIT (Site Engineer)	-
	Bush burning shall be avoided.	Inspection	Daily	Adherence to measures			
	Any cleared areas which are not used will be re-vegetated using plants or seeds of locally occurring species.	Inspection	Monthly after the site clearing phase	Re-vegetated land			
	The extent of vegetation to be cleared shall be clearly identified and appropriately demarcated. Clearing exceeding the approved working corridor shall be prohibited.	Inspection	Monthly before the site clearing activities	Adherence to measures			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Hunting or deliberate killing of animals by workers shall be prohibited and monitored. Workers shall be sensitized on ecological Protection	Inspection	Daily before the site clearing activities	Adherence to measures			
:	Removal of vegetation and soil cover shall be restricted to the areas required for the Project. Soil conservation measures shall be implemented such as stockpiling topsoil or for the remediation of disturbed areas.	Inspection	Daily	Re-vegetated land			
	Use of silt traps or similar systems to reduce discharge of silt shall be ensured.	Inspection	Monthly before the site clearing activities	Re-vegetated land			
Air quality impacts due to emission from site clearing equipment; increase in ambient noise levels	Site clearing equipment / machinery shall be operated and maintained under optimum fuel efficient conditions.	Maintenance records ; Fuel consumption records	Daily	Adherence to measures			
	Site clearing activities shall be carried out only during the daytime (08.00hr to 17.00hr during weekdays; and weekends 09.00hr-	Inspection	Daily	Adherence to measures			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	13.00hr)						
Mobilization of Materials and Equipment to Site							
Air quality impacts from vehicular emissions; Increase in ambient noise levels	Project vehicles with efficient engine performance and with minimal noise and air emissions shall be selected and used. This can be achieved through regular servicing and maintenance	Inspection; Maintenance records	Once befor e vehicle commences journey	Adherence to measures	EPC Contractor	REA (PMU) AFIT (Site Engineer)	2000
	All materials with potential to result in dust emissions shall be covered during transport.	Inspection	Once befor e vehicle commences Journey	Adherence to measures	EPC Contractor		
	Onsite vehicle speed on unhardened roads and surfaces shall be limited to about 15 – 20km/h so as to reduce dust generation.	Inspection	Daily	Adherence to measures	EPC Contractor		
	Unnecessary engine idling shall be avoided.	Inspection	Daily	Adherence to measures	EPC Contractor		
	Site roads and access roads shall be	Inspection	Daily	Adherence to measures	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	sprinkled as needed to prevent dust entrainment.						

Table 7.1b: Social Management Measures for Pre-construction Phase of the proposed Project

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requiremen t Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Loss of existing farmlands on site due to land take for the Project	Livelihood Restoration Plan (LRP) shall be developed and implemented (in consistent with the requirements of OP 4.12, Annex A - Involuntary Resettlement Instruments) to restore livelihood of the affected persons.	OP 4.12, Annex A - Involuntary Resettlement	Prior to mobilization to site clearing and construction	Involuntary Resettlement (OP/BP 4.12)	AFIT, Kaduna Management EPC Contractor	REA (PMU)	-
	Only the portion of the site required for Project development shall be cleared for construction.	Inspection	Prior to construction activities	Adherence to measure			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requiremen t Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	The affected farmers on the site shall be allowed to harvest their crops before commencement of construction activities.	Inspection	Prior to mobilization to site /site clearing and construction	Adherence to measure			
	FUE, Zaria shall provide alternative farmlands within the University for the affected persons.	Inspection	Prior to mobilization to site site clearingand construction	Alternative farmlands for the affected persons			
	The commitment for the provision of alternative land for the affected persons shall be documented in a letter signed by the FUE, Zaria Vice Chancellor or his designate	Letter o commitment f	Prior to mobilization to site /site clearing and construction	Adherence to measure			
Injuries and accidents to workers during loading and off-loading construction materials.	Provision of adequate PPE especially gloves, safety shoes, and hard hats to workers shall be ensured. All employees will be required to wear the appropriate PPE whilst performing their duties.	Availability of PPE	Daily	PPE compliance	EPC Contractor	REA (PMU) AFIT, Kaduna (Site Engineer)	500

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirement Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Unregistered labourers and touts shall not be engaged for off-loading materials.	Employment records of all staff on site	Once before commencement of mobilization	Labour Act	EPC Contractor		
Increase in vehicular movement and traffic including potential for road accident	A TMP shall be developed by the EPC contractor and implemented	TMP implementation records	Daily	Benchmarks stated in the TMP	EPC Contractor	REA (PMU) AFIT, Kaduna (Site Engineer)	1000
	Appropriate signage and safety measures (barrier, formalized crossing points) to reduce the risk of accidents in the Project area shall be provided.	Safety signs and barriers	Before and during mobilization	Adherence to measures	EPC Contractor		
	Speed limit around community areas shall be limited to a maximum of 20 km/hr	Evidence of consultation with local community	Before and during mobilization	Adherence to measures	EPC Contractor		
	Drivers' competency shall be assessed and where required, appropriate training shall be provided.	Drivers' competency assessments; training records	Once before commencement of mobilization	Passing of competency assessment or training completion certificates	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirement Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	A procedure for recording traffic incidents/accidents associated with the Project shall be developed and implemented.	Incident forms	Daily	Completed incident forms	EPC Contractor		
	Employee violations of speed limit and other traffic rules will result in disciplinary action ranging from warning to dismissal.	Incident forms, GRM	Daily	Completed incident forms	EPC Contractor		

Table 7.2a: Environmental Management Measures for Construction Phase of the proposed Project

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Civil and Electrical Works/ Installation Activities							
Air quality impacts due to emission from construction equipment;	Regular maintenance and servicing of construction equipment / machinery shall be ensured.	Maintenance records	Monthly during construction phase	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer)	
Increase in dust from cleared land	Routine water sprinkling shall be carried out to minimize	Inspection	Daily during civil work	Adherence to measures	EPC Contractor	Kaduna State Ministry of	

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
and windblown stockpiles	dust generation during construction.		activities			Environment	
Increase in noise level	Construction activities shall be limited to day-time (08.00hr to 17.00hr during weekdays; and weekends 09.00hr-13.00hr).	Inspection	Daily during construction phase	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) Kaduna State Ministry of Environment	
	Construction machinery shall be turned off when not in use.	Inspection	Daily during construction phase	Adherence to measures	EPC Contractor		
	Construction equipment shall be properly maintained and serviced.	Maintenance records	Monthly during construction phase	Adherence to measures	EPC Contractor		
	Noise complaints related to the construction activities shall be assessed and appropriately addressed.	Complaint records	Weekly during construction phase	World Bank Good Practice Note on Addressing Grievances	EPC Contractor		
	Noise monitoring at locations with persistent noise complaints shall be maintained.	Noise monitoring records	Monthly during construction phase	FMEnv Noise limit World Bank Noise Limit	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Increased soil erosion potential; reduction in structural stability and percolative ability of soil	Excavation works shall not be executed under aggressive weather conditions.	Inspection	Daily during excavation activities	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) Kaduna State Ministry of Environment	-
	Stockpiles shall be appropriately covered to reduce soil loss as a result of wind or water erosion.	Inspection	Daily during civil work activities	Adherence to measures	EPC Contractor		
Loss of plant species as a result of introduction of alien plants; loss of fauna as a result of	Construction workers shall be provided with appropriate training on ecological awareness, as appropriate to their work activities.	Training records	Once before start of construction phase	Certificates of Training	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer)	
Increased human activity and associated noise.	Regular monitoring will be undertaken to ensure that alien plants are not increasing as a result of the disturbance that	Monitoring records	Monthly during construction phase	Adherence to measures	EPC Contractor	Kaduna State Ministry of Environment	
Waste Disposal and Generation							
E-waste generation	A Waste Management Plan shall be developed and implemented	Waste Management records	Weekly during construction phase	Adherence to measures	EPC Contractor	REA-PMU AFIT,	

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Training shall be provided for workers on safe storage, use and handling of e-waste on site.	Training records	Once before commencement of construction	Certificates of Completion of trainings	EPC Contractor	Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	
	E-wastes generated shall be stored in appropriate locations prior to recycling and/or disposal	Waste consignment notes, waste receptacles on site	Weekly during construction phase	Adherence to measures	EPC Contractor		
Soil contamination from solid and liquid construction waste streams.	Hazardous substances and materials shall be stored in appropriate locations with impervious hardstanding and adequate secondary containment. Portable spill containment and clean-up kits shall be available onsite.	Inspection	Daily during construction phase	Adherence to measures World Bank General EHS Guidelines	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State	
	Constructionworkers shall be provided with adequate training on use, storage and handling of hazardous substances.	Training records	Once before commencement of construction	Certificates of Completion of trainings	EPC Contractor	Ministry of Environment	
Groundwater contamination of liquid construction	Training shall be provided for workers on safe storage, use and handling of hazardous	Training records	Once before commencement of	Certificates of Completion of trainings	EPC Contractor	REA-PMU	

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
wast e streams.	materials (e.g. fuel, lubricating oil) on site.		construction			AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	
	Hazardous substances and materials shall be stored in appropriate locations with impervious hardstanding and adequate secondary containment. Portable spill containment and clean-up kits shall be available onsite.	Inspection	Daily during construction phase	Adherence to measures World Bank General EHS Guidelines	EPC Contractor		
	Waste management plan (WMP) shall be developed and implemented.	WMP implementation records	Daily during construction phase	Benchmarks stated in WMP World Bank General EHS Guidelines	EPC Contractor		

Table 7.2b: Social Management Measures for Construction Phase of the proposed Project

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Civil and Electrical Works/ Installation Activities							

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Discrimination during employment and training opportunities	Employment of workers for construction activities shall be open and fair. However, no person under the age of 18 shall be engaged on the project sites.	Employment records	Once before start of construction	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	
GBV (sexual harassment, intimate partner violence, poor working)	The EEP GBV Action Plan shall be implemented for the Project	Implementation by the EPC Contractor	Once before start of construction	Evidence to show implementation of EEP GBV action plan	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State	
	All workers shall be required to undergo regular training and refreshers on GBV	Organize regular onsite training and refreshers	Monthly during construction phase	Records of regular training and attendance	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	All workers on the project shall be required sign a code of conduct to prohibit any form of Gender Based Violence/Sexual Exploitation and Abuse (GBV/ SEA)	Develop CoC forms for workers	Once before start of construction	Signed CoC forms	EPC Contractor	Ministry of Environment Kaduna State Ministry of Women Affairs and Social Development GBV/SEA service providers	
	GBV sensitive channels for reporting in GRM shall be implemented for the Project	Establish accessible GRM reporting channels	Monthly during construction	GRM records	EPC Contractor		
	The EPC Contractor shall be required to hire a Gender/GBV officer	Employ GRM Officer	Once before start of construction	Employment records and job description	EPC Contractor		
	Collaboration with appropriate government institutions or GBV service providers on potential GBV case management shall be ensured	Engagement of GBV service provider	Once before start of construction	Records of ongoing engagement and consultation with GBV service providers	EPC Contractor		
	The EPC Contractor shall provide separate facilities for men and women and add GBV-free signage at	Erection of separate convenience facilities and	Once before start of construction	Inspection of facilities to ensure adequacy	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	the project site	display of GBV signage					
Influx of people, increase in sexual transmitted diseases.	Construction workers (e.g. semi- skilled and unskilled craftsmen) shall be drawn from the local community as much as possible.	Employment records and prepare a labour management plan	Once before start of construction	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv	
	An induction and sensitization programme, including a Code of Conduct, for all construction workers shall be carried out prior to construction activities. This will increase sensitivity to local norms and customs, provide awareness to construction workers of appropriate and acceptable behaviours, and will govern worker interactions / fraternization with the local community.	Induction records and training on the code of conduct	Once before start of construction	Adherence to Measures	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Awareness education about GBV/SEA/HIV/AIDS and other sexually transmitted diseases shall be created among the workforce and extended to the local community	Training records	Once before start of construction	Adherence to measures	EPC Contractor		
	Public access shall be restricted to construction area via security fencing and appropriate signage	Inspection	Daily during construction phase	Adherence to measures	EPC Contractor		
	All workers on the project shall be required to sign a code of conduct to prohibit any form of Gender Based Violence/Sexual Exploitation and Abuse	Signed code of conduct records	Once before start of construction	Adherence to measures	EPC Contractor		
	The NEP GRM Procedure for receiving and addressing community concerns shall be developed and implemented.	Consultations and grievance records	Weekly during construction phase	World Bank Good Practice Note on Addressing Grievances	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Injury to construction workers during construction activities	Health and Safety Plan shall be developed and implemented.	Health and Safety plan implementation records	Daily during construction phase	Benchmarks stated in Health and Safety Plan	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment,	
	Community members and construction workers shall be sensitized and monitored on the need to be safety conscious. Daily toolbox talks prior to commencement of work activities shall be carried out for all workers.	Daily toolbox records	Daily during construction phase for workers and Monthly for communities as part of engagement	Benchmarks stated in Health and Safety Plan	EPC Contractor		
	Onsite safety officer shall be engaged to monitor the compliance of workers to safety rules.	Qualified and dedicated safety officer	Once before commencement of construction	Adherence to measures	EPC Contractor		
	PPE such as safety boot, coverall, eye google, safety helmets, reflective vests, etc. shall be provided to construction workers and the level of PPE compliance shall be monitored.	Availability of PPE	Daily during construction phase	PPE compliance	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Safety training focused on safe working practices, information on specific hazards, first aid and fire-fighting shall be included in the induction programme for workers.	Training records	Before commencement of construction and weekly	Certificates of Completion of trainings	EPC Contractor		
	A mechanism procedure for receiving and addressing the concerns of workers shall be put in place and implemented.	Completed grievance forms	Weekly during construction phase	Adherence to measures	EPC Contractor		
	Hazardous substances and materials shall be stored in appropriate location with impervious hardstanding and adequate secondary containment. Portable spill containment and clean-up kits shall be available onsite.	Inspection	Daily during construction phase	Adherence to measures World Bank General EHS Guidelines	EPC Contractor		
Road damage, traffic and safety impacts	TMP shall be developed by the EPC Contractor and implemented.	TMP implementation records	Daily during construction phase	Benchmarks stated in the TMP	EPC Contractor	REA-PMU AFIT, Kaduna (Site	
	Speed limits for all construction-	Inspection	Daily during construction	Adherence to measures	EPC Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	related vehicles shall be established and enforced.		phase			Engineer) FMEnv Kaduna State Ministry of Environment	
	Appropriate barriers and signage shall be provided to demarcate areas in which construction traffic is active.	Safety signs and barriers	Once before commencement of construction	Adherence to measures	EPC Contractor		
	Drivers' competency shall be assessed and where required training shall be provided.	Drivers' competency assessments; training records	Once before commencement of construction	Passing of competency assessment or training completion certificates	EPC Contractor		
	A procedure for recording all construction related traffic incidents/accidents shall be developed and implemented.	Incident forms	Daily during construction phase	Completed incident forms	EPC Contractor		
	The EPC contractor shall promptly repair damage to public infrastructure and repair or compensate for damage to private property.	Incident forms, GRM	Daily during construction phase	Completed incident forms	EPC Contractor		

Table 7.3a: Environmental Management Measures for Commissioning Phase

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Plant testing							
Increase in ambient noise level due to Plant testing	Strict compliance to the Standard Operating Procedures (SOPs)	SOPs	Once before commissioning	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	500
	The EPC contractor shall develop Standard Operating Procedures (SOPs) for the operational phase of the Project	SOPs	Once before commissioning	Adherence to measures	EPC Contractor		
	The Power Plant components shall be installed in line with the pre-established standards and as per	SOPs	Once before commissioning	Adherence to measures	EPC Contractor		

Table 7.3b: Social Management Measures for Commissioning Phase

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Plant testing							
Occupational health and safety hazards (e.g. injuries, electrocution, etc.) as a result of any wrong electrical connection.	Plant testing shall be carried out by experienced personnel.	Qualified and dedicated Engineer	Once before commissioning	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	200
	Adequate PPE shall be worn	Availability of PPE	Once before commissioning	Adherence to measures			
	Prior to the Plant commissioning, appropriate emergency equipment.	Availability of emergency response equipment	Once before commissioning	Adherence to measures			
Wrong electrical connection leading to explosion/fire	Plant testing shall be carried out by experienced personnel.	Qualifiedand dedicated Engineer	Once before commissioning	Adherence to measures	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	-

Table 7.4a: Environmental Management Measures for Operational Phase

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Power Generation and Evacuation							
Landscape alterations resulting in unpleasant changes in the visual character of the area	All lighting will be kept to a minimum within the requirements of safety and efficiency. Where such lighting is deemed necessary, low-level lighting, which is shielded and directed downward, to reduce light spillage will be used.	Inspection	Monthly during operations	Adherence to measures	O&M Contractor	REA-PMU AFIT, (Site Kaduna Engineer) FMEnv Kaduna State Ministry of Environment	-
Routine Maintenance, Waste Generation and Disposal							
E-waste generation and disposal	Training shall be provided for workers on safe storage, use and handling of e-waste on site.	Training records	At induction of new staff , and in annual refresher training	Certificates of completion of trainings	O&M Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of	2000
	E-wastes generated shall be stored in appropriate locations prior to recycling; consignment notes will be maintained	Waste consignment notes, waste receptacles on	Continuous during operations	Adherence to measures	O&M Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
		site				Environment	
	Waste receptacles shall be provided within a secured area for collection of solid waste.	Waste consignment notes, waste receptacles on site	Continuous during operations	Adherence to measures	O&M Contractor		
Soil contamination from spent batteries and inverters	Waste that cannot be reused or recycled shall be disposed of at an approved dumpsite. Spent batteries and inverters shall be sent to manufacturers in line with the Extended Producer Responsibility (EPR) policy.	Consignment notes for spent batteries to manufacturers for recycling	Yearly	World Bank General EHS Guidelines	O&M Contractor	REA-PMU AFIT, Kaduna (Site Engineer) Kaduna State Ministry of Environment	1000
	WMP shall be implemented.	WMP implementation records	Quarterly during operation phase	Benchmarks stated in WMP World Bank General EHS Guidelines	O&M Contractor		

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Groundwater abstraction from cleaning of PV panels	Water management / conservation plan shall be implemented	Implementation records of water management plan	Quarterly during operations	Benchmarks in water conservation plan World Bank General EHS Guidelines	EPC Contractor	REA-PMU AFIT, Kaduna (Site Engineer) Kaduna State Ministry of Environment	500

Table 7.4b: Social Management Measures for Operational Phase

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Power Generation and Evacuation							
GBV (sexual harassment, intimate partner violence, poor working)	The EEP GBV Action Plan shall be implemented during operations	Implementation by the O&M Contractor	Continuously during operations	Evidence to show implementation of EEP GBV action plan	O&M Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of	2000
	All workers shall be required to undergo regular training and refreshers on GBV	Organize regular onsite training and refreshers	Monthly during operation phase	Records of attendance			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	All workers on the project shall be required sign a code of conduct to prohibit any form of Gender Based Violence/Sexual Exploitation and Abuse (GBV/ SEA)	Develop CoC forms for workers	Once before start of operations	Signed CoC forms		Environment	
	GBV sensitive channels for reporting in GRM shall be implemented for the Project	Establish GRM reporting channels	Once before start of operations	GRM records			
	The EPC Contractor shall be required to hire a Gender/GBV officer	Hire GRM Officer	Once before start of operations	Employment records and job description			
	Collaboration with appropriate government institutions or GBV service providers on potential GBV case management shall be ensured	Engagement of GBV service provider	Once before start of operations	Records of ongoing engagement and consultation with GBV Service Providers			
	The EPC Contractor shall provide separate facilities for men and	Erection of separate	Once before start of Operations	Inspection of facilities to			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	women and add GBV-free signage at the project site	convenience facilities and display of GBV signage		Ensure Adequacy			
Health, safety and welfare of staff during Plant operation	Provision of medical insurance scheme for employees shall be ensured.	Employment forms of employees	Quarterly during operations	Adherence to measures	O&M Contractor	REA-PMU AFIT, Kaduna (Site Engineer) FMEnv Kaduna State Ministry of Environment	3000
	Appropriate safety signage shall be placed at strategic locations within the site.	Safety signs	Quarterly during operations	Adherence to measures			
	Strict compliance to the SOPs shall be ensured.	SOPs	Quarterly during operations	Adherence to measures			
	The NEP grievance mechanism procedure for receiving and addressing the concerns of employee shall be put in place and implemented.	Completed grievance forms	Monthly during operations	Adherence to measures			
Routine Maintenance, Waste Generation and Disposal							
Electric	Appropriate PPE shall be	Availability of	Quarterly during	Adherence	O&M Contractor	REA-PMU	500

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
shock, injuries to personnel during maintenance	provided for workers.	PPE	operations	to measures		AFIT, Kaduna (Site Engineer) Kaduna State Ministry of Environment	
	Strict compliance to the SOPs shall be ensured.	SOPs	Quarterly during operations	Adherence to measures			

7.3 Roles, Responsibilities and Accountabilities

The main responsibility for overseeing the implementation of the ESMP lies with the REA PMU throughout the project life span. However, conformance with the specific environmental measures detailed in Chapter Six of this report will be ensured by the EPC contractor during the construction phase and Operations and Maintenance (O&M) Contractor at the operational phase of the Project.

7.3.1 Pre-construction Phase

The key personnel and institutions with major roles in the implementation of the ESMP during pre-construction phase are:

AFIT, Kaduna Director of Physical Planning

- Select the land for the proposed Project
- Appoint a Site Engineer
- Arrange and ensure adequate training is carried out for the Site Engineer
- Review the ESMP from the consultant
- Ensure the Institute's commitment to the ESMP implementation

REA-PMU

- Provide technical support to the University in identifying sufficient and suitable land for power station construction and the training center
- Appoint an EPC contractor
- Supervise the activities of the EPC contractor
- Review the ESMP from the consultant
- Ensure REA's commitment to the ESMP implementation

AFIT, Kaduna Site Engineer

- Attend adequate training on ESMP implementation
- Supervise the activities of the EPC contractor and ensure compliance ESMP with mitigation measures
- Report to AFIT, Kaduna Director of Physical Planning on ESMP compliance and non-compliance issues

EPC Contractor

- Familiarize with ESMP requirements
- Ensure that all personnel are made aware of the management measures/plans that are to be implemented
- Report to the REA-PMU and AFIT, Kaduna Site Engineer on ESMP compliance and non-compliance issues
- Implement ESMP requirements relevant to work being undertaken

7.3.2 Construction Phase

The key personnel and institutions with major roles in the implementation of the ESMP during construction phase are:

AFIT, Kaduna Director of Physical Planning

- Supervise the activities of the Site Engineer by reviewing reports on ESMP issues
- Suggest ESMP improvements to REA-PMU to address non-compliance and upcoming issues

REA-PMU

- Supervise the activities of the EPC contractor by reviewing reports on ESMP issues
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning to address non-compliance and upcoming issues
- Monitors the implementation of the ESMP

AFIT, Kaduna Site Engineer

- Supervise the activities of the EPC contractor and ensure compliance ESMP with mitigation measures
- Report to AFIT, Kaduna Director of Physical Planning on ESMP compliance and non-compliance issues

EPC Contractor

- Implement ESMP requirements relevant to work being undertaken
- Hire a Gender/GBV officer
- Report to the REA-PMU and AFIT, Kaduna Site Engineer on ESMP compliance and non-compliance issues

FMEnv Representatives

- Monitor the implementation of ESMP requirements (impact mitigation monitoring) relevant to work being undertaken
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning and REA-PMU to address non-compliance and upcoming issues

Kaduna State Ministry of Women Affairs and Social Development and GBV service provider

- Monitor the implementation of Gender mitigation measures relevant to work being undertaken
- Discuss ESMP improvements with the Gender/GBV officer, AFIT, Kaduna Director of Physical Planning, and REA-PMU to address non-compliance and upcoming issues

Kaduna State Ministry of Environment Representatives

- Monitor the implementation of ESMP requirements (impact-mitigation monitoring) relevant to work being undertaken
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning and REA-PMU to address non-compliance and upcoming issues

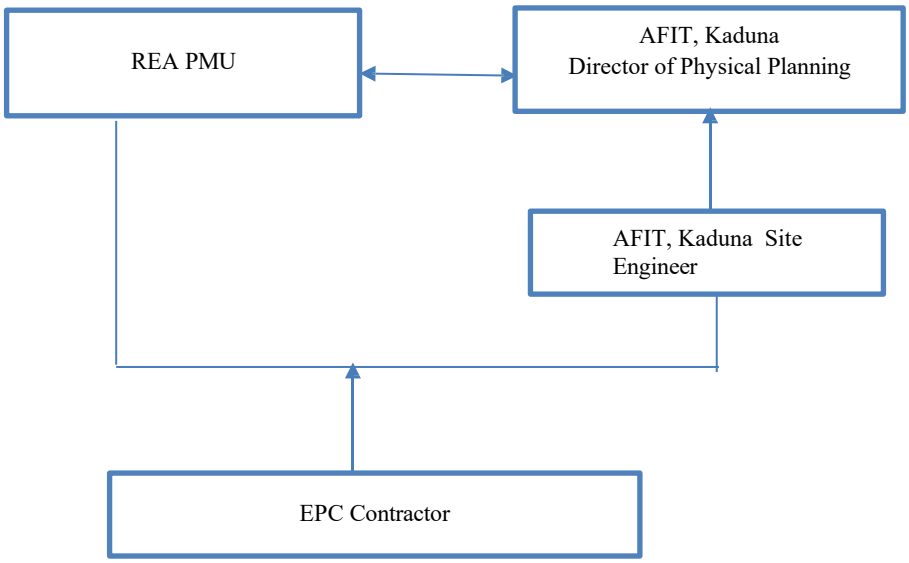


Figure 7.1: Roles and Responsibilities for the Pre Construction and Construction Phase

7.3.3 Operational Phase

AFIT, Kaduna Director of Physical Planning

- Supervise the activities of the Site Engineer by reviewing reports on ESMP issues
- Suggest ESMP improvements to O&M Contractor and PMU to address non-compliance and upcoming issues

REA-PMU

- Appoint a O&M Contractor
- Supervise the activities of the O&M Contractor by reviewing reports on ESMP issues
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning to address non-compliance and upcoming issues

AFIT, Kaduna Site Engineer

- Supervise the activities of the O&M Contractor and ensure compliance ESMP with mitigation measures
- Report to AFIT, Kaduna Director of Physical Planning on ESMP compliance and non-compliance issues

O&M Contractor_Implement ESMP requirements relevant to work being undertaken

- Hire a Gender/GBV officer
- Report to the REA-PMU and AFIT, Kaduna Site Engineer on ESMP compliance and non-compliance issues

FMEnv Representatives

- Monitor the implementation of ESMP requirements (environmental compliance monitoring) relevant to work being undertaken
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning and REA-PMU to address non-compliance and upcoming issues

NESREA Representatives

- Monitor the implementation of ESMP requirements (environmental compliance monitoring) relevant to work being undertaken
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning and REA-PMU to address non-compliance and upcoming issues

Kaduna State Ministry of Women Affairs and Social Development and GBV service provider

- Monitor the implementation of Gender mitigation measures relevant to work being undertaken
- Discuss ESMP improvements with the Gender/GBV officer, AFIT, Kaduna Director of Physical Planning, and REA-PMU to address non-compliance and upcoming issues

Kaduna State Ministry of Environment Representatives

- Monitor the implementation of ESMP requirements (environmental compliance monitoring) relevant to work being undertaken
- Discuss ESMP improvements with AFIT, Kaduna Director of Physical Planning and REA-PMU to address non-compliance and upcoming issues

7.4 Additional Management Plans

This section provides a framework for the contents of additional management plans to be developed and implemented, in support of this ESMP, for the proposed Project. As the Project progresses, the management plans will be expanded to include specific procedures to guide implementation by the relevant Project personnel including contractor and subcontractors.

The documents will be prepared strictly in line with the requirements set out in the relevant international standards and guidelines such as the AfDB's ISS Guidelines as well as other applicable national and local regulations and guidelines.

7.4.1 Stakeholder Engagement Plan

A Stakeholder Engagement Plan (SEP) shall be developed and implemented throughout the lifecycle of the proposed Project. The objectives of developing SEP for the proposed Project include the following:

- Ensuring stakeholder inclusion and involvement across the various phases of the project;
- Ensuring clarity and understanding through an open, inclusive and transparent process of culturally appropriate engagement and communication undertaken to ensure that stakeholders are well informed about the proposed Project;
- Building and maintaining productive relationship between REA and its various stakeholders through supporting open dialogue;
- Engaging vulnerable groups through an open and inclusive approach to consultation, thereby increasing the opportunity for stakeholders to provide comment and voice their concerns on the proposed Project;
- Managing expectations to ensure that the proposed Project does not create or allow unrealistic expectations to develop amongst stakeholders about proposed Project benefits. The engagement process will serve as a mechanism for understanding and managing stakeholder and community expectations, where the latter will be achieved by disseminating accurate information in an accessible way.
- Ensuring compliance with both local regulatory requirements and international best practice.
- Ensuring stakeholders are free of external manipulation or coercion.

REA is committed to implementing stakeholder management as part of its operations. As such REA will ensure that the responsibility for implementing the SEP is duly assigned and all components of the plan are well-defined within its organizational processes. REA shall also commit to providing the necessary support to implement the SEP.

In line with the Environmental and Social Management framework (ESMF) for NEP, an effective SEP should:

- ❖ Describe regulatory, lender, company, and/or other requirements for consultation and disclosure.
- ❖ Identify and prioritize key stakeholder groups, focusing on Affected Communities.
- ❖ Provide a strategy and timetable for sharing information and consulting with each of these groups.
- ❖ Describe resources and responsibilities for implementing stakeholder engagement activities.
- ❖ Describe how stakeholder engagement activities will be incorporated into the Institution‘s management system.

A sample SEP is outlined in the Environmental and Social Management framework (ESMF) for NEP (NEP ESMF, 2019).

Grievance Redress Mechanism

A Grievance Redress Mechanism (GRM) has been developed for NEP. The proposed solar-hybrid power plant and associated infrastructure in AFIT, Kaduna is part of the NEP. The GRM provides a framework for addressing Project-related complaints, including logging, tracking, and grievances resolution. The GRM will be communicated to all stakeholders in the course of Project development and implementation and will make publicly available a record documenting the responses to all grievances received. The GRM shall be maintained throughout the project life cycle.

Emergency Preparedness and Response Plan (EPRP)

An Emergency Preparedness and Response Plan (EPRP) shall be developed and implemented for the proposed Power Plant. As part of the EPRP, the fire protection system for the Project will be designed to meet the requirements of the local fire codes under the National Fire Protection Association. In addition, the grounding and lightning protection systems for the Project shall be installed in a manner that will limit the effect of ground potential gradients to such voltage and current levels that will not endanger the safety of people or equipment under normal and fault conditions.

The EPRP shall include procedures for addressing all reasonably foreseeable and possible emergencies such as: fire, spill or release of hazardous wastes, medical and weather-related emergencies. It shall address the following aspects, amongst others:

- o Identification of the emergency scenarios and the development of appropriate and specific emergency response procedures for each scenario;
- o Training of emergency response teams on the appropriate procedures and the use of emergency response equipment;
- o Identification of emergency contacts and support services and the development of effective communication systems / protocols;
- o Emergency equipment and facilities must be provided (e.g., first aid stations, fire-fighting equipment, personal protective equipment);
- o Development of decontamination / clean-up procedures and identify critical remedial measures

to contain, limit and reduce pollution;

- Identification of potential risk relating the uncontrolled release of hazardous materials and the preparation of a spill prevention, control, and response plans including:
  - Training of operators on spill prevention.
  - Implementation of inspection programmes to confirm the integrity of secondary containment structures and equipment.
  - Development of standard operating procedures for filling containers or equipment and the transfer of hazardous materials.
  - Identification and availability of the appropriate personal protective equipment and equipment.

Waste Management Plan (WMP)

The primary purpose of the WMP is to ensure that wastes (hazardous/non- hazardous) are avoided or minimized, and any wastes that are generated are properly managed and disposed in an environmentally sound manner. The waste management hierarchy is expressed as follows:

- Prevention: avoid waste generation;
- Reduction at source - minimization of waste generation through installation of pollution abatement equipment;
- Reuse - Using an item for its original purpose, or similar purpose, in its original form;
- Recycling – conversion of waste materials into reusable objects;
- Disposal - disposal of wastes in an environmentally sound manner.

Occupational Health and Safety (OHS) Plan

The OHS plan must include the following elements, amongst others:

- Identification of potential hazards and development of responses to eliminate sources of risk or minimize workers' exposure to hazards;
- Provision of Personal Protective Equipment (PPE) to workers at no cost;
- Provision of training to all workers on all relevant aspects of occupational health and safety issues associated with their daily work, including emergency arrangements;
- Third parties (visitors and external service providers) must be briefed on the relevant aspects of health and safety and emergency response when accessing the site premises.

Local and Employment Management Plan (LEMP)

The LESMP should aim to promote Employment opportunities and training for local people in the Project's area of influence and include, amongst others:

- Targets for employing local labour;
- Targets for work experience opportunities;
- Notification of all Employment and training opportunities prior to them being advertised elsewhere;
- Measures to provide verifiable monitoring information regarding training and Employment. The training status for all workers must be recorded;

Erosion Control Management Plan

This Plan should aim to control soil erosion in the Project area. The timing of works and the installation of control measures has a major influence on the management of storm water. The Plan should include the following measures, amongst others:

- Clearing of only those areas necessary for construction works shall be ensured.
- Slopes of all cut and fill areas shall be rigorously controlled and will at no time be allowed to be greater than the slope established in the final design;
- Piles of soil or other materials shall be allowed for short periods of time and will be located only in flat areas and away from any storm water courses;
- Temporary protection of exposed soil surfaces with measures such as plastic film, bio-membranes or other means, will be implemented whenever necessary;

Water Conservation Plan

The Plan will address the appropriateness of water conservation, and efficient use of groundwater for construction activities and cleaning of PV panels during the operational phase of the Project.

EEP Gender-Based Violence (GBV) Action Plan

The GBV action plan shall be implemented throughout the project lifecycle. The components of the plan include:

- A GBV risk assessment; which has been conducted as part of the ESIA.
- Integration of GBV risk management in the ESMP.
- REA-PMU shall define GBV requirements in the contractor bid documents including the hiring of a Gender/GBV officer.
- REA-PMU shall evaluate GBV response protocol of the contractors before finalizing engagement contract.
- Contractors shall ensure that there are GBV-sensitive channels for reporting in GRM.
- Contractors shall inform Project affected communities about GBV risks.
- Contractors shall ensure code of conducts (CoC) forms are signed and understood by all workers. Workers shall be trained on CoC including regular training and refreshers
- Contractors shall ensure separate facilities for men and women and install GBV-free signage at the Project site.

Timely implementation of the EEP GBV action plan shall reduce GBV/SEA risks that may arise during Project development and operation.

Summary of Additional Management Plans

Table 7.5 summarizes the additional management plans required for the Project, including the cost estimate for developing each of the plans.

Table 7.5: Additional Management Plans and Timing for Development

S/N	Plan	Timing for Development	Cost Estimates (US Dollars)
1.	Emergency Preparedness and Response Plan	Pre-construction	2000
2.	Traffic Management Plan	Pre-construction	2000
3.	Waste Management Plan	Pre-construction	3000
4.	Occupational Health and Safety	Pre-construction	2000
5.	Local and Employment Management Plan	Pre-construction	1500
6.	Erosion and Sediment Control Plan	Pre-construction	2000
7.	Water Conservation Plan	Pre-construction	1000
8.	EEP Gender Action Plan	Pre-construction	2000
9.	Stakeholder Engagement Plan	Pre-construction	2000
Total			**17,500**

7.5 Environmental Monitoring Programme

Monitoring shall be conducted to ensure compliance with regulatory requirements as well as to evaluate the effectiveness of operational controls and other measures intended to mitigate potential impacts. Table 7.6 summarizes the environmental monitoring programme for the Project.

Table 7.6: Environmental Monitoring Programme for the proposed Project

Environmental Components/ Matrix	Sampling Locations	Sampling Method	Environmental/ Social Parameters to be monitored	Compliance Requirement	Frequency of Monitoring	Responsible Party	Project Development Phase	Estimated Cost (US Dollars)
Atmosphere (Air Quality & Noise)	• Project Site • Power evacuation route	• Air Quality Monitoring Equipment • Sound level meter	TSP, CO, NOX, SOX, Noise Level (dBA)	FMEnv/ WHO/ AfDB	Monthly monitoring; Monthly reporting	EPC Contractor	• Construction Phase	1000
Groundwater Quality	Borehole within the University	Thermometer, Water sampler, Turbidity meter, pH meter, AAS etc.	Temperature, pH, salinity, TDS, conductivity, DO, BOD, TOC, COD, NO3, PO4, Chloride, sulphate, Microbiology, Heavy metals, TSS and Turbidity	FMEnv/ WHO	Quarterly monitoring and reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	4000
Soil	Unpaved sections of the Plant	Composite soil samples collection for laboratory analysis.	pH, Moisture, TOC, THC, TPH, NO3, PO4, Chloride, sulphate, Microbiology, Heavy metals.	NESREA/ AfDB	Quarterly monitoring and reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	4000

Environmental Components/ Matrix	Sampling Locations	Sampling Method	Environmental/ Social Parameters to be monitored	Compliance Requirement	Frequency of Monitoring	Responsible Party	Project Development Phase	Estimated Cost (US Dollars)
Solid Waste	Operational areas	Monitor the handling and disposal of solid wastes generated onsite; waste tracking documentation.	Operational solid wastes including used packaging waste.	FMEnv/NESREA/ AfDB	Monthly monitoring; Quarterly reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	2000
Health and Safety	Workers and Operational areas	Observe compliance to PPE and unsafe working conditions	Health and Safety Plan	FMEnv/NESREA/ AFDB	Daily monitoring; Quarterly reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	2000
Training	Workers	Observe compliance with existing training plan	Training plan and records	FMEnv/NESREA/ AfDB	Quarterly monitoring and reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	2000
General Housekeeping	Construction sheds and operational areas	Observe cleanliness and aesthetics of Plant	Cleanliness and aesthetics of Plant	FMEnv/NESREA/ AfDB	Daily monitoring; Quarterly reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	2000
Stakeholder Engagement	• Local community • Regulatory agencies	Observe evidence of stakeholder consultations	Stakeholder Engagement Plan	FMEnv/NESREA/ AfDB	Quarterly monitoring and reporting	EPC Contractor O&M Contractor	• Construction Phase • Operations Phase	2000

Training, Awareness and Capacity Building

REA shall identify, plan, monitor, and record training needs for personnel whose work may have a significant adverse impact upon the environmental or social conditions. The Project recognizes that it is important that employees at each relevant phase of the Project are aware of the potential impacts of their activities; and roles and responsibilities in achieving conformance with the management measures documented in this ESMP. This will be achieved through a formal training process.

In addition, training for local community on general environmental awareness and ESMP mitigation measures pertaining to community health, safety and security shall as be provided as indicated in Table 7.7.

Table 7.7: Institutional Capacity Strengthening Plan

Target Audience	Training Overview	Cost Estimates (US Dollars)
Site Engineer, REA, EPC contractor and their sub-contractors, O&M contractor	In-depth understanding of the mitigation measures proffered by the ESMP. Training in the implementation of all emergency response procedures; training on Health, Environment, Safety, and Security Management Plan	2000
Local community	General environmental awareness and mitigation measures proffered by the ESMP pertaining to community health, safety and security.	1000
Total		**3000**

Implementation Schedule and Reporting

The implementation of the ESMP will take place from the planning stages to ensure quality equipment and support services is sourced, through construction, commissioning, operation to decommissioning phases. Once monitoring of the ESMP begins the officers responsible will report all issues identified to respective authorities in REA and corrective/ remedial actions taken without delay to ensure optimal performance of the Project while promoting environmental sustainability.

Also, REA shall keep the regulatory authorities (FMEnv, NESREA, Kaduna State Ministry of Environment) informed of the Project performance with respect to E&S related matters through reports that will be made available to the regulators when required. REA will provide appropriate documentation of HSE related activities, including internal inspection records, training records, and reports to the relevant authorities.

ESMP Costing

Table 7.8 provides the summary of cost estimate required to effective and efficiently implement the recommended mitigation measures and management plans required to address the potential and associated impacts of the proposed Project.

Table 7.8: ESMP Costing

S/N	Fundamental ESMP Activities	Cost Estimates (US Dollars)
1.	Pre-construction phase E&S management activities	4,000
	Construction phase E&S management activities	13,500
	Commissioning phase E&S management activities	700
	Operational phase E&S management activities	9,000
2.	Preparation of additional management plans	17,500
3.	Institutional Capacity Strengthening Plan	3,000
4.	Monitoring and Evaluation Programme	19,000
Total		**66,700**

7.6 Stakeholder Engagement and Grıevance Redress Mechanısm

This section describes the Stakeholder engagement activities as well as the grievance mechanism to be implemented for the proposed 2MW solar power plant and associated infrastructure at Air Force Institute of Technology (AFIT) Kawo, Kaduna State, as part of the Federal Government of Nigeria (FGN) Energizing Education Programme (EEP) Phase II.

7.6.1 Stakeholder Engagement

Stakeholder engagement is an ongoing process of sharing Project information, understanding stakeholder concerns, and building relationships based on collaboration. Stakeholder consultation is a key element of engagement and essential for effective Project delivery. Disclosure of information is equally as vital and must focus on informed consultation and participation with the local community and relevant stakeholders. If there are risks or adverse impacts from a Project, consultation must be inclusive and culturally appropriate and provide stakeholders with opportunities to express their views. In line with current guidance from the AfDB, consultation should ensure "***that appropriate project information on environmental and social risks and impacts is disclosed to stakeholders in a timely, understandable, accessible and appropriate manner and format***" In other words, effective consultation requires the prior disclosure of relevant and adequate Project information to enable stakeholders to understand the risks, impacts, and opportunities. The Project's consultation program was intended to ensure that stakeholder concerns are considered, addressed and incorporated in the development process, especially during the ESIA.

7.6.2 Legal and Administrative Framework Guiding Stakeholder Engagement

The stakeholder engagement was carried out to ensure compliance with both Nigerian legislative requirements, as well as international standards. This section presents the relevant standards and legislation that relate directly to the public participation and stakeholder engagement requirements for the proposed Project.

Nigerian Legislative Requirements

EIA Act No. 86 of 1992 (as amended by the EIA Cap E12 LFN 2004)

The EIA Act is the primary Act governing the environmental and social assessment of developmental projects or activities in Nigeria. Section 2(2) of the Act requires that where the extent, nature or location of a proposed project or activity is such that it is likely to significantly affect the environment, an EIA must be undertaken in accordance with the provisions of the Act.

Section 55 of the EIA Act provides for the maintenance of a Public Registry to facilitate public access to records relating to environmental assessments. Public hearings to which interested members of the public are invited are a key part of the approval process for EIA reports by the Federal Ministry of Environment (FMEnv). However, this project shall not be subject to a public hearing but rather an in-

house review to be conducted by the FMEnv. This arrangement was adopted based on the abridged EIA process for the Nigeria Electrification Projects (NEP), which has been approved by the FMEnv.

7.6.3 Objectives of Stakeholder Engagement

The stakeholder engagement process was designed to conform to the Nigerian EIA Act and international standards. For this Project, the key objectives for stakeholder engagement are:

- inform and educate stakeholders about the proposed Project;
- gather local knowledge to improve the understanding of the environmental and social context;
- better understand the locally-important issues;
- provide a means for stakeholders to have input into the Project planning process; take into account the views of stakeholders in the development of effective mitigation measures and management plans; and
- lay the foundation for future stakeholder engagement.

7.6.4 Stakeholder Identification and Analysis

Stakeholders are persons or groups who are directly or indirectly affected by a project, as well as those who may have interests in a project and/or the ability to influence its outcome, either positively or negatively (IFC, 2007). Stakeholders may include locally affected communities or individuals and their formal and informal representatives, national or local government authorities, politicians, religious leaders, civil society organizations and groups with special interests, the academic community, or other businesses.

Proper stakeholder identification forms the basis on which the stakeholder engagement was conducted for the Project as well as the development of the stakeholder engagement plan. It is necessary to determine who the stakeholders of a project are and understand their priorities and objectives. In addition it is also essential that stakeholders are classified based on their position, influence, capacity and interests in order to develop a functional Stakeholder Engagement Plan (SEP) that is tailored to meet the individual and group needs of the identified stakeholders.

A list of identified stakeholders for the Project is shown in Table 7.9. This consists of individuals, groups, and organizations that may be affected by or may influence project development positively or negatively. The list was developed using international guidance and considered the following groups: national and local governments; Local community leaders; community members including potentially vulnerable sub-groups such as women, youth and elderly; international, national and local environmental and social Non-Government Organizations (NGOs); Potential contractors and service suppliers; and local businesses/cooperatives and associations.

Table 7.9: Identified stakeholders associated with the Project

Stakeholder Group and Interest in the proposed project	Stakeholder Name	Stakeholder Level				Connection to the Proposed Project
		Internationa	National	State	Local	
Development Financial Institution	AfDB	□				Provide financial and technical support to project development and operation
Regulatory Authorities	Federal Ministry of Environment (FMEnv)		□			Has the responsibility for overseeing EIA process for the proposed Solar Projects and ensuring compliance to relevant environmental lawsand regulations
	National Environmental Standards and Regulations Enforcement Agency (NESREA)		□			Has the responsibility of enforcing the environmental laws, guidelines, standards and regulations in Nigeria, specifically during the operational phase of developmental projects.
	Federal Ministry of Power (Department of Renewable Energy)		□	□		The Department of the Renewable Energy and Rural Power Access of the Federal Ministry of Power, Works and Housing is charged with the responsibility to coordinate all issues relating to renewable energy and energy efficiency
	Nigerian Electricity Regulatory Commission (NERC)		□	□		Responsible for granting operating licences for the Solar Projects
	Kaduna State Ministry of Environment		□	□		The Ministry oversees the protection of environment in Kaduna State
	Kaduna State Environmental Protection Authority		□	□		Responsible for waste management in Kaduna State
	Kaduna State Ministry of Women Affairs and Social Development		□	□		Promotes the development of women with equal rights and corresponding responsibilities including gender inclusion
	Kaduna State Ministry of Sports and youth development		□			Responsible for the inclusion of youths in Nigeria's development as well as the coordination of sports and recreational activities in the State

Stakeholder Group and Interest in the proposed project	Stakeholder Name	Stakeholder Level				Connection to the Proposed Project
		Internationa	National	State	Local	
	Igabi Local Government Authority			□		
Communities	Unguwar Fulani Community				□	Households, communities and groups that may be directly or indirectly affected by the proposed Project and its activities.
Institute Representatives	Management of AFIT, Kaduna				□	Direct Project beneficiaries.
	Physical Planning Office				□	
	AFIT, Kaduna Student Union Body				□	
Project Affected persons	Farmers within the project site				□	Farmers are all families of AFIT, Kaduna staff with farmlands on the project site.

Stakeholder Register

The project shall maintain a stakeholder engagement register for recording stakeholder information such as contact details, dates of engagement with comments and follow up requirements.

Stakeholder Engagement Process

REA adopts a proactive approach towards building and maintaining mutually beneficial relationships with all relevant stakeholders, throughout its operations. The engagement program shall be implemented to comply with national and international standards. The stakeholder engagement will be free of manipulation, interference, coercion, and intimidation. It is conducted on the basis of timely, relevant, understandable and accessible information.

Effective stakeholder engagement depends on mutual trust, respect and transparent communication between the Project and its stakeholders. It thereby improves REA's decision-making and performance by:

- **Managing costs:** Effective engagement can help project REA avoid costs, in terms of money and reputation;
- **Managing risk:** Engagement helps project REA and communities to identify, prevent, and mitigate environmental and social impacts that can threaten project viability;
- **Enhancing reputation:** By publicly recognising human rights and committing to environmental protection, REA and financial institutions (World Bank) involved in financing the project can boost their credibility and minimise risks;
- **Avoiding conflict:** Understanding current and potential issues such as land rights and proposed project activities;
- **Improving corporate policy:** Obtaining perceptions about a project, which can act as a catalyst for changes and improvements in REA corporate practices and policies;
- **Identifying, monitoring and reporting on impacts:** Understanding a project's impact on stakeholders, evaluating and reporting back on mechanisms to address these impacts; and

- **Managing stakeholder expectations:** Consultation also provides the opportunity for REA to become aware of and manage stakeholder attitudes and expectations. Table 7.10 presents elements of the stakeholder engagement program to be implemented by REA.

Table 7.10: Stakeholder Engagement Process

Stakeholder Engagement Activity	Approach
Stakeholder Identification and Analysis	An initial stakeholder identification and analysis has been conducted as part of this ESIA. REA shall maintain a register of identified stakeholders and undertake periodic review on a need basis.
Information Disclosure	REA shall ensure that information is provided to relevant stakeholders on an on-going basis over the course of the Project lifecycle. REA shall maintain regular communication with its stakeholders throughout the project lifecycle.
Stakeholder Consultation	REA shall consult with its various stakeholders on mutual concerns to fulfil its compliance obligations in line with industry best practice. REA shall maintain records of its consultation with its various stakeholders.
Negotiation and Partnerships	REA shall adopt a stakeholder management process that fosters the mutual interest of all parties and adds value to its operation.
Grievance Management	REA shall provide appropriate channels for stakeholders to raise their concerns and grievances about its operations
Stakeholder Involvement	This entails procedures that allow the direct involvement of stakeholders in project related functions in order to foster transparency and credibility.
Reporting to Stakeholders	REA shall establish reporting procedure that allows information disclosure to stakeholders about the environmental social and economic performance of its operations.
Management Functions	REA shall build and maintain management capacity within the company to manage the process of stakeholder engagement, track commitments and report on progress.

Stakeholder Engagement Tool and Communication

REA recognizes the need to tailor its stakeholder engagement approach and information disclosure to suit the needs of each of its stakeholder. REA shall adopt a variety of communication and engagement methods to ensure continuous engagement, dialogue and feedback is established during its engagement activities. Table 7.11 presents various tools and methods to be adopted by REA during its stakeholder engagement process.

Table 7.11: Stakeholder Engagement Tools and Communication

Medium	Most Appropriate Application
Stakeholder meetings	
One-on-one consultations	REA shall on a need basis hold consultation meetings with its individual stakeholders. These meetings will be held to: • Solicit views and opinions; • Discuss freely and confidently about stakeholder concerns and provide feedback etc.; • Build personal relations with stakeholders.

Medium	Most Appropriate Application
Focus group discussions	REA shall on a need basis hold focus group discussions (FGDs) to pull together a small group of people with the same interest into a single meeting to engage them on common issues. FGDs would have specific objective and be aligned with the expectations and interest of the stakeholders present.
Workshops	REA shall on a need basis hold workshops with its various stakeholders. Workshops are ad-hoc outcomes based meetings that seek to find solutions for specific issues facing the environment and social aspects. When conducting a workshop, REA shall use participatory exercises to facilitate group discussions, brainstorm issues, analyse information, and develop recommendations strategies.
Forum	REA shall on a need basis use forums to engage with various stakeholders. Participatory tools and methodologies such as workshops, town hall meetings, and FGDs will continue to be utilized, as they are more likely to increase stakeholder involvement in the process and elicit alternative responses, especially if there is controversy or complexity, or a need to build a consensus around possible solutions.
❖ Written / visual/electronic communication	
	REA shall use a variety of communication methods to disseminate information to its stakeholders. The approach adopted shall be based on the nature of the issue and the concerned stakeholder. External communications will include: o Project newsletters o Emails o Meetings o Executive Summary of the Environmental Impact Assessment o Mass Media, newspapers print etc. o Surveys

Table 7.12 presents a stakeholder analysis with respect to appropriate levels of consultation for each of the major stakeholder groups. REA shall determine the frequency of these interactions.

Table 7.12: Stakeholder Group Consultation Methods

STAKEHOLDER GROUP	CONSULTATION METHOD
Government and Regulators	• Email exchanges and letters • One-on-one consultations • Formal meetings • Print media • Compliance reporting • Performance report (Audits)
Project beneficiaries (AFIT, Kaduna Management, Physical Planning, Students)	• Formal meetings • One-on-one consultations • Print media • Strategic collaboration • Information Centre
Employees	• Phone / email / text messaging/ WhatsApp • Print media • Workshops • Focus group meetings • Surveys • Management/departmental meetings • Performance appraisal • Trainings

STAKEHOLDER GROUP	CONSULTATION METHOD
NGO's	• Phone / email • One-on-one interviews • Town hall meetings • Focus group meetings • Information Centre

Principles for Effective Stakeholder Engagement

Stakeholder engagement is usually informed by a set of principles defining core values underpinning interactions with stakeholders. Common principles based on International Best Practice include the following:

- **Commitment** is demonstrated when the need to understand, engage and identify the key stakeholders is recognized and acted upon;
- **Integrity** occurs when engagement is conducted in a manner that fosters mutual respect and trust;
- **Respect** is created when the rights, values and interests of stakeholders and neighbours are recognized;
- **Transparency** is demonstrated when stakeholder concerns are responded to in a timely, open and effective manner;
- **Inclusiveness** is achieved when broad participation is encouraged and supported by appropriate participation opportunities; and
- **Trust** is achieved through open and meaningful dialogue that respects stakeholder's values and opinions.

7.7 Management Function and Grievance Mechanism

Management Commitment

REA is committed to implementing stakeholder management as part of its operations. As such REA will ensure that the responsibility for implementing the SEP is duly assigned and all components of the plan are well-defined within its organizational processes. REA shall also commit to providing the necessary support to implement the SEP. The management structure for the SEP shall include the following elements.

Systems: REA will pursue its Stakeholder engagement activities as scheduled in a systematic manner that creates predictability in the eyes of the stakeholder in order to support and foster a relationship that is based on trust.

Structure: REA will establish a Stakeholder focused-structure within its organizational processes to provide the needed decision-making authority to enable quicker turnaround time on Stakeholder engagement activities and grievance feedback.

Skills: REA will ensure that the required internal capacity for effective Stakeholder engagement is provided for the implementation of the stakeholder engagement plan. Roles and Responsibilities

REA shall assign the responsibilities of conducting and organizing stakeholder consultation and involvement to competent individuals. The individuals shall be qualified professionals with relevant skills and experience. The REA Project Management Unit shall have the overall responsibility of overseeing the implementation of the SEP. The role of managing stakeholder engagement shall be given to the University's Community Liaison Officer (CLO). The CLO shall monitor the implementation of the Project's stakeholder engagement program and report findings to the REA Project Management Unit.

7.8 Grievance Redress Mechanism (GRM)

A grievance redress mechanism (GRM) has been developed by REA which is applicable to all components of the NEP; including the EEP Projects (Available in Appendix 9.3). The NEP GRM was developed to provide project affected persons (including interest groups) directly affected by its development activities with access to mechanisms for them to present their grievances and find solutions through avenues that are legitimate, reliable, transparent, cost-effective and easily accessible at the lowest level, without allowing them to escalate into unmanageable levels. This access will be all inclusive with consideration for people living with disabilities and vulnerable groups.

With respect to the EEP component of the NEP, the GRM has identified potentials for grievance associated with the proposed project. The GRM also outlines the following:

- Identification of core institutional blocks for the EEP;
- Provision of grievance uptake points, including a description of communication channels, actions, and timeframe;
- Composition of the Project Management Unit (PMU) Grievance redress committee, with details about their activities;
- Composition of the community-based Grievance redress committee; and
- GRM structure to be implemented for the EEP Projects.

CHAPTER EIGHT
REMEDIATION PLAN AFTER DECOMMISSIONING / CLOSURE

8.0 Introduction

This chapter discusses the activities associated with the decommissioning of the proposed Project, including the potential impacts associated with the decommissioning activities as well as the environmental and social measures to address the issues. In addition, the overview of remediation plan after the decommissioning/closure of the Project is provided.

8.1 Decommissioning Activities

Decommissioning refers to the process of removing all the operating assets of a project after completion of its life cycle. The average life span of the solar Photovoltaic (PV) power plant to be provided as part of the proposed Project is 25 years (which can be extended through regular maintenance). Even after the 25 years, the PV panels can still generate up to 90% of the design capacity.

The decommissioning activities will typically include the following:

- Dismantling and removal of PV panels and associated infrastructure (mounting structure, power evacuation cable, inverters, transformers, batteries, etc.);
- Removal of any sub-surface installations (e.g. underground cables);
- Waste generation and management;
- Rehabilitation of any impacted environmental component (e.g. soil).

8.2 Management of Decommissioning Activities

In the event of decommissioning, REA, in conjunction with the leadership of AFIT, Kaduna, shall ensure that the Project site is left in a safe and environmentally acceptable condition. A standard decommissioning, abandonment and closure program shall be invoked. The tasks will include, amongst others:

- Evacuation of the dismantled PV panels and other related items (such as inverters, and control devices) to the manufacturers for recycling.
- Transportation of spent batteries to recycling facilities.
- Restoration of the Project site to baseline conditions (as much as practicable) in line with legislative and regulatory requirements.
- Assessing the residual impact, if any, the project has on the environment.
- Monitoring the abandoned project environment as necessary.

Decommissioning activities will only begin after due consultation with the relevant stakeholders including the regulatory authorities. The decommissioning activities shall be carried out in line with the relevant provisions of the National Guidelines for Decommissioning of Facilities in Nigeria (2017) issued by the FMEnv.

Typically, the following actions shall be undertaken for decommissioning:

- An updated plan which takes into account the most cost-effective and best practicable methods, legal requirements and industry practices at that time for the facility decommissioning shall be

developed and submitted to the FMEnv and other relevant regulatory authorities for approval. The plan shall include, but not limited to the following:

- Description of the site and components to be decommissioned.
- Description of the decommissioning scope, objectives, end state and strategy;
- Activities to be performed during the decommissioning;
- Schedule of decommissioning activities;
- Estimate of the decommissioning cost;
- Estimated inventory of waste streams to be generated during the decommissioning and handling techniques;
- Decommissioning team (qualifications, roles and responsibilities)

- To ensure that due consideration is given to all options a detailed evaluation of facility decommissioning options shall be carried out. The options will include facility mothballing, partial facility decommissioning or complete site decommissioning. The evaluation will consider environmental issues in conjunction with technical, safety and cost implications to establish the best practicable environment friendly options for the Project decommissioning.
- A risk assessment shall be conducted to ensure that nothing, which could be constituted as a hazard for other users of the site or for the environment in general, will be left at the site. The Project site shall be left in a safe and environmentally acceptable condition.
- Hazard identification and analysis shall be conducted to determine special safety concerns to be addressed.
- An appropriate Health, Safety and Environment (HSE) plan shall be implemented to ensure that the decommissioning activities are carried out in an environmentally sound manner and in conformity with relevant laws and regulations guiding such operations
- Third party notifications shall be carried out before any demolition and shall be conducted in a phased sequence.
- Socio-economic considerations of facility decommissioning shall be carried out. These will include assessment of potential effects associated with termination of employment (at the end of operational phase) and the measures to minimize the effects by:
    - Ensuring that employees are fully informed about the decommissioning and how it will affect them before the project finally closes.
    - Building community capacity to manage opportunities and impacts arising from the decommissioning and post-decommissioning phase of the Project.
    - Providing training to build local skills tailored to project decommissioning and post-decommissioning activities (e.g. equipment dismantling, rehabilitation activities, monitoring, etc.).
    - Providing training to transfer project-learned skills to alternative and secondary industries tailored to respond to market economy.
- An effective waste management plan shall be developed for the decommissioning activities. The decommissioning options for redundant structures and equipment will include: the complete dismantling of structures and equipment and the return of all components to the equipment manufacturer for recycling. A detailed record of all suitable recycling materials shall be

maintained.

The environmental and social management measures for the identified potential impacts of the decommissioning activities are presented in Table 8.1.

8.2.1 Used Battery Management at Decommissioning Phase

Lithium-ion batteries that have reached the end of their life spans are classified as hazardous waste. The used batteries decommissioned from the power plant shall be packed separately from other materials. Damaged batteries in a critical stage, in particular, require special expertise in handling, as they can be flammable. Currently, Lithium-ion battery recycling in Nigeria is at the infancy stage as most local recycling companies specialize in recycling lead-acid batteries. This presents a challenge to the recycling of used batteries locally. Therefore, the Extended Producer Responsibility (EPR) policy shall be adopted for the project. It includes the take- back, recycling and final disposal of the product including its packaging. The manufacturers / suppliers of the batteries shall be responsible for the recycling and safe disposal of the used batteries. The costs of recycling and disposal will be internalized in the price of the batteries or take-back agreements will be provided. During decommissioning activities, the batteries shall be removed, discharged, and packaged according to the manufacturer / supplier's instructions before transportation to the endpoint. Conversely, the University shall be encouraged to develop end-of-life management plans for the batteries and other electrical components. The plan shall include the development of procedures for safe handling, storage, and transport of the used batteries generated during Project operations. Also, procedures for identification and engagement of NESREA certified battery recycling companies based in Nigeria shall be developed and implemented for the Project.

8.2.2 Abandonment Plan

Prior to site abandonment, REA shall establish a standard procedure for incorporating the following practices:

- Identification of the components of the Project that will be abandoned and/or removed;
- The proposed methods for abandonment or re-use of the Project equipment/material applicable;
- Processes put in place to mitigate potential environmental impacts associated with the abandonment process; and
- Appropriate site rehabilitation programs (including re-vegetation of the site with native plant species) to return the Project site to its original status (as much as possible).

The decommissioning, abandonment and/or closure programme shall generally be managed by a team of competent personnel from REA-Project Management Unit, the Department of Works and Physical Planning in AFIT, Kaduna, the Federal Ministry of Environment and the Kaduna State Ministry of Environment. A close out report shall be prepared and archived for future reference.

8.3 Roles, Responsibilities and Accountabilities for Decommissioning Phase

The key personnel and institutions with major roles in the implementation and monitoring of environmental and social measures for the Project decommissioning/closure are as follows:

Contractor(s) Engaged for Decommissioning Activities

- Implement environmental and social measures and management actions put in place for the decommissioning activities.

REA-PMU

- Supervise the activities of the contractor(s) engaged for decommissioning purpose by ensuring

that the recommended environmental and social measures and management actions are implemented.

- Discuss environmental and social management plan improvements with the Director of Works and Physical Planning Department in AFIT, Kaduna to address non- compliance and upcoming issues.

AFIT, Kaduna Site Engineer/Manager

- Directly monitor the activities of the contractor(s) engaged for decommissioning and ensure compliance to the implementation of environmental and social measures and management actions put in place to address potential impacts and risks associated with the decommissioning activities.
- Report to the Director of Works and Physical Planning Department in AFIT, Kaduna on contractor's performance regarding the implementation of environmental and social measures.

Director of Works and Physical Planning Department in AFIT, Kaduna

- Jointly supervise the activities of the contractor(s) engaged for decommissioning
- Suggest environmental and social management plan improvements to REA- PMU to address non-compliance issues and upcoming issues.

FMEnv/Kaduna State Ministry of Environment Representatives

- Approve the decommissioning plan for the Project
- Monitor the implementation of environmental and social measures and management actions documented in the decommissioning plan.
- Discuss environmental and social management plan improvements to REA- PMU to address non-compliance issues and upcoming issues.

Table 8.1: Environmental and Social Management Measures for Decommissioning Phase

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Removal of PV panels, batteries and inverters; demolition of buildings and associated facilities							
Soil contamination due to waste generation; soil compaction;	Excavation works shall not be executed under Aggressive weather conditions.	Inspection	Daily	Adherence to measures	Contractor(s) engaged for facility decommissioning	REA-PMU AFIT, Kaduna (Site Manager and Director of Works and Physical Planning) FMEnv Kaduna State Ministry of Environment	5000
	Stockpiles shall be appropriately covered to reduce soil loss as a result of wind or water Erosion	Inspection	Daily	Adherence to measures			
	Hazardous substances and materials (e.g. fuel, lubricating oil, etc.) shall be stored in appropriate locations with impervious hardstanding and adequate secondary containment (bund wall). Portable spill containment and clean-up kits	Inspection	Daily	Adherence to measures AfDB ISS General EHS Guidelines			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	shall be available onsite.						
	PV panels, batteries and inverters shall be collected and returned to the manufacturer for recycling.	Consignment notes for batteries to recycling plants	Daily	AfDB ISS Guidelines			
	All impacted soil area shall be re-vegetated with native plant species	Inspection	Daily	Re-vegetated land			
	A decommissioning plan approved by the relevant regulatory authorities shall be developed and implemented.	Implementation records of decommissioning plan	Daily	Benchmarks in decommissioning plan			
Air quality impact; increase in dust level.	Dust suppression measures shall be implemented.	Inspection	Daily	Adherence to measures	Contractor(s) engaged for facility decommissionin	REA-PMU AFIT, Kaduna	1000

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Decommissioning equipment shall be properly serviced and maintained.	Inspection; Maintenance records	Before commencement of decommissioning activities	Adherence to measures	g	(Site Manager and Director of Works and Physical Planning) FMEnv Kaduna State Ministry of Environment	
Discomforting noise from decommission, equipment and related activities	Noise suppression equipment (e.g. mufflers) shall be fitted on decommissioning equipment / machinery.	Inspection	Daily	Adherence to measures	Contractor(s) engaged for facility decommissioning	REA-PMU AFIT, Kaduna (Site Manager and Director of Works and Physical Planning) FMEnv Kaduna State Ministry of Environment	2000
	Decommissioning activities shall be limited to day-time (08.00hr to 17.00hr during weekdays; and weekends 09.00hr-13.00hr).	Inspection	Daily	Adherence to measures			
	Equipment shall be turned off when not in use.	Inspection	Daily	Adherence to measures			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Equipment shall be properly maintained and serviced.	Inspection; Maintenance records	Once before Commencement	Adherence to measures			
	Noise complaints related to the construction activities shall be assessed and appropriately addressed.	Complaint records	Weekly	AfDB Good Practice Note on Addressing Grievances			
	Noise monitoring at locations with persistent noise complaints shall be maintained.	Noise monitoring records	Monthly	FMEnv Noise limit World Bank Noise Limit			
Groundwater and surface water contamination due to waste generation	Training shall be provided for workers on safe storage, use and handling of hazardous materials (e.g. fuel, lubricating oil) on site.	Training records	Once before commencement	Certificates of Completion of trainings	Contractor(s) engaged for facility decommissioning	REA-PMU AFIT, Kaduna (Site Manager and Director of Works and Physical Planning)	1500

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
	Hazardous substances and materials (e.g. fuel, lubricating oil, etc.) shall be stored in appropriate locations with impervious hardstanding and adequate secondary containment. ortable spill containment and clean-up kits shall be available onsite.	Inspection	Daily	Adherence to measures AfDB ISS Guidelines		FMEnv Kaduna State Ministry of Environment	
	Waste Management Plan shall be implemented.	WMP implementation records	Daily	Benchmarks stated in WMP AfDB ISS Guidelines			
Traffic due to transportation of dismantled equipment and materials from site including	TMP shall be implemented.	TMP implementation records	Daily	Benchmarks stated in the TMP	Contractor(s) engaged for facility decommissioning	REA-PMU AFIT, Kaduna (Site Manager and Director of Works and	2500
	Appropriate barriers and signage shall be provided to demarcate areas in	Safety signs and barriers	Once before commencement	Adherence to measures			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
wastes	which traffic is active.					Physical Planning)	
	Drivers' competency shall be assessed and where required training shall be provided.	Drivers' competency assessments; training records	Once before commencement	Passing of competency assessment or training completion Certificates		FMEnv Kaduna State Ministry of Environment	
	A procedure for recording all decommissioning related traffic incidents/accidents shall be developed and implemented. This will include date/time, location, reason for accident, corrective measures, etc.	Incident forms	Daily	Completed incident forms			

Summary of Potential Impact	Mitigation Measures	Monitoring			Responsible Party		Cost (US Dollars)
		Requirements / Parameters	Frequency	Performance Indicator	Implementation	Monitoring	
Exposure to injuries, electrical shock, slip, trip and fall	All workers involved in the decommissioning activities shall be sensitized and monitored on the need to be safety conscious. Daily toolbox talks prior to commencement of work activities shall be carried out.	Daily toolbox records	Daily	Benchmarks stated in Health and Safety Plan	Contractor(s) engaged for facility decommissioning	REA-PMU AFIT, Kaduna (Site Manager and Director of Works and Physical Planning) FMEnv Kaduna State Ministry of Environment	2500
	Appropriate PPE shall be provided for workers.	Availability of PPE	Daily	PPE compliance			
	Onsite safety officer shall be engaged to monitor the compliance of workers to safety rules.	Qualified and dedicated safety officer	Once before commencement	Adherence to measures			
	Health and safety plans shall be implemented.	Health and Safety plan implementation records	Daily during construction phase	Benchmarks stated in Health and Safety Plan			

CHAPTER NINE
SUMMARY AND CONCLUSION

9.1 Summary

The project is part of the Federal Government's Energising Education Programme (EEP), aimed at providing reliable and sustainable 24-hour uninterrupted electricity to Air Force Institute of Technology (AFIT), Kaduna.

The scope of the EEP includes provision of off-grid, dedicated and independent power plant, rehabilitation of existing electricity distribution infrastructure, and provision of street lighting (for illumination and improved security) as well as a world class renewable energy training centre for each of the beneficiary universities. AFIT Kaduna is one of the beneficiary universities under the EEP Phase II.

In compliance with the relevant requirements of the Federal Ministry of Environment (FMEnv.) and other relevant regulatory agencies in Nigeria, as well as the applicable requirements of the African Development Bank Integrated Safeguards System (ISS, 2024), the ESIA of the proposed Project in AFIT Kaduna has been conducted.

The ESIA study covers the entire life cycle of the Project (i.e. pre-construction, construction, commissioning, operation, decommissioning, and closure) and it involves key issues identification, baseline environmental and socio-economic data gathering, stakeholder consultation, identification and evaluation of impacts, development of mitigation measures and environmental and social management plan.

The proposed 2MW Solar-Hybrid Power Plant at the AFIT Kaduna is part of the Energizing Education Programme (EEP) under the Nigeria Electrification Project (NEP). The Project is designed to provide reliable and sustainable electricity to the University in order to enhance teaching, research, technological development, and overall institutional performance. As a Institute of Technology, AFIT Kaduna requires stable power supply for engineering laboratories, workshops, ICT facilities, administrative operations, and student hostels. The current dependence on unstable grid supply and diesel generators results in operational disruptions, high energy costs, and environmental emissions. The proposed solar-hybrid system will address these challenges by providing a dedicated and cleaner source of electricity. The Project also supports Nigeria's Nationally Determined Contributions (NDCs) under the Paris Agreement (2016) by promoting renewable energy and reducing greenhouse gas emissions. Furthermore, it aligns with the Power Sector Recovery Programme (PSRP) approved by the Federal Executive Council (FEC) on 22 March 2017, which aims to improve reliability and sustainability in Nigeria's power sector.

9.2 Conclusion

The ESIA of the proposed 2MW solar power plant and associated infrastructure in the AFIT Kaduna, under the EEP, has been conducted in accordance with the relevant requirements of the FMEnv guidelines and the applicable AfDB Safeguard Policies.

The ESIA study consists of a number of key steps including: desktop review, scoping, consultations with relevant stakeholders including relevant government authorities and

potentially affected community in the Project's area of influence, field data gathering, laboratory analysis of field samples, potential impact identification and evaluation, development of mitigation measures and environmental management plan, report writing and disclosure.

The essence of the ESIA process is aimed at ensuring informed decision-making and environmental accountability, and to assist in achieving environmentally sound operation and social acceptance throughout the life cycle of the proposed Project.

Consistent with the regulatory standards, the assessment of the environmental status and the socio-economic aspects of the proposed Project's area of influence have been carefully carried out using accepted scientific methodology. Evaluation of associated and potential impacts of the proposed Project identified both positive and negative interactions with the receiving biophysical and socio-economic environment.

The positive impacts associated with the Project include:

- Stimulation of academic and research activities within the University as a result of access to constant and reliable power supply, thereby promoting educational advancement.
- Reduction in fossil fuel consumption by the Institute thereby leading to reduction in carbon emissions and improvement in eco-balance.
- Significant reduction in the cost of power generation by the Institution through diesel-fuelled generators. Such savings would be used for other undertakings that will benefit the University.
- Increase in social interactions within the Institute. There will be enhanced security at the Institution as a result of more streetlights for illumination which would help keep off opportunistic crimes and gender-based violence.
- Enhancement of learning in renewable energy leading to certification as a result of training centre to be provided as part of the Project.
- Improvement in livelihood enhancing activities within the Institution.
- Direct and indirect employment opportunities during Project development and operation. The employment opportunities will lead to acquisition of new skills and introduction of all manners of income generating spill-over effects.
- Increase in local and regional economy through award of contracts and purchase of supplies for Project development.
- Increase in financial and technical collaborations between the FGN, the University, REA, World Bank and other relevant Ministries, Departments and Agencies (MDAs).
- Contribution to the Nigeria's NDC to cut carbon emission by 20 % to 30 % by the year 2030, under the Paris Agreement.

The identified negative impacts of the proposed Project were mostly of minor to moderate significance, and they are largely site-specific and localized. The preferred site for the proposed Project within the Institution does not trigger any physical and economic displacement. In addition, there are no cultural resources within and around the Project site that would be affected during the Project development and operation. The identified potential negative impacts include:

- Decreased in ambient air quality due to construction and decommissioning activities.
- Increase in ambient noise level due to construction and decommissioning activities.
- Decrease in soil quality due to improper management of generated wastes during construction, operation and decommissioning.
- Minimal loss of terrestrial flora species during site preparation for construction activities.
- Environmental nuisance due to improper disposal of e-waste especially spent/damaged batteries.
- Influx of potential job seekers during construction which could pose indirect impacts on the nearby local community.
- Occupational health and safety issues during construction, operation and decommissioning.

Based on the nature and extent of the proposed Project and the findings of the ESIA study, it is believed that the potential negative impacts associated with the proposed Project can be mitigated to as low as reasonably practicable through the implementation of the proffered mitigation measures documented in Chapter 6 of this report, while the positive impacts can also be enhanced. In addition, an ESMP has been established (refer to Chapter 7 of this report) to assess the efficiency and effectiveness of the recommended mitigation measures and ensure long-term monitoring of the Project.

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APPENDIX I

SOCIO-ECONOMICS QUESTIONAIRE SAMPLE

SOCIO-ECONOMIC IMPACT ASSESSMENT QUESTIONNAIRE OF THE PROPOSED PREPARATION OF ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) FOR THE 2MW SOLAR POWER PROJECT AT THE AIR FORCE INSTITUTE OF TECHNOLOGY, NIGERIAN AIRFORCE BASE, KAWO, KADUNA STATE.

The Federal Government of Nigeria (FGN), through the Rural Electrification Agency (REA), is implementing the Energizing Education Program (EEP) Nigeria Electrification Project Phase II (Desert-to-Power) with financial support from the African Development Bank (AfDB). As part of the exercise, BOLBEN Energy and Environmental Services Limited is saddled with the responsibility of identifying the potential socio-economic impacts of the project on the local communities. Therefore, your assistance is required in filling out this brief survey. The questionnaire can be completed by ticking in the preferred boxes like this √ and providing appropriate answers in the available spaces.

Section A: Background Information

1. Name of Project Host Community/AoI .....

2. Gender (a) Male ☐ (b) Female ☑

3. Age (a) 18 – 30 yrs. ☐ (b) 31 – 45 Yrs. ☑ (c) 46 – 54 Yrs. ☐ (d) 55 Yrs. and above ☐

4. Religion: (a) Christianity ☑ b) Islam ☐ (c) Traditional ☐ (d) Other (specify).....

5. Education: (a) Informal Education ☐ (d) NCE/ND ☐
(b) Primary School ☐ (e) HND/B.Sc. ☑
(c) Secondary School ☐ (f) Others (Specify) .....

6. Occupation: (a) Student ☐ (b) Academic Staff ☐ (c) Non-academic Staff ☑ (d) Trader ☐
(d) Military Personnel (e) Others (Specify) .....

7. Monthly Income: (a) #0 - #30, 000 ☐ (b) #31, 000- #60,000 ☐ (c) # 61, 000-#90, 000 ☐
(d) #120,000 and above ☑

8. Duration of stay in the institution/community (a) 1-5 Yrs. ☑ (b) 6–10 Yrs. ☐ (c) 11–19 ☐
(d) 20 and above ☐

9. Types of language spoken in the communities; English ☑ Hausa ☑ Fulfulde (Fulani) ☐
Yoruba ☐ Igbo ☐ Others.....

Section B: Health Status

10. What is the health facility available in your institution/community (a) Primary Health Centre ☐
(b) General Hospital ☐ (c) Private Hospitals ☐ (d) Sick bay ☑
(e) Others(Specify)...N.S.T. Hosp. Unit

11. Condition of the health facility within the Institution/community; Very Good ☐ Good ☑
Fair ☐ Poor ☐

12. Please tick the health conditions you experience most frequently.

Health Conditions	Tick	Health Conditions	Tick	Others (specify)
Malaria	✓	Tuberculosis		
Typhoid fever		Hypertension		
Cholera		Asthma		
Rheumatism		Diabetics		
Pneumonia		Rashes		

13. Do you think the proposed project will have a negative impact on your health/environment?
(a) YES ☐ (b) NO ☑
If yes, how? (a) Air Pollution ☐ (b) Noise Pollution ☐ (c) Ground water contamination
(d) Surface water contamination ☐ (e) others (specify) .....

14. How do you think these impacts can be averted .....

Section C: Gender Based Violence

15. Have you or anyone in your household had experienced gender-based violence?
(a) YES ☐ (b) NO ☑

1

16. Do you think men and women have equal access to economic opportunities in your institution/community? (a) YES ☑ (b) NO ☐

17. Do you believe that cultural norms in your institution/community influence the prevalence of GBV?(a) YES ☐ (b) NO ☑

18. Are there adequate support services available for survivors of GBV in your institution/community? (a) YES ☐ (b) NO ☐

Section D: Public Services

19. What is the source of water supply in your institution/community? (a) Well ☐ (b) Borehole ☑ (c) River/Stream ☐ (d) Govt Water Board ☐ (e) Others (specify) .....

20. Condition of portable water within the institution/community: Very Good ☑ Good ☐ Fair ☐ Poor ☐

21. What is the available source of power in the institution/community? (a) National Grid ☑ (b) Generator ☐ (c) Lantern ☐ (d) Touch light ☐ (e) Solar power ☑ (f) Others (specify) .....

22. Condition of public electricity within the institution/community: Very Good ☐ Good ☐ Fair ☑ Poor ☐

23. Sanitation facility in the institution/community; Water closet ☑ Pit Latrine ☐ Open Defecation ☐ Others ☐

24. What is the most available/affordable source of cooking? (a) Gas cooker ☑ (b) Stove ☐ (c) Firewood ☐ (d) Charcoal ☐ (e) Others (specify) .....

25. What are the educational institutions available in your institution/community? (a) Primary school ☐ (b) Secondary school ☐ (c) Tertiary Institution ☑ (d) Others (specify).....

26. Waste disposal method:- Bush Burning ☐ Public open dump ☐ Private Open dump ☐ Organized collection ☑ Burying ☐ Others _____

Section E: Existing Socio-Economic Condition of the Study Area

27. Indicate the traditional economic activity practiced by member of the institution/community:
(a) Trading ☑ (b) Cybercafe ☐ (c) POS Services ☑ (d) Printing Press ☐
(e) Others (specify) .....

28. Do you think the proposed project will affect any valued resources/ cultural assets / archeological sites within the institution/community? (a) YES ☐ (b) NO ☑

If yes, mention the name(s) of the resources.....

Section F: Potential Socio-Economic Impact of the Proposed Project

29. Do you think the institution management members are fully aware of the proposed project? (a)YES ☑ (b) NO ☐

30. What do you think is the socio-economic benefit of the project?

_____

_____

31. Indicate the social associations existing in your institution/community: (a) Student Union ☐
(b) Teaching Staff Association ☐ (c) Non-Teaching Staff Association ☐
(d) Traders Association ☐ (e) Others Specify .....

32. Which neighboring institution/communities do you think will benefit from the new developmental project?

.....

2

APPENDIX II

CHAIN OF CUSTODY FORM

Pollution Control Laboratory, Farm Centre
Ministry of Environment, Kano
Block No. 5 AuduBako Secretariat

No. 125 T/ShanuTarauni, Kano State.
Hon. Commissioner: 064-668371
Perm. Secretary Fax: 669423

Page: 1 of 3

CUSTODY TRANSFER FORM

Client Name:	BOLBEN ENERGY LIMITED	Relinquished by(Signature):	Date: 18/7/26	Time: 10:00
Project Name:	2MW SOLAR PROJECT (NEP)	Received by (Signature):	Date:	Time:
Address:	AIR FORCE INSTITUTE OF TECH. KADUNA	FMEVT Representative:	Date:	Time:
Consultant		Address:		

Type of Simple

Water Sample [ ] Soil Sample [✓] Others (Specify): [ ]

Number of Samples: 12 Soil Samples

Date Sampled: 18/7/26

S/No.	Sample ID	Sample Location	Laboratory Description of Sample
1	S1 Top	AFIT Kaduna	S1 Top
2	S1 Botton	✓ ✓	S1 Botton
3	S2 Top	✓ ✓	S2 Top
4	S2 Botton	✓ ✓	S2 Botton
5	S3 Top	✓ ✓	S3 Top
6	S3 Botton	✓ ✓	S3 Botton
7	S4 Top	✓ ✓	S4 Top
8	S4 Botton	✓ ✓	S4 Botton
9	S5 Top	✓ ✓	S5 Top
10	S5 Botton	✓ ✓	S5 Botton
11	Scontrol Top	✓ ✓	Scontrol Top
12	Scontrol Botton	✓ ✓	Scontrol Botton

APPENDIX III

LABORATORY ANALYSIS RESULT (SURFACE WATER/GROUND WATER SAMPLES)

MINISTRY OF ENVIRONMENT AND CLIMATE CHANGE
POLLUTION CONTROL LABORATORY
Address: Farm Centre, Near Cool FM, Kano State.
Tel: +2347030166686

CLIENT: **BOLBEN ENERGY LIMITED**
PROJECT NAME: **ESIA OF NIGERIA ELECTRIFICATION PROJECT (NEP) UNDER RURAL ELECTRIFICATION AGENCY TO 2MW SOLAR POWERED PROJECT**
PROJECT ADDRESS: **AIRFORCE INSTITUTE OF TECHNOLOGY (AFIT) AIRFORCE BASE, KADUNA STATE**

WATER QUALITY ASSESSMENT RESULT

Sequel to the analysis conducted on your samples below are the data obtained on the condition submitted to the laboratory.

S/N	PARAMETERS	UNIT	SW1	SW2	SW3	GW1	GW2	GW3	GW5	GW5	FMENT LIMIT
(A)	PHYSIOCHEMICAL TEST										
1.	Colour	Tcu	Pale brown	Pale brown	Pale brown	Clear	Clear	Clear	Clear	Clear	Clear
2.	Odour	-	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	unobjectionable
3.	Taste	0	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Unobjectionable
4.	PH	-	7.63	7.01	7.17	7.28	7.22	6.94	6.35	6.30	6.5 - 8.5
5.	Temperature	°c	29.7	29.9	29.8	29.6	28.4	29.7	29.8	30.0	Ambient
6.	Electrical conductivity	us/cm	84	94	92	78	248	63	50	68	1000

LABORATORY ANALYSIS RESULT (SURFACE WATER/GROUND WATER SAMPLES) CONTINUATION….

7.	Turbidity	NTU	0	1	1	0	0	0	0	0	50
8.	Total dissolve solid	ppm	42	47	46	39	120	32	25	32	500
9.	Total suspended solid	ppm	100	96	112	37	24	15	18	22	20
10.	Dissolve oxygen	mg/l	2.3	2.6	2.2	3.9	4.2	5.0	4.6	4.4	2-8
11.	B.O.D	mg/l	0.9	1.2	0.8	2.0	0.5	1.6	2.1	2.0	NS
12.	C.O.D	mg/l	0	3	1	0	0	0	0	0	30
13.	Salinity	%	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	<1000
14.	ORP	mV	125	130	115	149	178	131	181	178	200-600
(B)	**CHEMICAL TEST**										
15.	Aluminium (Al^{3+})	mg/l	0.34	0.46	0.38	0.07	0.08	0.05	0.07	0.09	
16.	Calcium (Ca^{2+})	mg/l	2.15	2.28	2.21	0.48	0.36	0.28	0.47	0.43	
17.	Magnesium (mg^{2+})	mg/l	1.20	1.32	1.41	0.22	0.28	0.19	0.17	0.24	
18.	Total hardness	mg/l	54	43	37	18	12	8	14	17	
19.	Potassium (K^{+})	mg/l	2.6	3.0	2.7	0.6	1.2	1.6	0.9	1.8	
20.	Nitrate (NO^{2-}_{3})	mg/l	21.2	18.9	15.6	3.4	2.8	3.7	3.6	4.1	
21.	Nitrite (NO_{-2})	mg/l	0.7079	0.036	0.067	0.024	0.016	0.021	0.023	0.032	
22.	Sulphate (SO^{2-}_{4})	mg/l	24	28	33	5	3	6	4	7	
23.	Phosphate (PO^{3-}_{4})	mg/l	4.64	3.81	4.24	2.33	1.72	1.86	1.33	1.25	
24.	Sulphide ($^{S2-}$)	mg/l	24	28	33	5	3	6	4	7	
25.	Chloride (Cl)	mg/l	11.3	10.7	9.6	0.9	1.3	2.1	2.2	2.8	
26.	Flouride (Fl)	mg/l	1.02	0.96	0.84	0.22	0.17	0.13	0.20	0.24	
(C)	**HEAVY METALS**										
27.	Copper (Cu^{2+})	mg/l	1.32	0.84	0.72	0.28	0.33	0.36	0.24	0.29	
28.	Chromium (Cr^{3+})	mg/l	0.32	0.26	0.31	0.01	0.00	0.01	0.02	0.04	

LABORATORY ANALYSIS RESULT (SOIL SAMPLES)

SOIL ANALYSIS REPORT

SAMPLE TYPE: SOIL
SAMPLE QUANTITY: 5KG

(A)	PHYSICAL TEST	UNIT	S1 TOP	S1 BASE	S2 TOP	S2 BASE	S3 TOP	S3 BASE	S4 TOP	S4 BASE	S5 TOP	S5 BASE	CONTROL TOP	CONTROL BASE
1.	Colour	Tcu	Brown	Very dark brown	Very dark brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Dark yellowish brown	Very dark brown	Very dark brown
2.	PH	-	6.52	6.48	6.60	6.13	6.37	6.45	6.63	6.55	6.65	6.23	6.94	6.81
3.	Electrical conductivity	us/cm	1632	1776	1768	1573	1479	1714	1736	1714	1712	1762	1891	1786
4.	Temperature	°C	27.4	28.5	28.6	27.3	30.0	28.3	29.0	29.9	29.7	28.5	28.6	27.4
5.	Salinity	%	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.09
6.	ORP	mV	120	86	125	134	210	152	130	72	118	177	178	215
(B)	**EXCHANGEEABLE CATION**													
7.	Calcium	mg/kg	2.62	2.28	1.90	1.86	2.05	2.06	2.74	2.72	1.98	1.92	1.33	1.33
8.	Aluminium	mg/kg	0.032	0.042	0.039	0.038	0.040	0.041	0.092	0.037	0.038	0.059	0.000	0.000
9.	Magnesium	mg/kg	0.98	0.96	0.76	0.72	1.00	0.01	0.10	1.10	0.96	0.94	0.26	0.21
10.	Potassium	mg/kg	4.0	3.3	3.6	2.8	3.8	3.4	2.2	1.9	2.8	2.8	1.7	1.3
11.	Ammonium	mg/kg	0.05	0.03	0.07	0.06	0.05	0.05	0.06	0.08	0.06	0.05	0.03	0.02
(C)	**EXCHANGEABLE ANION**													
12.	Chloride	mg/kg	0.6	0.5	0.5	0.8	0.4	0.6	0.9	0.5	0.4	0.5	0.5	0.7
13.	Fluoride	mg/kg	0.08	0.07	0.02	0.02	0.03	0.03	0.05	0.06	0.02	0.02	0.01	0.01
14.	Nitrate	mg/kg	2.6	2.2	3.9	3.8	2.7	2.8	4.8	4.5	2.9	2.7	1.9	1.7
15.	Nitrite	mg/kg	0.020	0.017	0.015	0.018	0.028	0.022	0.009	0.011	0.017	0.009	0.009	0.006
16.	Sulphate	mg/kg	6	4	5	5	8	7	7	6	4	3	2	2
17.	Phosphate	mg/kg	6	4	5	5	8	7	7	6	4	3	2	2
(D)	**HEAVY METAL**													
18.	Chromium	mg/kg	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.06	0.03	0.03	0.01	0.01
19.	Copper	mg/kg	0.14	0.11	0.13	0.11	0.16	0.14	0.10	0.39	0.13	0.18	0.15	0.12
20.	Iron	mg/kg	0.15	0.16	0.28	0.26	0.18	0.17	0.28	0.26	0.36	0.33	0.09	0.11
21.	Lead	ug/kg	0.015	0..018	0.006	0.008	0.014	0.013	0.02	0.021	0.016	0.016	0.003	0.005
22.	Manganese	mg/kg	0.5	0.7	0.5	0.5	0.7	0.8	0.3	0.7	0.1	0.3	0.2	0.2

LABORATORY ANALYSIS RESULT (SOIL SAMPLES) CONTINUATION….

29.	Cadmium (cd^{2+})	ug/l	0.024	0.038	0.036	0.002	0.012	0.006	0.008	0.002	
30.	Lead (Pb^{2+})	ug/l	0.06.2	0.047	0.038	0.000	0.001	0.004	0.003	0.003	0.001
31.	Zinc (Zn^{2+})	mg/l	0.84	0.72	0.78	0.08	0.22	0.26	0.23	0.19	
32.	Iron (Fe^{2+})	mg/l	0.22	0.31	0.26	0.02	0.38	0.30	0.21	0.24	
33.	Nickel (Ni^{2+})	mg/l	0.067	0.072	0.068	0.003	0.000	0.001	0.003	0.005	0.007
34.	Cobalt (co^{2+})	mg/l	0.074	0.078	0.072	0.004	0.007	0.005	0.007	0.008	
35.	Mercury (Hg^{+})	mg/l	0.003	0.008	0.034	0.000	0.001	0.008	0.006	0.013	
(D)	**ORGANICS**										
36.	Phenols	mg/l	0.136	0.062	0.123	0.025	0.011	0.009	0.017	0.022	
37.	Oil and grease	mg/l	0	0	0	0	0	0	0	0	
38.	Benjene	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
39.	Toluene	mg/l	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
40.	Ethyl benzene	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
41.	Xylene	mg/l	0	0	0	0	0	0	0	0	
(E)	**MICROBIOLOGICAL TEST**										
42.	E. Coli	cfu/ml	16	12	12	0	0	0	0	0	Nil
43.	Total coliform	cfu/ml	243	168	161	3	6	8	2	1	10

LABORATORY ANALYSIS RESULT (SOIL SAMPLES) CONTINUATION….

23.	Mercury	ug/kg	0.005	0.008	0.002	0.002	0.004	0.004	0.008	0.008	0.004	0.003	0.000	0.000
24.	Cobalt	mg/kg	0.1	0.7	0.8	0.8	0.0	0.0	0.3	0.3	0.2	0.2	0.1	0.0
25.	Nickel	mg/kg	0.001	0.001	0.007	0.006	0.005	0.001	0.001	0.001	0.003	0.002	0.000	0.000
(E)	**ORGANICS**													
26.	Oil and grease	mg/kg	0	0	0	0	0	0	0	0	0	0	0	0
27.	Phenols	mg/kg	0.18	0.021	0.018	0.017	0.029	0.026	0.022	0.019	0.018	0.018	0.010	0.011
28.	BTEX	mg/kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(F)	**SOIL CHARACTERISTICS**													
29.	Sandy	%	43	36	29	31	43	29	26	19	29	20	11	15
30.	Loam	%	51	59	49	57	21	36	41	62	51	48	44	39
31.	Clay	%	3	5	12	8	25	20	15	6	19	13	31	26
32.	Silt	%	3	0	10	2	11	15	18	3	1	19	14	20
(G)	**MICRO BIOLOGICAL TEST**													
33.	E. Coli	cfu/100kg	5	5	5	4	3	7	19	6	9	2	11	12
34.	Fungal	cfu/100kg	73	68	68	59	112	150	203	29	31	203	74	116

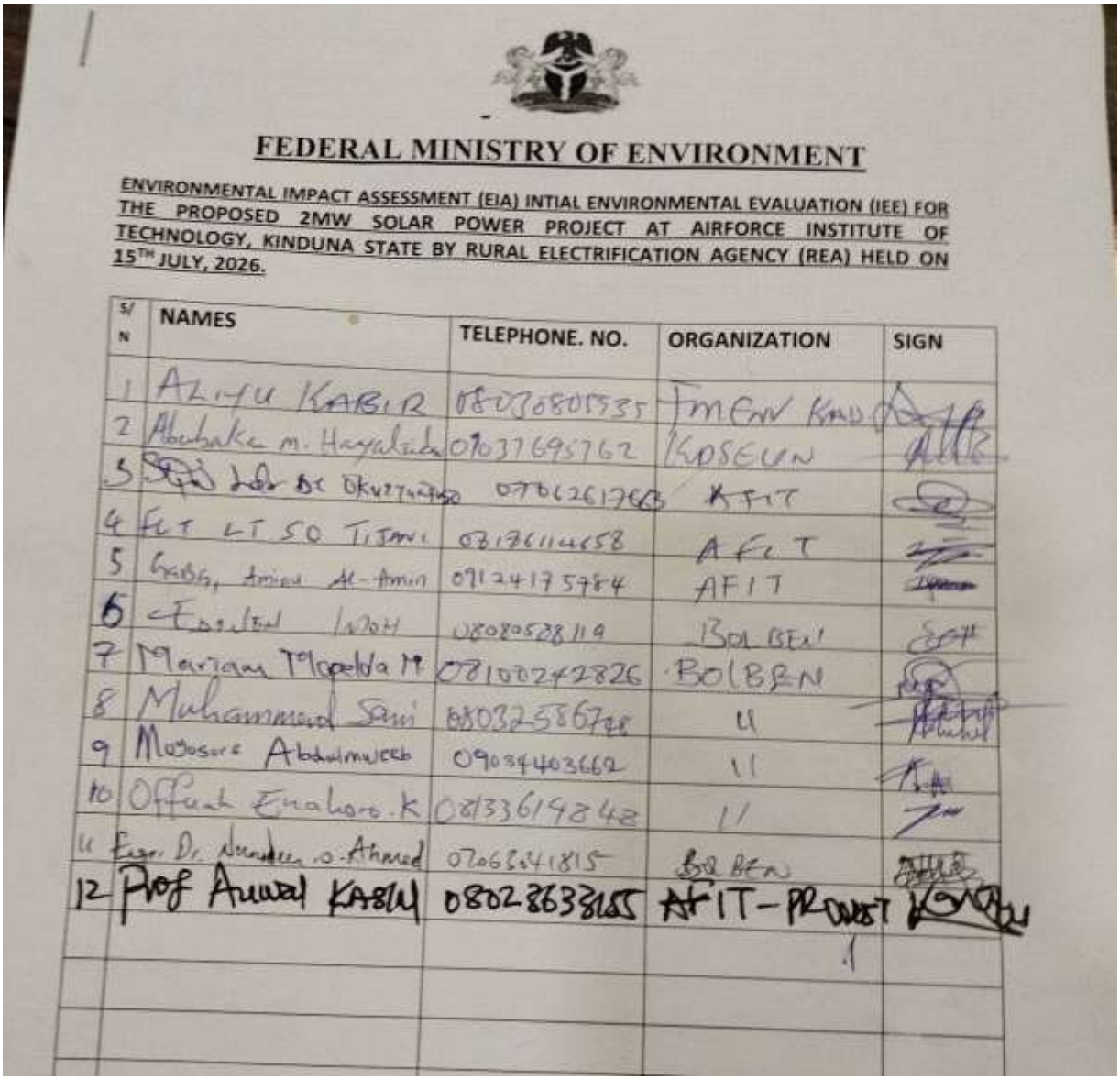
Best Wishes,



San. Abdulkadir H. Umar (ACSO)
ASSISTANT CHIEF SCIENTIFIC OFFICER

APPENDIX IV

ATTENDANCE SHEETS



FEDERAL MINISTRY OF ENVIRONMENT

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) INTIAL ENVIRONMENTAL EVALUATION (IEE) FOR THE PROPOSED 2MW SOLAR POWER PROJECT AT AIRFORCE INSTITUTE OF TECHNOLOGY, KINDUNA STATE BY RURAL ELECTRIFICATION AGENCY (REA) HELD ON 15TH JULY, 2026.

S/N	NAMES	TELEPHONE. NO.	ORGANIZATION	SIGN
1	AZIYU KABIR	08030805535	FMENV KND	
2	Abubakar M. Hayatudeen	07037695762	KDSEUN	
3	[illegible]	07062617663	AFIT	
4	FLT LT SO TIJANI	08136114658	AFIT	
5	GABA, Aminu Al-Amin	07124175784	AFIT	
6	[illegible]	08080528119	BOLBEN	
7	Maryam Magaji M.	08100242826	BOLBEN	
8	Muhammad Sani	08032586788	"	
9	Mojisola Abdulmuiz	09034403662	"	
10	Offiah Enahoro. K	08133614848	"	
11	Engr. Dr. Surajudeen O. Ahmed	07068241815	BOLBEN	
12	Prof Auwal KABIR	08028638185	AFIT-PROJECT	

ATTENDANCE SHEET CONTINUATION….

BOLBEN ENERGY
AND ENVIRONMENTAL SERVICES LTD

ENVIRONEMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) RECONNAISANCE VISIT FOR THE PROPOSED REA-NEP (DtP PHASE II) POWER PROJECT, AFIT, KADUNA STATE.

PROJECT TITLE: 2 MW SOLAR PHOTOVOLTAIC POWER PROJECT AND ASSOCIATED INFRASTRUCTURE UNDER THE NIGERIA ELECTRIFICATION PROGRAM (NEP) DESERT TO POWER PHASE II (DTP II) BY RURAL ELECTRIFICATION AGENCY.

LOCATION: Air Force Institute of Technology (AFIT), Nigerian Air Force Base, Kawo LGA

STATE: KADUNA STATE

DATE: _____

S/N	NAME	DESIGNATION/POSITION	PHONE NO.	SIGN
1	Awm Oc Ubadike.	Deputy Commandat	07036704164	
2	Prof Awal KASIM	Provost	08023633155	
3	Sqn Ldr G Ezra	Director & Logistics	07061335652	
4	Mariam Motolola Moshood	CEO/MD BOLBEN	08160249826	
5	Muhammad Sani Muhammad	Bolben	08032556748	
6	Edidem Imoh	Bolben	08080528119	
7	Sqn Ldr BC Okwuyungbo	Director Physical Planning	07062617663	
8	Fg Offr U Hussaini	Works Offr	07034674377	
9				
10				

BOLBEN ENERGY
AND ENVIRONMENTAL SERVICES LTD

ENVIRONEMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) SITE VERIFICATION AND BASELINE DATA GATHERING EXERCISES FOR THE PROPOSED REA-NEP (DtP PHASE II) POWER PROJECT, AFIT, KADUNA STATE.

PROJECT TITLE: 2 MW SOLAR PHOTOVOLTAIC POWER PROJECT AND ASSOCIATED INFRASTRUCTURE UNDER THE NIGERIA ELECTRIFICATION PROGRAM (NEP) DESERT TO POWER PHASE II (DTP II) BY RURAL ELECTRIFICATION AGENCY.

LOCATION: Air Force Institute of Technology (AFIT), Nigerian Air Force Base, Kawo LGA

STATE: KADUNA STATE

DATE: _____

S/N	NAME	DESIGNATION/POSITION	PHONE NO.	SIGN
1	Abdulsalam M. Hayatudeen	AD SEcon	07031675762	
2	Aziz U Kaoran	D.SO /Controller	08037855335	
3	MAXWELL LINUS	AMENV ABUJA	07063114730	
4	Sqn Ldr BC Okwuyungbo	DPP	07062617663	
5	Flt Lt SO Tijani	Works officer	08136114658	
6	Garba Aminu	Surveyor / DPP	09124175784	
7	Edidem Imoh	Bio BEN LTD	08080528119	
8	Moyosore Abdulmuheeb	U	09084462366	
9	Engr. Dr Surveyor Olawale Ahmed	Bolben Energy Ltd.	07063041815	
10	Ufuoma Enghovo		08177614248	
11				

APPENDIX V

PICTORIAL EVIDENCE OF STAKEHOLDER ENGAGEMENT









APPENDIX VI

PICTORIAL EVIDENCE OF SOIL SAMPLING ACTIVITIES



APPENDIX VII

PICTORIAL EVIDENCE OF AMBIENT AIR QUALITY AND NOISE LEVEL SAMPLING









APPENDIX VIII

PICTORIAL EVIDENCE OF WATER SAMPLING









APPENDIX IX

LIST OF SAMPLING EQUIPEMENTS

Category	*Equipment*	*Purpose*
Navigation & Survey	Handheld GPS	Record sampling locations and project coordinates
	Measuring Tape (30–100 m)	Distance measurements
Documentation	Digital Camera	Photographic documentation
	Smartphone	Data collection, GPS, communication
	Field Notebook	Recording observations
	Clipboard	Support for field forms
	Pens/Markers	Writing
	Paper Tape	Sample identification
	Chain of custody forms	Samples logging and tracking
Water Quality Sampling	Water Sampling Bottles	Water sample collection
	Cooler Box with Ice Packs	Preserve samples during transport
	Multiparameter Water Quality Meter	Measure pH, EC, TDS, DO, Temperature
Soil Sampling	Soil Auger	Collect soil samples
	Hand Trowel	Surface soil sampling
	Ziploc Bags	Store soil samples
Social Survey	Questionnaires	Stakeholder surveys
	Attendance Sheets	Stakeholder engagement records
Health & Safety	High-Visibility Vest	Personnel safety
	Safety Boots	Foot protection

Detection limits for air quality instruments

Parameter Measured	Equipment	Detection Limit
PM2.5	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 999 µg/m³
PM10	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 999 µg/m³
Formaldehyde (HCHO)	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 5 mg/m³ (Resolution: 0.001 mg/m³)
Total VOC (TVOC)	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 5 mg/m³ (Resolution: 0.001 mg/m³)
Temperature	VT-9IN1 Air Quality Monitor Tester	32°F to 158°F (0°C to 70°C)
Relative humidity	VT-9IN1 Air Quality Monitor Tester	0% to 99% RH
AQI	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 999
Particle number	Elitech Temtop LKC-1000S+ 2nd Generation	0 to 9,999 particles per liter (particles/L) [1, 2]
CO_2 / Oxygen (O_2)	VT-9IN1 Air Quality Monitor Tester	CO_2 ranges from 400 to 5000 ppm; and 0–30% vol for O_2
Ambient noise level	V-Resourcing Hand-Held Sound Level Meter	30 dBA to 130 dBA (Accuracy: ±1.5 dB)