ENIGERIAN 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

NATIONAL OPEN UNIVERSITY OF NIGERIA (NOUN), MAIN CAMPUS, ABUJA – FCT UNDER THE NIGERIA ELECTRIFICATION PROJECT (DESERT TO POWER) PHASE II

SUBMITTED TO:

FEDERAL MINISTRY OF ENVIRONMENT, ABUJA

DRAFT REPORT **OCTOBER 2026**

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

OF THE PROPOSED

2 MW SOLAR-HYBRID POWER PLANT AND ASSOCIATED INFRASTRUCTURE AT NATIONAL OPEN UNIVERSITY OF NIGERIA (NOUN), MAIN CAMPUS, ABUJA - FCT

Report No.: REA/DTP II-NOU-10-2026/001

Client: **RURAL ELECTRIFICATION AGNECY**

Date of Report: **October 2026**

Project Consultant: **BOLBEN ENERGY AND ENVIRONMENTAL SERVICES LIMITED**

Bolben Quality Assurance/Quality Control:

	Name	**Function**	**Signature**	**Date**
Reviewed & approved by	Mariam Mopelola .M	QA/QC Expert		10/2026
Compiled by	Edinen Imoh	Environmental Analyst		10/2026
Version	Status			
1	**Draft ESIA Report**		**October 2026**	

Table of Contents

Title Page ix
Table of Content ix
List of Figures ix
List of Tables x
List of Plates xii
List of Acronyms, Units and Abbreviations v
Executive Summary xv
Acknowledgement xxxii

CHAPTER ONE: INTRODUCTION 1
1.1 Project Background 1
1.2 Project Overview 2
1.3 Project Proponent 3
1.4 Project Location 3
1.4.1 Detailed Description of Site 1 5
1.4.2 Detailed Description of Site 2 6
1.4.3. Existing Campus Infrastructure and Utilities 6
1.4.3.1 Electricity Supply and Distribution 6
1.4.3.2 Water, Wastewater and Solid Waste 6
1.5 Rationale and Objectives for the ESIA 8
1.6 Scope of the Study/Terms of Reference 9
1.6.1 Spatial Scope 9
1.6.2 Temporal Scope 10
1.6.3 Thematic Scope 10
1.7 ESIA Methodology 10
1.8 Policy, Legal and Institutional Framework 11
1.8.1 International Convention and Agreements, Best Practice Standards and Guidelines 22
1.8.2 FGN Requirements and Relevant Legislation 31
1.8.3 National Policy, Guidelines and Regulations 12
1.8.3.1 Federal Ministry of Environment (FMEnv) 12
1.8.3.2 National Environmental Standards and Regulation Enforcement Agency (NESREA) 14
1.8.3.3 Federal Ministry of Power 16
1.8.3.4 Rural Electrification Agency Act 2005 17
1.8.4 FCT Policy, Guidelines and Regulations 21
1.8.4.1 Federal Capital Territory Administration (FCTA) 21
1.8.4.2 Federal Capital Development Authority (FCDA) 21
1.8.4.3 Abuja Environmental Protection Board (AEPB) 22
1.8.4.4 Abuja Municipal Area Council (AMAC) 22
1.9 Structure of ESIA Report 31

CHAPTER TWO: PROJECT JUSTIFICATION 33
2.1 Introduction 33
2.2 Justification and Need for the Project 33
2.2.1 National Energy Transition Imperative 33
2.2.2 Economic Justification 34
2.2.3 Environmental and Climate Justification 35
2.2.4 Social and Developmental Justification 35
2.2.5 Strategic Alignment with Rural Electrification Objectives 35
2.3 Value of the Project 36
2.4 Expected Benefits of the Project 36
2.5 Sustainability of the Project 36
2.5.1 Technical Sustainability 36
2.5.2 Social Sustainability 37
2.5.3 Economic Sustainability 38
2.5.4 Environmental Sustainability 39
2.6 Project Alternatives 39
2.6.1 Alternative Sites Considered for the Project 40
2.6.2 Power Generation Alternatives 41
2.6.3 Panel Technology Alternatives Considered 43
2.6.4 Solar Batteries Alternatives Considered: 44
2.6.4.1 Lead-Acid Batteries 44
2.6.4.2 Lithium-Ion Batteries 44
2.6.4.3 Nickel Cadmium Batteries 45
2.6.4.4 Flow Batteries 45
2.6.5 Sites Alternatives Considered: .....**Error! Bookmark not defined.**
2.7 Project Development Options: 45
2.7.1 No Project Option: 45
2.7.2 Technical Implications of the No-Project scenario: 46
2.7.3 Environmental Implications of the No-Project scenario: 46
2.7.4 Economic Implications of the No-Project scenario: 46
2.7.5 Go ahead with the Project Option: 47

CHAPTER THREE: PROJECT DESCRIPTION 48
3.1 Introduction 48
3.2 Key Project Components 48
3.3 Project Phases for Implementation 59
3.3.1 Pre-Construction Phase 59
3.3.2 Construction Phase 61
3.3.3 Operational Phase 62
3.3.4 Decommissioning Phase 64
3.4 Manpower Requirement 66
3.5 Water Requirement 66

3.6 Solar PV network installation standards and Codes 67
3.7 Health and Safety 67
3.8 Emergency Shut-Down Measures 68
3.9 Waste Management 68
3.9.1 Types of Wastes: Identification, Categories, and Estimated Quantities 69
3.10 Project Schedule 72

CHAPTER FOUR: DESCRIPTION OF THE EXISTING ENVIRONMENT ..74
4.1 Background.....74
4.2 The ESIA Study Approach.....74
4.2.1 Desktop Research 74
4.2.2 Field Visit and Data Gathering Exercise.....74
4.2.2.1 Minutes of The Stakeholder Consultation Meetings.....74
4.2.2.2 Field Sampling Equipments and Materials 74
4.2.3 Laboratory Analysis of Field Samples 80
4.3 Physical Characteristics of the Proposed Project Area 81
4.3.1 General Overview of FCT's Location, Climate and Weather Patterns.....82
4.3.2 Discussions on the Macro-climate of the FCT.....82
4.3.2.1 Relative Humidity and Temperature 83
4.3.2.2 Rainfall 84
4.3.2.3 Sunshine Hours.....85
4.3.2.4 Wind Speed and Direction 87
4.4 Baseline Study of the Project Area 88
4.4.1 Air Quality and Noise Assessment.....94
4.4.2 Geology 100
4.4.2.1 Soil Studies.....103
4.4.2.1.1 Interpretation and Discussion of Soil Laboratory Results 109
4.4.2.1.2. Exchangeable Cations and Soil Fertility Indices 111
4.4.2.1.3. Macronutrients.....114
4.4.2.1.4 Organic Matter Characteristics.....116
4.4.2.1.5 Anions.....117
4.4.2.1.6 Heavy Metals.....119
4.4.2.1.7 Microbiological Characteristics 121
4.4.2.2 Groundwater Sampling & Quality Assessment 124
4.4.2.2.1 Laboratory Analysis, Interpretation and Discussions for Groundwater127
4.4.2.2.2 Physicochemical Characteristics 129
4.4.2.2.3 Major-Ion Characteristics.....132
4.4.2.2.4 Metals and Trace Elements 134
4.4.2.2.5 Microbiological Characteristics 137
4.4.2.3 Hydrology, Topography, Drainage and Water Supply 140
4.4.2.4 Surface Water Sampling/Quality 141

4.4.2.4.1 Laboratory Analysis, Interpretation and Discussions for Surface Water: 143
4.4.2.4.2 Physicochemical Characteristics 145
4.4.2.4.3 Major-Ion Characteristics 152
4.4.2.4.4 Metals and Trace Elements 155
4.4.2.4.5 Microbiological Characteristics of Surface Water 159
4.5 Land Use, Land Cover and Land Utilization. 163
4.6 Ecological Description of the Project Site 163
4.6.1 Ecological Setting 163
4.6.2 Methodology for Flora and Fauna Assessment at the Study Area 164
4.6.3 Flora Sampling 164
4.6.4 Fauna Assessment 169
4.7 Socio-economic and Health Conditions of the Study Area 170
4.7.1 Study Approach and Methodology 171
4.7.1.1 Study Design 172
4.7.1.2 Sample Size and Target Population for the Study 172
4.7.1.3 Ethical Considerations 173
4.7.2 Background of the National Open University of Nigeria (NOUN) 173
4.7.3 University Community Administrative Structure & Governing Council 175
4.7.4 Land Tenure and Ownership 176
4.7.5 Sampled Population/NOUN Socioeconomic Characteristics 178
4.7.6 Traffic Survey 192
4.8 Consultation Process 194
4.8.1 Institutional Consultation 195
4.8.2 Public Involvement 195
4.8.3 Stakeholder Consultation 195
4.8.3.1 Introduction 195
4.8.3.2 Stakeholder Engagement Requirements and Approach 195
4.8.3.3 Stakeholder Identification 196
4.9 Outcome of Focus Group Discussion and Key Informant Interview 197

CHAPTER FIVE: POTENTIAL AND ASSOCIATED IMPACTS 200
5.1 Introduction 200
5.2 Impact Methodology Description 201
5.2.1 Environmental and Social Indicators 201
5.2.2 Impact Identification and Characterization Technique 204
5.2.3 Determination of Impact Significance 205
5.3 Impact Methodology Description 206
5.4 Impact Severity and Profiling 207
5.5 Project Phases, Associated Activities and Potential Impacts 232
5.5.1 Discussion on the Identified Impacts for Pre-Construction Phase 233
5.5.2 Discussion on the Identified Impacts for Construction Phase 233

5.5.3 Discussion on the Identified Impacts for Operations Phase.....235
5.5.4 Discussion on the Identified Impacts for Decommissioning Phase.....236
5.6 Risk Assessment.....237
5.7 Residual Impacts.....239
5.7.3 Cumulative Impacts.....241

CHAPTER SIX: MITIGATION MEASURES.....242
6.1 Introduction.....242
6.2 Mitigation Objectives and Approach.....242
6.3 Summary of Mitigation Measures.....262

CHAPTER SEVEN: ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN.....264
7.1 Introduction.....264
7.2 Objectives of the ESMP.....265
7.3 Institutional Framework for ESMP Implementation.....266
7.3.1 Communication and Reporting Framework.....267
7.4 Environmental Management Measures.....267
7.4.1 Environmental Management Measures for all phases of the project.....267
7.4.2 Environmental Monitoring Programme.....286
7.5 Additional Management Plans.....287
7.5.1 Stakeholder Engagement Plan (SEP).....287
7.5.1.1 Grievance Redress Mechanism (GRM).....288
7.5.2 Traffic Management Plan (TMP).....289
7.5.3 Waste Management Plan (WMP).....290
7.5.4 Occupational Health and Safety (OHS) Plan.....290
7.5.5 Local Employment Management Plan (LEMP).....291
7.5.6 Erosion Control Management Plan.....291
7.5.7 Water Conservation Plan.....291
7.5.8 Emergency Preparedness and Response Plan (EPRP).....292
7.5.9 REA Gender-Based Violence (GBV) Action Plan.....293
7.5.10 Cost for Implementation of Additional Management Plans.....293
7.6 Training, Awareness and Capacity Building.....294
7.7 Implementation Schedule and Reporting.....295
7.8 ESMP Costing.....296
7.9 Stakeholder Engagement.....297
7.9.1 Objectives of Stakeholder Engagement.....297
7.9.2 Stakeholder Identification and Analysis.....298
7.9.5 Stakeholder Register.....300
7.9.6 Stakeholder Engagement Process.....301
7.9.7 Stakeholder Engagement Tools and Communication.....303
7.9.8 Principles for Effective Stakeholder Engagement.....305

7.9.9 Summary of Previous Stakeholder Engagement Activities 306
7.10 Management Function and Grievance Mechanism.....308
7.10.1 Management Commitment.....308
7.10.2 Roles and Responsibilities.....309
7.10.3 Grievance Redress Mechanism (GRM) 309
7.10.4 Special Procedures for GBV/SEA/SH Cases.....311
7.10.5 Grievance Redress Mechanism (GRM) Tools 311

CHAPTER EIGHT: REMEDIATION PLAN AFTER DECOMMISSIONING / CLOSURE.....312
8.1 Introduction 312
8.2 Decommissioning Activities 312
8.3 Management of Decommissioning Activities.....313
8.3.1 Decommissioning Planning Requirements 313
8.3.2 Evaluation of Decommissioning Options 314
8.3.3 Risk Assessment and Safety.....314
8.3.4 Socio-Economic Considerations 314
8.3.5 Waste Management During Decommissioning 314
8.3.6 Used Battery Management at Decommissioning Phase 315
8.4 Abandonment Plan 315
8.5 Roles, Responsibilities and Accountabilities for Decommissioning Phase.....316
8.6 Monitoring Requirements.....318

CHAPTER NINE: SUMMARY AND CONCLUSION.....325
9.1 Summary.....325
9.2 Conclusion.....326

REFERENCE 327

APPENDIX I: Socioeconomic Questionnaire Sample ..... **Error! Bookmark not defined.**
APPENDIX II: Chain of Custody and Lab Accreditations .. **Error! Bookmark not defined.**
APPENDIX III: Laboratory Analysis Results (Water Samples) . **Error! Bookmark not defined.**
APPENDIX IV: Laboratory Analysis Results (Soil Samples) .... **Error! Bookmark not defined.**
APPENDIX V: Pictorial Evidence of Attendance Sheets .... **Error! Bookmark not defined.**
APPENDIX VI: Pictorial Evidence of Stakeholder Engagments **Error! Bookmark not defined.**
APPENDIX VII: Pictorial Evidence of Soil Collection ..... **Error! Bookmark not defined.**

APPENDIX VIII: Pictorial Evidence of Ambient Air-Quality and Noise Level Measurements.....**Error! Bookmark not defined.**
APPENDIX IX: Pictorial Evidence of Water Sampling..... **Error! Bookmark not defined.**
APPENDIX X: List of Sampling Equipments.....**Error! Bookmark not defined.**
APPENDIX XI: Detection Limits of Air-Quality Instruments....**Error! Bookmark not defined.**

LIST OF FIGURES

Figure 1.1: Map of Nigeria showing the 36 States and FCT (highlighting FCT). 7
Figure 1.2: Administrative Map of the Federal Capital Territory showing the six Area Councils including Abuja Municipal Area Council (AMAC). 7
Figure 1.3: Aerial View of NOUN (Main Campus) showing the locations of the proposed sites. 8
Figure 1.4: Federal Ministry of Environment EIA Flowchart 11
Figure 3.1: Simplified electrical configuration diagram 50
Figure 3.2: Example of a Monofacial Si-poly photovoltaic module 51
Figure 3.3: Example of string photovoltaic inverter 52
Figure 3.4: String Inverter Single Line Diagram 54
Figure 3.5: Example of Transformer 55
Figure 3.6: Example of a power station 56
Figure 3.7: Power station Single line Diagram 56
Figure 3.8: Typical Road Cross Section 57
Figure 3.9: NOUN 11kv Distribution Network Layout 59
Figure 3.10: Typical EPC Construction Phase and Handover Protocol 73
Figure 4.1 - Average Relative Humidity of the FCT (2004 - 2025) 83
Figure 4.2a - Average Minimum Temperature of the FCT (2004 - 2025) 84
Figure 4.2b - Average Maximum Temperature of the FCT (2004 - 2025) 84
Figure 4.3 - Average Monthly Rainfall of the FCT (2004 - 2025) 85
Figure 4.4 - Average Monthly Sunshine Hour of the FCT (2004 - 2025) 86
Figure 4.5: A graphical illustration of the Sunshine hours, Cloud Cover and Solar Irradiance in the FCT. 86
Figure 4.6 - Average Monthly Wind Speed in the FCT (2004 - 2025) 87
Figure 4.7: Illustration of the Frequency of Direction in the FCT (2004 – 2025) 88
Figure 4.8: Sampling Map Indicating Groundwater and Surface Water Sampling Locations. 89
Figure 4.9: Sampling Map Indicating Air Quality and Noise Level Measurement Locations. 89
Figure 4.10: Sampling Map Indicating Soil Sampling Locations. 90
Figure 4.11: Graphical Illustration of Relative humidity and Temperature Measured in the Study Area 93
Figure 4.12: Ambient noise level within the study area 98
Figure 4.13: Geological Map of the FCT 101
Figure 4.14: Aerial map highlighting the project sites, NOUN and Jabi Community. 171
Figure 4.15: A Snapshot of the University's Growth 173
Figure 4.16: Organizational Structure of NOUN 174
Figure 5.1: Impact Methodology Overview 200
Figure 5.2: Impact Evaluation Matrix 205

LIST OF TABLES

Table 1.1 Boundary Coordinates of Site 1 — Reclaimed Land Area 5
Table 1.2 Boundary Coordinates of Site 2 — Central Car Park..... 6
Table 1.3 - Some of the guiding principles applicable to the project and how they apply across the construction, operation, and decommissioning phases. 24
Table 2.1: Potential SPV System Configurations and Design Assumptions based on 4.8 daily hours of peak power output. 40
Table 2.2 - Factors for site consideration and selection 40
Table 2.3 Environmental Trade-Off Analysis 41
Table 2.4: Environmental Trade-Off Analysis 43
Table 2.5: Comparative Analysis between Solar Panel Technology for the project 44
Table 2.6: Comparison between battery alternatives for the project 45
Table 3.1: Main characteristics of the fixed mounting structure 49
Table 3.2 Summary of the project's characteristics 49
Table 3.3: Photovoltaic module characteristics 51
Table 3.4: Inverter characteristics 53
Table 3.5: Transformer characteristics 55
Table 3.6: Power station characteristics 56
Table 3.7: List of Construction Equipment and Material for the Project 61
Table 3.8: Breakdown of the Estimated Workforce for the Construction and Operation Phases. 66
Table 3.9: Waste Streams of Project Phases..... 69
Table 3.10: Pre-Construction Phase Waste Inventory and Handling Strategies 69
Table 3.11: Construction Phase Waste Inventory and Handling Strategies 70
Table 3.12: Operation Phase Waste Inventory and Handling Strategies..... 72
Table 3.13 implementation schedule 72
Table 4.1: Values for Relative Humidity and Temperature Measured in the Study Area 92
Table 4.2 Detection Limits of Air Quality Instruments..... 93
Table 4.3: Ambient Air Quality Level around the Project Area 95
Table 4.4: Air Quality Rating Table 99
Table 4.5: Air quality index of the project area..... 99
Table 4.6a: Summary of Soil Samples Collected 102
Table 4.6b: Soil Sampling Locations, Coordinates and Sample Details 103
Table 4.7: Laboratory Results for Soil Samples Analysis..... 104
Table 4.8: Physico-Chemical and Biological Characteristics of Soil Samples (Secondary data) ... 122
Table 4.9: Groundwater Sampling Locations..... 125
Table 4.10: In-Situ Results of Ground Water measurements 125
Table 4.11: Laboratory Results of Ground Water 126
Table 4.12: Physico-Chemical and Biological Characteristics of the Groundwater (Secondary data)138
Table 4.13: Surface Water Sampling Locations 141
Table 4.14: Surface Water In-Situ Testing 142
Table 4.15: Surface Water Laboratory Results 142
Table 4.16: Surface Water Result for Physico-Chemical & Microbial Characteristics (Secondary data) 161
Table 4.17: Name, Description and Economic Importance of Dominant Flora Species Recorded within the Study Area 164
Table 4.18: Dominant Fauna and Evidence of Faunal Activities within the Study Area..... 168
Table 4.19: Some of the Observations..... 175

Table 4.20: Respondent's Socio-Economics Characteristics 179
Table 4.21: Stakeholders for the Project: 195
Table 4.22: Highlights of the KII 197
Table 5.1: Valued Environmental and Social Components (VECs) 202
Table 5.2: Impact Descriptions 203
Table 5.3: Impact Significance Criteria 204
Table 5.4: Sensitivity of Receptor and Extent 204
Table 5.5: Impact Likelihood Criteria 204
Table 5.6: Summary of Key Impacts and Receptors for Pre-Construction Phase 207
Table 5.7: Summary of Key Impacts and Receptors for Construction Phase 208
Table 5.8: Summary of Key Impacts and Receptors for Operation Phase 217
Table 5.9: Summary of Key Impacts and Receptors for Decommissioning Phase 224
Table 5.10: Waste Colour Coding System 234
Table 5.11: Risk Assessment 237
Table 6.1: Summary of Mitigation Approach. 241
Table 6.2: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Pre-construction Phase) 244
Table 6.3: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Construction Phase) 247
Table 6.4: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Operation Phase) 252
Table 6.5: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Decommissioning Phase) 256
Table 7.1: Roles, Responsibilities and Accountabilities for ESMP Implementation 265
Table 7.2: Environmental Management Measures for the Pre-construction Phase of the Proposed Project 267
Table 7.3: Environmental Management Measures for the Construction Phase of the Proposed Project 270
Table 7.4: Environmental Management Measures for the Operation Phase of the Proposed Project 276
Table 7.5: Environmental and Social Monitoring Programme 282
Table 7.6 Environmental and Social Compliance Reporting 285
Table 7.7: Summary of Additional Management Plans 293
Table 7.8: Institutional Capacity Strengthening Plan 294
Table 7.9: Cost of ESMP Implementation 295
Table 7.10: Identified Stakeholders Associated with the Proposed Project 297
Table 7.11: Stakeholder Engagement Process 301
Table 7.12: Stakeholder Engagement Tools and Communication 303
Table 7.13: Stakeholder Group Consultation Methods 303
Table 7.14: Initial Stakeholder Consultation Findings at NOUN 306
Table 7.15: Grievance Resolution Procedure 310
Table 8.1: Environmental Management Measures for the Decommissioning Phase of the Proposed Project 318

LIST OF PLATES

Plate 1.1: Main Entrance of the National Open University of Nigeria (NOUN), Main Campus, Jabi, Abuja. .4
Plate 1.2: NOUN Back Gate Adjacent to Proposed Project Site 1. 5
Plate 4.1: Reconnaissance Visit Meeting (NOUN Representative Team and Bolben Ltd Team) 78
Plate 4.2: Site Verification Visit Meeting (NOUN Representative Team and Bolben Ltd Team at the office of the DPP).....78
Plate 4.3: Site Verification Visit Meeting (NOUN Vice-Chancellor, DPP and Bolben Ltd Team) 79
Plate 4.4: Photograph of Sampling Equipment.....80
Plate 4.5a: View of the proposed project site (Site 1).....81
Plate 4.5b: View of the proposed project site (Site 2). 82
Plate 4.6: Air Quality Measurement 90
Plate 4.7: Noise Level Measurement 91
Plate 4.8: Soil Sampling Activities 91
Plate 4.9: Collection and In-situ Measurements of Groundwater. 91
Plate 4.10: Collection of Surface water 92
Plate 4.11a: Madagascar Umbrella Tree (Terminalia mantaly) 166
Plate 4.11b: Oriental Arborvitae (Platycladus orientalis) 166
Plate 4.11c: Tropical Almond (Terminalia catappa).....166
Plate 4.11d: Mango (Mangifera indica) 166
Plate 4.11e: Orange Jasmine / Mock Orange (Murraya paniculata) 167
Plate 4.11f: Mango (Mangifera indica).....167
Plate 4.11g: Coat Buttons (Tridax procumbens).....167
Plate 4.11h: Banana/Plantain (Musa spp.) 167
Plate 4.11i: Lead Tree (Leucaena leucocephala). 167
Plate 4.11j: Signal grass (Brachiaria decumbens).....167
Plate 4.12: Cows grazing on the field. 169
Plate 4.13: Termite Mound. 169
Plate 4.13: Admin Block 1 & Admin Block 2 176
Plate 4.14: Mosque 176
Plate 4.15: Christian Fellowship Centre 176
Plate 4.16: Central Library.....176
Plate 4.17: Sports Complex.....176
Plate 4.18: ACETEL Building 177
Plate 4.19: Block of Shops.....177
Plate 4.20: Transformer (Close to Main Gate).....177
Plate 4.21: View of Substation/PowerStation 177
Plate 4.22: View of the University Clinic 177
Plate 4.23: Inside the University Clinic 177
Plate 4.24: Convocation Arena 178
Plate 4.25: Open Dumping of Wastes within the Study Area.....178
Plate 4.26: A Supermarket in the host Community 178
Plate 4.27: Trading activity within the host Community 178
Plate 4.28a: Traffic situation along Abdulrasheed Na'allah way 193
Plate 4.28b: Traffic situation along the NOUN-EFCC road.....193
Plate 4.58c: Traffic situation at EFCC-NOUN Checkpoint Junction 193
Plate 4.28d: Traffic situation at EFCC-NOUN Checkpoint Junction 193
Plate 4.28e: Traffic at FMC Junction/Police Checkpoint along Kado - Galadima Expressway.....193

LIST OF ACRONYMS, UNITS AND ABBREVIATIONS

Abbreviation/ Acronym	Meaning
AC	Alternating Current
AEPB	Abuja Environmental Protection Board
AfDB	African Development Bank
ALARP	As Low As Reasonably Practicable
AMAC	Abuja Municipal Area Council
APHA	American Public Health Association
APPI	Area of Potential Project Influence
ASTM	American Society for Testing and Materials
AQ	Air Quality
BESS	Battery Energy Storage System
BOD	Biochemical Oxygen Demand
CBO	Community-Based Organization
CFU	Colony Forming Unit
CLO	Community Liaison Officer
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CR	Critically Endangered
dB(A)	A-weighted Decibel
DC	Direct Current
DO	Dissolved Oxygen
EEP	Energizing Education Programme
EHS	Environment, Health and Safety
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EMS	Environmental Management System
EPC	Engineering, Procurement and Construction
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
FCT	Federal Capital Territory
FEMD	FCT Emergency Management Department
FMEnv	Federal Ministry of Environment
GBV	Gender-Based Violence
GIS	Geographic Information System
GPS	Global Positioning System
GRM	Grievance Redress Mechanism
GRC	Grievance Redress Committee
GW	Groundwater
HSE	Health, Safety and Environment
H_2S	Hydrogen Sulphide
IFC	International Finance Corporation
ISO	International Organization for Standardization
ISS	Integrated Safeguards System
ITCZ	Inter-Tropical Convergence Zone

Abbreviation/ Acronym	Meaning
IUCN	International Union for Conservation of Nature
KII	Key Informant Interview
km	Kilometre
kV	Kilovolt
kVA	Kilovolt-Ampere
kWh	Kilowatt-hour
LTI	Lost Time Injury
m	Metre
m^2	Square Metre
m^3	Cubic Metre
mg/L	Milligram per Litre
mm	Millimetre
MW	Megawatt
MWh	Megawatt-hour
N	Nitrogen
NAAQS	Nigerian Ambient Air Quality Standards
NDC	Nationally Determined Contribution
NEP	Nigeria Electrification Programme
NESREA	National Environmental Standards and Regulations Enforcement Agency
NGO	Non-Governmental Organization
NH_3	Ammonia
NO_2	Nitrogen Dioxide
NOUN	National Open University of Nigeria
NTU	Nephelometric Turbidity Unit
OHS	Occupational Health and Safety
PPE	Personal Protective Equipment
PV	Photovoltaic
QA/QC	Quality Assurance/Quality Control
REA	Rural Electrification Agency
REMP	Renewable Energy Master Plan
SEA	Sexual Exploitation and Abuse
SEP	Stakeholder Engagement Plan
SH	Sexual Harassment
SO_2	Sulphur Dioxide
SW	Surface Water
TDS	Total Dissolved Solids
THB	Total Heterotrophic Bacteria
TOR	Terms of Reference
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
UPS	Uninterruptible Power Supply
WHO	World Health Organization
WMP	Waste Management Plan

EXECUTIVE SUMMARY

ES 1 INTRODUCTION

The Rural Electrification Agency (REA), under the Nigeria Electrification Programme (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 National Open University of Nigeria (NOUN), Main Campus, Jabi, Abuja Municipal Area Council (AMAC), Federal Capital Territory (FCT).

This is in response to the continued challenge faced by Nigeria in achieving reliable and sustainable electricity supply to meet growing national demand. This challenge is due to several reasons including infrastructure deficits, transmission bottlenecks, and distribution inefficiencies causing institutions and commercial entities to rely heavily on self-generation through diesel and petrol generators, resulting in high operational costs, greenhouse gas emissions, noise pollution, and localized air quality deterioration.

The Federal Government of Nigeria (FGN) has adopted policies and programmes aimed at promoting renewable energy development and decentralized electrification. A key intervention in this regard is the Nigeria Electrification Programme (NEP), a significant initiative designed to bridge the energy access deficit across the country. The NEP is a private sector-driven programme that seeks to provide reliable electricity services to households, Micro, Small and Medium Enterprises (MSMEs), educational institutions, and healthcare facilities located in underserved and unserved communities. The programme supports increased access to electricity through the deployment of mini-grids, standalone Solar Home Systems (SHS), rooftop solar systems, captive power plants, and productive-use appliances.

The Nigeria Electrification Programme forms part of the African Development Bank (AfDB) broader engagement in Nigeria's power sector and has laid the foundation for subsequent large-scale renewable energy interventions. Notably, the programme serves as a precursor to the Desert to Power Initiative, a transformative regional renewable energy programme aimed at harnessing the abundant solar resources of Northern Nigeria and the wider Sahel region to expand electricity access, stimulate economic growth, and strengthen climate resilience. Building on the achievements of the NEP, the Rural Electrification Agency (REA), under the Desert to Power Initiative (Phase II), proposes the installation of a 1-Megawatt (MW) Solar-Hybrid Photovoltaic (PV) Power Plant and associated infrastructure within the premises of the National Open University of Nigeria (NOUN) Main Campus, Jabi, Abuja.

The Desert to Power Initiative is a strategic renewable energy programme aimed at harnessing the high solar irradiation potential of Northern Nigeria to improve electricity access while contributing to national energy transition and climate commitments. The FCT experiences high solar insolation averaging between 5.5 and 6.5 kWh/m²/day, making it technically suitable for utility-scale and institutional solar photovoltaic deployment.

The Energizing Education Programme (EEP) is a strategic Federal Government of Nigeria initiative aimed at developing dedicated off-grid and solar-hybrid independent power plants, as well as rehabilitating and strengthening existing distribution infrastructure, in order to provide clean, reliable, and sustainable electricity to Federal Universities and affiliated University Teaching Hospitals across the country.

Under this programme, beneficiary institutions will receive:

- Utility-scale solar-hybrid mini-grid systems with a minimum of 1 Megawatt (MW) capacity;
- Rehabilitation and upgrading of internal distribution networks;
- Solar-powered street lighting systems for improved illumination and campus security;
- Establishment of world-class Renewable Energy Workshop and Training Centres to enhance local capacity development in solar power engineering, operations, and maintenance.

The proposed 1 Megawatt (MW) Solar-Hybrid Power Plant and Associated Infrastructure project will be sited within the premises of the National Open University of Nigeria (NOUN) Main Campus, Jabi, Abuja. The project originally conceived to be a 2-Megawatt (MW) Solar Photovoltaic (PV) Power Project but due to the unavailability of a contiguous land area, will be developed on two parcels of land in the school. Together, the two sites have a reported area of approximately 6,494.89 m², equivalent to about 0.65 ha. One site (Site 1) is located between the Faculty of Management Sciences and the Faculty of Social Sciences, adjacent to the University's substation. The site, a reclaimed and sand-filled area, occupies approximately 2,093.25 m² (0.21 ha). The second site (Site 2) is situated within the University's Car Park which is proximate to the school gate. This site is situated in front of the Senate Building and Convocation Arena, and is opposite the Central Library, Directorate of Physical Planning and Development (DPP) Building. The site covers approximately 4,401.64 m² (0.44 ha). The sites are approximately 218 m apart, with Site 1 located north of Site 2. Site 1 is bounded by the following geographical coordinates: Point A: 9°01'21.64"N 7°24'36.72"E; Point B: 9°01'21.95"N 7°24'36.88"E; Point C: 9°01'23.18"N 7°24'36.90"E; Point D: 9°01'23.18"N 7°24'36.90"E; and Point E: 9°01'23.86"N 7°24'35.40"E. Site 2 is bounded by Point A: 9°01'13.04"N 7°24'30.14"E; Point B: 9°01'12.54"N 7°24'31.40"E; Point C: 9°01'15.41"N 7°24'32.90"E; and Point D: 9°01'16.10"N 7°24'31.91"E.

The 1 MW solar-hybrid power system will consist of Ground-mounted solar photovoltaic (PV) arrays; Lithium-ion Battery Energy Storage System (BESS); Inverters, transformers, and switchgear; Substation and internal transmission/distribution network; Control room and operations building. The Project is designed to:

- Provide uninterrupted power supply to support teaching, research, and innovation;
- Reduce reliance on diesel generators and unstable grid supply;
- Enhance institutional productivity and academic excellence;
- Improve campus safety and security;
- Contribute to Nigeria's renewable energy transition and climate change mitigation commitments.

Bolben Energy and Environmental Services Limited (an established and experienced Environmental Management accredited firm) ensured that the ESIA was conducted in accordance with national environmental legislation, African Development Bank Integrated Safeguards System (ISS, 2023), and international best practices to ensure that all environmental and social risks are properly identified, assessed, and mitigated throughout the Project lifecycle.

Legal and Administrative Framework

To establish the proposed 1 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.
- ✓ **Abuja Environmental Protection Board (AEPB) Regulations** – Establish environmental management and pollution control requirements applicable within the Federal Capital Territory (FCT).
- ✓ **Abuja Municipal Area Council (AMAC) Regulations** – 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 1 MW Solar-Hybrid Power Plant at the National Open University of Nigeria (NOUN) Main Campus, Jabi, Abuja, is primarily based on the urgent need to provide stable, reliable, and sustainable electricity supply to Nigeria's Federal Universities 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 universities face persistent electricity challenges characterized by:

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

The proposed 1-MW Solar Hybrid Power Project is designed to provide a reliable, clean and sustainable source of electricity for the National Open University of Nigeria (NOUN), thereby supporting its statutory mandate of delivering quality open and distance learning. The project will assist the University strengthen its academic, research, administrative and community engagement functions by providing uninterrupted electricity for lecture theatres, administrative offices, libraries, digital learning centres, computer laboratories, research facilities, examination centres, server rooms, telecommunication systems, internet infrastructure, water supply systems, security installations and other critical campus facilities.

The Energizing Education Programme (EEP), under the Nigeria Electrification Project (NEP), is part of the Federal Government's broader strategy to reform and stabilize energy supply within public tertiary institutions. It is also aligned with Nigeria's climate change mitigation commitments. The Project contributes directly to Nigeria's Nationally Determined Contributions (NDCs) under the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), which commits Nigeria to achieving at least a 20% reduction in greenhouse gas emissions by 2030 (unconditional target), with potential for 47% conditional reduction. By replacing diesel-based electricity generation and reducing grid instability, the proposed project will significantly lower carbon emissions while enhancing institutional performance.

Benefits of the Project

The benefits of the proposed Project include, but are not limited to, the following:

- **Stimulation of Academic and Research Activities**: Provision of constant and reliable electricity will significantly improve laboratory experiments, engineering simulations, fabrication processes, ICT systems, and research productivity within the University thereby enhancing academic output and global competitiveness.
- **Improvement in Health and Safety Infrastructure**: Reliable power will support campus health facilities, water supply systems, emergency services, and improve safety systems across the University.
- **Reduction in Fossil Fuel Consumption:** The solar-hybrid system will drastically reduce reliance on diesel generators, thereby lowering fuel consumption, reducing greenhouse gas emissions, minimizing noise pollution, and decreasing air pollutant concentrations.
- **Reduction in Operational Costs:** The University will experience significant cost savings from reduced diesel procurement and generator maintenance. These savings can be redirected toward research development, infrastructure improvement, staff welfare, and student services.

- **Renewable Energy Capacity Development:** The establishment of a Renewable Energy Workshop and Training Centre under the Programme will provide hands-on technical training in solar power systems, battery storage, and smart grid technologies, enhancing employability and skill development among students.
- **Improvement in Livelihood Activities:** Reliable electricity supply supports small-scale businesses within the campus such as printing services, ICT hubs, food services, and other entrepreneurial ventures.
- **Direct and Indirect Employment Opportunities:** The Project will create employment during construction (skilled and unskilled labor), and during operations and maintenance phases, including technical, administrative, and security roles.
- **Support to a critical Policy:** Support Nigeria's Energy Transition Plan (ETP) 2022 to achieve net-zero carbon emissions by 2060. As a renewable energy project, it will reduce over-reliance on diesel generators thereby cutting down on carbon emissions.

The sustainability of the project has been assessed under the four recognized sustainability pillars:

- Technical Sustainability: The project is expected to operate safely, efficiently, and reliably over its intended lifespan (at least 25 years) using solar photovoltaic technology integrated with battery energy storage.
- Economic Sustainability: The project will reduce expenditure on diesel fuel, generator maintenance and electricity procurement over its operational life of approximately 25 years, thereby improving long-term financial sustainability for the University. Reduced operating costs will enable more efficient allocation of institutional resources towards teaching, research and infrastructure development.
- Environmental Sustainability: Electricity generated from solar energy will reduce greenhouse gas emissions, minimize dependence on fossil fuels and improve ambient air quality within the University environment. The project has a relatively small physical footprint, requires minimal water during operation and incorporates measures for responsible management of batteries, electronic waste and end-of-life solar modules through recycling and environmentally sound disposal practices.
- Social Sustainability: The project will improve the quality and reliability of electricity services for the University community while enhancing occupational health and safety, stakeholder participation, gender inclusion and grievance management. The project has been designed to avoid involuntary resettlement and minimize disturbance to existing university operations through appropriate site selection and implementation planning.

ES 3 PROJECT DESCRIPTION

Project Components and Activities

The proposed development involves the engineering design, procurement, construction, installation, commissioning, operation and maintenance of a 1-MW Solar Hybrid Power Plant with an integrated Battery Energy Storage System (BESS) within the Main Campus of the National Open University of Nigeria (NOUN), located along the Nnamdi Azikiwe Expressway, Jabi, Abuja, Federal Capital Territory (FCT). The facility will be interconnected with the University's existing electrical distribution network to provide a reliable and sustainable source of electricity for academic, administrative and ancillary facilities across the campus.

The major components include:

- A ground-mounted solar PV farm installed on fixed-tilt mounting structures;
- Lithium-ion Battery Energy Storage System (BESS) to ensure power stability and nighttime supply;
- A substation with transformers and switchgear for voltage regulation and power evacuation;
- Internal transmission lines and solar-powered street lighting within the campus;
- Buildings including a control room, site office, and Renewable Energy Workshop/Training Centre.

The project shall have four distinct phases

***Pre-construction Phase*:** This phase includes detailed engineering design, statutory approvals, procurement, site surveys, stakeholder engagement, mobilization of contractors, establishment of temporary site facilities and implementation of environmental and social management measures prior to commencement of physical works.

***Construction Phase*:** Activities include site preparation, limited vegetation clearance, excavation, foundation construction, installation of mounting structures, erection of photovoltaic modules, installation of battery energy storage systems, inverter stations, transformers, electrical cabling, equipment testing and commissioning. Construction will also involve transportation of equipment, temporary workforce mobilization and implementation of environmental, health and safety management measures. Physical construction is expected to be completed within approximately 6–9 months, followed by testing, commissioning and commencement of commercial operation.

***Operation Phase*:** Following commissioning, the facility will generate renewable electricity for the University through routine operation of the solar PV system and associated battery storage. Maintenance activities will include periodic inspection, panel cleaning, vegetation control, preventive maintenance of electrical equipment, battery monitoring, replacement of defective components and continuous environmental monitoring.

Decommissioning Phase: At the end of the project life, the facility may be upgraded, re-powered or decommissioned. Decommissioning activities will include safe dismantling of PV modules, battery systems, electrical equipment and ancillary infrastructure, segregation of reusable and recyclable materials, environmentally sound disposal of residual wastes, restoration of disturbed areas and post-decommissioning environmental verification. The project is expected to have a lifespan of at least 25 years.

Waste generation is expected throughout the project lifecycle but will be effectively managed through the Environmental and Social Management Plan. During the pre-construction and construction phases, anticipated wastes include vegetation residues, excavated soil, concrete debris, scrap metals, timber off-cuts, packaging materials, plastics, paper, food waste, sanitary waste, used lubricants, spent filters, oily rags and domestic wastewater. During operation, wastes will mainly comprise packaging materials from maintenance activities, damaged

electrical components, used oils, defective PV modules, spent batteries, electronic waste and domestic refuse from maintenance personnel. Decommissioning will generate larger quantities of construction and demolition waste, including PV modules, batteries, electrical cables, transformers, mounting structures, concrete debris, scrap metals and electronic equipment, all of which shall be managed through approved recycling, recovery and environmentally sound disposal procedures.

ES 4 DESCRIPTION OF THE PROJECT 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 Friday, 3 July 2026, while the scoping workshop, site verification and detailed field investigations were carried out on Monday, 6 July 2026. Laboratory analyses of environmental samples were subsequently undertaken at Bio-Metrics Geo Consult Laboratory, Abuja, 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 extracted from the approved 2022 ESMP for the Construction of the Africa Centre of Excellence on Technology Enhanced Learning (ACETEL) at NOUN Main Campus, together with long-term climatic information obtained from the Nigerian Meteorological Agency (NiMet). 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 1-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:

- Air Quality: measurements at 11 sampling locations and 4 control stations (15 monitoring locations in total);
- Ambient Noise: measurements at the same 11 sampling locations and 4 control stations;
- Groundwater: 4 borehole sampling locations;
- Surface Water: 2 sampling locations;
- Soil: 4 sampling locations and 1 control location; and
- Flora, fauna and land-use surveys: undertaken across both proposed project sites and the surrounding Area of Influence.

Climate and Meteorology

The project area experiences a tropical wet-and-dry (Guinea Savannah) climate, characterised by two distinct seasons: a rainy season extending approximately from April to October and a dry season from November to March. Long-term meteorological records indicate mean annual temperatures generally between 26°C and 28°C, annual rainfall of approximately 1,200–1,600 mm, mean relative humidity exceeding 70% during the wet season and declining to below 40% during the dry season, and average wind speeds of approximately 4.7 m/s. These climatic conditions provide favourable solar irradiance for photovoltaic electricity generation throughout the year, although cloud cover during the rainy season may temporarily reduce energy production. Integration of the Battery Energy Storage System (BESS) will improve system reliability during periods of reduced solar radiation.

Micro-climatic measurements undertaken during field investigations indicate that weather conditions on the survey days were generally cloudy to partly cloudy, reflecting the prevailing wet-season conditions. Field measurements were conducted between 10:00 a.m. and 5:00 p.m., during which ambient temperatures, relative humidity and wind conditions were typical of the season. Light to moderate south-westerly winds promoted effective atmospheric dispersion of pollutants, while the existing open campus landscape and absence of major industrial emission sources contributed to good ambient air quality. The measured micro-climatic conditions confirm that the project site possesses favourable environmental conditions for the installation and long-term operation of a solar hybrid power system.

Air quality measurements demonstrated that the project area presently enjoys a relatively clean atmosphere. Concentrations of $PM_{2.5}$, PM_{10} and gaseous pollutants were below applicable FMEnv and WHO guideline values, while Air Quality Index (AQI) values ranged from 24 to 56, indicating predominantly ‘Good’ air quality with only one control location classified as Moderate, attributable to traffic along the Nnamdi Azikiwe Expressway. Ambient noise levels ranged between 46.7 dB(A) and 84.1 dB(A) and were generally consistent with an educational environment influenced by moderate vehicular activity.

Geology

The project area is underlain by the Precambrian Basement Complex which is characteristic of the Federal Capital Territory, comprising granitic and migmatitic rocks that weather into competent residual soils suitable for light engineering structures such as photovoltaic mounting systems. Hydrogeologically, groundwater occurs within the weathered and fractured basement aquifer system.

Groundwater quality was evaluated using both in-situ measurements and laboratory analyses of four (4) borehole water samples. The results indicate that the groundwater is generally fresh, weakly mineralized, clear and chemically stable, with pH (6.84–7.29), turbidity (0–4 NTU), total dissolved solids (25.9–253.8 mg/L) and electrical conductivity (37–362 µS/cm) complying with the National Environmental (Surface and Ground Water Quality Control) Regulations, 2011. Major-ion concentrations were generally low and reflected natural groundwater–rock interaction within the Basement Complex terrain. However, groundwater was classified as very hard, with elevated

calcium and total hardness in all sampling locations. Laboratory analyses also identified elevated concentrations of iron, lead and cadmium, together with elevated total bacterial counts and localized occurrence of total coliforms and fungi, indicating that although the groundwater is suitable for construction activities, irrigation and periodic cleaning of solar photovoltaic panels, treatment is required before potable or domestic consumption. These results establish an important environmental baseline for future groundwater monitoring during project implementation.

Surface water quality was assessed through in-situ measurements and laboratory analyses at two (2) sampling locations representing the nearest surface water receptors to the proposed project. The results indicate that the sampled water bodies are freshwater systems with neutral pH, low salinity and relatively low mineralization. Dissolved oxygen concentrations were generally favourable, indicating good oxygenation of the aquatic environment. Most physicochemical parameters complied with applicable regulatory standards. However, elevated biochemical oxygen demand (BOD) and localized nutrient enrichment suggest moderate organic loading associated with urban runoff rather than project-related contamination. Overall, the surface water exhibits good baseline environmental quality, and no significant pollution attributable to industrial or hazardous activities was identified within the project area at the time of the survey.

Five (5) soil samples, comprising four (4) project locations and one (1) control location, were analyzed to establish baseline soil conditions. The results indicate that the soils are generally well-drained, slightly acidic to neutral, moderately fertile and structurally suitable for supporting the proposed solar photovoltaic infrastructure. Concentrations of major nutrients and most heavy metals were generally low and reflected natural geochemical conditions. No evidence of significant hydrocarbon contamination or widespread anthropogenic pollution was observed. Microbiological activity was typical of healthy tropical soils, indicating active nutrient cycling and favourable soil biological productivity. Overall, the soils are considered suitable for the proposed development, provided that appropriate erosion control and soil management measures are implemented during construction.

Flora & Fauna

Adopting a Rapid Ecological Assessment (REA) method, ecological investigations confirmed that the proposed development sites comprise previously disturbed institutional land characterized by maintained lawns, ornamental vegetation, grasses and scattered secondary plant species. Wildlife is limited to common urban-adapted fauna such as birds, reptiles and small mammals. No protected areas, critical habitats or threatened flora and fauna species were identified within the project footprint, indicating low ecological sensitivity. The project site have been subjected to prolonged anthropogenic activities, resulting in significant habitat disturbance.

Representative flora recorded during the survey include Wild Lemon Grass (*Cymbopogon* spp), Crabgrass/Paspalum Grass (*Digitaria* spp), Guava tree (*Psidium guajava)* Lawn grasses (Cynodon spp. and Axonopus spp.), and other ornamental shrubs maintained for landscaping purposes. Faunal observations were limited because of the highly developed nature of the University campus. The principal fauna recorded comprised Zebu cattle (Bos indicus) grazing outside the university

perimeter and termites (Macrotermes spp.) occurring in termite mounds along the perimeter wall. No threatened, endangered or protected species, wildlife breeding grounds or ecologically sensitive habitats were identified within the project footprint. Consequently, the ecological value of the proposed development area is considered low, and significant impacts on flora and fauna are not anticipated, provided construction activities remain within the approved project boundaries.

Stakeholder Engagement

The socio-economic assessment was deliberately limited to the University environment because the project is entirely located within the NOUN Main Campus. Primary data were obtained through stakeholder consultations and administration of questionnaires to university staff. Although 50 questionnaires were distributed, 37 were retrieved, and 35 valid questionnaires were analysed. Academic and non-academic staff constituted the respondent population because students were not on campus during the survey period. The survey adopted a stratified purposive sampling approach, ensuring representation of the principal staff categories with direct knowledge of campus infrastructure and operations. Findings indicate strong stakeholder support for the project, with respondents identifying improved electricity reliability, reduced dependence on diesel generators, enhanced teaching and research, improved ICT services, lower operating costs and environmental sustainability as the principal anticipated benefits. Concerns raised during consultations primarily related to temporary construction disturbances, traffic management, occupational and community safety, waste management, and the need for effective stakeholder engagement, all of which have been addressed through the Environmental and Social Management Plan (ESMP).

ES 5 ASSOCIATED AND POTENTIAL IMPACTS OF THE PROJECT

The assessment of potential environmental and social impacts associated with the proposed 1 MW Solar-Hybrid Power Plant project was carried out using a systematic and structured methodology. An interaction matrix was developed to identify the relationship between project activities (pre-construction, construction, commissioning, and operation phases) and key environmental and social receptors, including soil, vegetation, air quality, groundwater, biodiversity, socio-economic conditions, and occupational health and safety.

Following impact identification, a Risk Assessment Matrix was applied to screen and rank potential impacts based on:

- Nature of impact (positive or negative);
- Magnitude;
- Duration (short-term or long-term);
- Spatial extent (site-specific or wider area);
- Reversibility;
- Likelihood of occurrence.

The impact assessment identified that the majority of potential adverse impacts are temporary, localized and reversible. Some of the anticipated High and Moderate impacts are listed below:

High Risk Impacts

- Occupational accidents and injuries during construction and equipment installation.

- Electrical hazards associated with installation, commissioning and operation of the PV system and Battery Energy Storage System (BESS).
- Community health and safety risks arising from construction activities, movement of heavy vehicles and restricted work areas.
- Fire and explosion hazards associated with battery storage systems and electrical equipment.
- Improper handling, storage and disposal of spent lithium-ion batteries and damaged photovoltaic modules during operation and decommissioning.
- Occupational risks associated with dismantling, lifting operations and electrical isolation during decommissioning.

Moderate Risk Impacts

- Temporary alteration of land use and localized soil disturbance during site preparation.
- Soil erosion and sediment transport resulting from excavation and earthworks.
- Localized contamination of soil and groundwater from accidental fuel, oil or lubricant spills.
- Increased suspended sediments entering nearby drains during construction.
- Temporary deterioration of ambient air quality due to dust generation and equipment exhaust emissions.
- Temporary increases in ambient noise and vibration from construction equipment and vehicular movement.
- Construction traffic leading to temporary congestion and increased accident potential within the University.
- Generation of construction waste, domestic waste, hazardous waste and electronic waste.
- Temporary disruption of normal academic and administrative activities.
- Gender-related risks including Gender-Based Violence (GBV), Sexual Exploitation and Abuse (SEA), Sexual Harassment (SH) and other forms of inappropriate worker conduct.
- Occupational health risks arising from exposure to dust, noise, manual handling and heat stress.
- Visual impacts associated with temporary construction activities.
- Waste generation during decommissioning, including photovoltaic modules, batteries, electrical equipment and demolition debris.

ES 6 MITIGATION MEASURES

Appropriate mitigation measures have been proffered for every significant impact identified in the assessment and incorporated into the Environmental and Social Management Plan (ESMP). Mitigation measures for the High-Risk impacts listed in ES 5 include:

- Implementation of a comprehensive Occupational Health and Safety Management Plan incorporating Job Hazard Analysis (JHA), Permit-to-Work systems, Lock-Out/Tag-Out procedures, emergency preparedness and routine HSE inspections.
- Mandatory induction training, daily toolbox meetings, provision and enforcement of appropriate Personal Protective Equipment (PPE), and employment of competent personnel for specialized electrical works.

- Development and implementation of a Community Health and Safety Plan, including traffic management measures, warning signage, restricted access zones, emergency response procedures and stakeholder notification.
- Installation of fire detection and suppression systems for battery storage facilities, together with battery monitoring systems, emergency isolation devices and routine preventive maintenance.
- Preparation and implementation of a Battery Management Plan and Electronic Waste Management Plan to ensure environmentally sound storage, transportation, recycling and disposal of end-of-life batteries, PV modules and electrical equipment through licensed facilities.
- Strict implementation of the Stakeholder Engagement Plan (SEP), Workers' Code of Conduct, Gender Action Plan and confidential Grievance Redress Mechanism (GRM) to prevent and address GBV, SEA and SH.

Mitigation measures for the Moderate Risk impacts listed in ES 5 include:

- Restriction of site clearing and excavation to approved work areas, with prompt restoration of disturbed surfaces following construction.
- Installation of temporary erosion and sediment control measures, including drainage protection and stabilization of exposed soils.
- Designation of approved fuel storage and equipment maintenance areas with spill containment facilities and readily available spill response kits.
- Regular dust suppression through water spraying, speed control for construction vehicles, covering of haulage trucks and prompt rehabilitation of exposed surfaces.
- Restriction of noisy construction activities to normal daytime working hours, regular maintenance of construction equipment and provision of hearing protection where required.
- Preparation and implementation of a Construction Traffic Management Plan to regulate vehicle movement and maintain safe access throughout the campus.
- Segregation, reuse, recycling and environmentally sound disposal of construction, domestic, hazardous and electronic wastes in accordance with applicable FMEnv and NESREA requirements.
- Continuous stakeholder consultation, timely disclosure of project information and prompt resolution of grievances through the established Grievance Redress Mechanism.
- Routine environmental monitoring of air quality, noise, soil, surface water, groundwater and occupational health and safety indicators throughout project implementation.
- Preparation and implementation of a comprehensive Decommissioning Environmental and Social Management Plan to ensure safe dismantling, material recovery, recycling and restoration of the project site at the end of its operational life.

ES 7 ENIRONMENTAL AND SOCIAL MANAGEMENT PLAN (ESMP)

The Environmental and Social Management Plan (ESMP) constitutes a core component of this Environmental and Social Impact Assessment (ESIA). It provides a structured framework for

managing, monitoring, and mitigating the identified environmental and social impacts associated with the proposed 1 MW Solar-Hybrid Power Plant project.

The ESMP covers the entire lifecycle of the Project, including pre-construction, construction, commissioning, operation, and eventual decommissioning phases. It outlines:

- Specific mitigation measures;
- Desired environmental and social outcomes;
- Performance indicators;
- Monitoring parameters and frequency;
- Institutional responsibilities;
- Estimated implementation costs.

The estimated cost for the implementation is presented below:

S/N	ESMP Activities	Cost (USD)
1	Pre-Construction Phase Implementation (disclosure, staffing, approvals, early monitoring)	*5,666.67*
2	Construction Phase ESMP Implementation (monitoring, mitigation execution, supervision, reporting)	*18,000*
3	Operational Phase ESMP Implementation (monitoring, waste management oversight, safety compliance)	*8,000*
4	Commissioning Phase ESMP Activities (inspection, testing oversight, reporting)	*500*
5	Direct Mitigation Measures (environmental controls, erosion measures, safety controls, signage, etc.)	*6,100*
6	Capacity Building and Training	*1,900*
7	Additional Management Plans	*19,500*
TOTAL ESTIMATED ESMP COST		***59,666.67***

To ensure that adverse environmental and social impacts associated with the project are effectively managed throughout the project lifecycle, a comprehensive Environmental and Social Management Plan (ESMP) has been developed. The ESMP translates all mitigation measures identified in the ESIA into implementable actions, clearly defining responsibilities, monitoring requirements, reporting obligations and indicative implementation costs. The ESMP is intended to ensure continuous compliance with the Federal Ministry of Environment (FMEnv), National Environmental Standards and Regulations Enforcement Agency (NESREA), Federal Capital Territory Administration (FCTA), Abuja Environmental Protection Board (AEPB), African Development Bank (AfDB) Integrated Safeguards System (ISS, 2023) and other applicable statutory requirements.

The recommended environmental and social management measures are detailed within the report, categorized by project phase and impact type. The Rural Electrification Agency Project Management Unit (REA-PMU) shall retain principal oversight responsibility for the implementation of the ESMP. While certain responsibilities may be delegated to the EPC

Contractor and subsequently to the Operations and Maintenance (O&M) Contractor, REA-PMU shall ensure compliance through supervision, audits, and performance reporting.

Relevant regulatory authorities at Federal, State, and Local Government levels, including the Federal Ministry of Environment and Abuja Environmental Protection Board, shall participate in monitoring and compliance verification as required by law.

Regular environmental and social monitoring will be conducted throughout the project phases to:

- Ensure adherence to national regulatory requirements;
- Evaluate the effectiveness of mitigation measures;
- Identify emerging risks;
- Implement corrective actions where necessary.

Stakeholder consultations initiated during the ESIA process shall continue throughout the Project lifecycle in accordance with the Stakeholder Engagement Plan (SEP), and the Grievance Redress Mechanism (GRM) shall remain active to address concerns in a timely and transparent manner.

ES 8: REMEDIATION PLAN AFTER DECOMMISSIONING / CLOSURE

The proposed solar hybrid power plant has an anticipated operational life of approximately 25 years, after which the facility may be re-powered, upgraded or decommissioned depending on institutional energy requirements and technological advancement. Decommissioning activities will be undertaken in accordance with the Decommissioning Environmental and Social Management Plan to ensure that environmental and social impacts are minimized and the project site is restored to an environmentally acceptable condition. The plan describes the anticipated decommissioning activities, identifies potential environmental and social impacts associated with such activities, and presents management and remediation measures to ensure that the Project site is restored to a safe and environmentally acceptable condition.

Although solar PV facilities are generally characterized by low operational emissions and limited long-term environmental risks, proper end-of-life planning is essential to prevent contamination, ensure safe dismantling of electrical systems, and promote responsible material recovery and recycling.

This chapter therefore provides:

- An overview of decommissioning activities;
- A framework for managing environmental and social risks during closure;
- Measures for remediation and site restoration;
- Provisions for used battery management;
- Alignment with applicable national regulations and good international practice.

Some of the anticipated High and Moderate impacts for the decommissioning phase are listed below:

High-Risk Impacts

- Electrical hazards during isolation and dismantling of PV systems and Battery Energy Storage Systems (BESS).

- Fire and explosion risks associated with damaged lithium-ion batteries.
- Occupational injuries arising from dismantling operations, lifting activities and work at height.
- Improper handling and disposal of hazardous waste, including batteries, transformers and electronic equipment.

Moderate-Risk Impacts

- Temporary soil disturbance and land degradation.
- Localized air pollution from dust generated during dismantling.
- Temporary increases in ambient noise and vibration.
- Increased traffic associated with removal of equipment and wastes.
- Generation of demolition debris, electronic waste, scrap metals, damaged PV modules and construction waste.
- Temporary disruption of campus activities.
- Community health and safety risks associated with movement of heavy equipment.
- Labour-related issues, including occupational health and worker welfare.
- GBV/SEA/SH risks associated with contractor personnel.
- Visual impacts associated with dismantling operations.

Key Mitigation Measures: To minimize these impacts, the REA, EPC Contractor and Supervising Engineer shall ensure that:

- all electrical systems are fully isolated and certified safe before dismantling activities commence; competent and trained personnel undertake dismantling of PV modules, battery systems and electrical equipment;
- appropriate Personal Protective Equipment (PPE) is provided and mandatory for all workers;
- batteries, transformers, electrical cables, PV modules and electronic components are recovered and transported by licensed hazardous waste handlers for recycling or environmentally sound disposal;
- reusable equipment and recyclable materials are recovered to minimize waste generation;
- dust suppression, traffic management and noise control measures are implemented throughout decommissioning;
- temporary erosion control measures and site restoration are completed immediately following dismantling;
- community awareness, stakeholder engagement and grievance management continue throughout the decommissioning phase;
- all contractor personnel comply with the Code of Conduct and GBV/SEA/SH Action Plan; and
- the site is rehabilitated and restored to conditions agreed with NOUN and relevant regulatory authorities.

ES 9 SUMMARY AND CONCLUSION

The proposed 1 MW Solar-Hybrid Power Plant under the Energizing Education Programme (EEP) at the National Open University of Nigeria Main Campus, Abuja is an environmentally sustainable and socially beneficial development. The Project aligns with Nigeria's renewable energy transition objectives and contributes to climate change mitigation efforts under the Paris Agreement. It will significantly improve electricity reliability within the University, enhance research and academic performance, reduce diesel dependence, lower operational costs, and strengthen campus security through solar-powered street lighting.

Although certain adverse environmental and social impacts have been identified, these impacts are localized, manageable, and largely short-term in nature. Appropriate mitigation measures have been incorporated into the Environmental and Social Management Plan (ESMP), and institutional arrangements have been established to ensure effective implementation and monitoring.

Based on the benefits associated with the Project, and subject to full implementation of the ESMP, the proposed 1-MW Solar Hybrid Power Plant should be considered for environmental approval and regulatory clearance.

.

ACKNOWLEDGEMENT

The Rural Electrification Agency (REA) wishes to express its sincere appreciation to the Federal Government of Nigeria, the Federal Ministry of Finance, and the Federal Ministry of Environment for the opportunity granted to undertake this Environmental and Social Impact Assessment (ESIA) for the proposed 1 MW Solar-Hybrid Power Plant at the *National Open University of* Nigeria Main Campus, Jabi, Abuja under the Nigeria Electrification Project (NEP).

The Agency acknowledges the valuable contributions of the Environmental Consultant, Bolben Energy and Environmental Services Ltd, contracted to carry out this ESIA study. Their technical expertise, professional diligence, and commitment to environmental and social best practices were instrumental in the successful completion of this assessment.

We are particularly grateful to the Management and Staff of the National Open University Nigeria (Main Campus), Jabi - Abuja for their cooperation, provision of relevant information, logistical support, and access to facilities throughout the duration of the study.

The Agency also appreciates the participation and constructive inputs of stakeholders, including community representatives, regulatory agencies, and other relevant institutions who contributed to the ESIA process through consultations and engagement activities.

Their collective support and collaboration have significantly enriched the quality and integrity of this assessment.

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 country's electricity sector, many public institutions continue to experience inadequate and unreliable power supply arising from grid instability, increasing electricity demand, ageing transmission and distribution infrastructure, and the high operating costs associated with fossil fuel-based backup generation. These challenges are also felt within tertiary educational institutions, where uninterrupted electricity supply is essential for teaching, research, digital learning, laboratory operations, administrative functions, healthcare services, security systems, and other critical campus activities.

Recognizing these challenges, the Federal Government of Nigeria, through the Rural Electrification Agency (REA), has continued to implement strategic renewable energy programs aimed at expanding access to clean and reliable electricity across under-served communities and public institutions. Some key initiatives by the REA include the Nigeria Electrification Program (NEP), a significant initiative designed to bridge the energy access deficit across the country; the Energizing Education Program (EEP), an essentially specialized program that focuses specifically on the education sector; 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 among others. These initiatives support the development of 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 Program forms part of the African Development Bank (AfDB) broader engagement in Nigeria's power sector and has laid the foundation for subsequent large-scale renewable energy interventions. Notably, the Nigeria Electrification Program (NEP) is a precursor to the Desert to Power Initiative, a transformative regional renewable energy program aimed at harnessing the abundant solar resources of Northern Nigeria and expand electricity access, stimulate economic growth, and strengthen climate resilience.

As part of this initiative, REA proposes the development of a **1-MW Solar Hybrid Power Plant Project** at the National Open University of Nigeria (NOUN) Main Campus, located along Nnamdi Azikiwe Expressway, Jabi, Abuja, Federal Capital Territory (FCT). 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 Environmental Impact Assessment (EIA) Act, Cap E12, Laws of the Federation of Nigeria, 2004, requires that projects of this nature undergo an Environmental Impact Assessment (EIA) prior to implementation in order to identify potential environmental and social impacts, evaluate project alternatives, recommend appropriate mitigation measures, and develop an Environmental and Social Management Plan (ESMP) to guide project implementation. Consequently, the Rural Electrification Agency (REA) commissioned Bolben Energy and Environmental Services Limited (an established and experienced Environmental Management accredited firm) to conduct the Environmental Impact Assessment (ESIA) Study 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 Environmental and Social Impact Assessment (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 1-MW Solar Photovoltaic Power project is implemented in an environmentally responsible, socially acceptable, technically feasible, and economically sustainable manner.

1.2 Project Overview

The National Open University of Nigeria (NOUN) was established under the NOUN Act No. 53 of 1983 and re-established by the NOUN (Amendment) Act No. 1 of 2002. NOUN delivers education through open and distance learning, making its ICT infrastructure and e-learning platforms central to its core operations. Reliable electricity is therefore not a luxury for NOUN, it is a basic operational requirement.

Like most public institutions in Nigeria, NOUN currently relies on 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 Federal Government, through REA and the Energizing Education Program, identified NOUN as a priority beneficiary for a dedicated clean energy solution under the Nigeria Electrification Project (Desert to Power – Phase II).

The proposed 1-MW Solar Hybrid Power Plant Project, originally conceived to be a 2-Megawatt (MW) Solar Photovoltaic (PV) Power Project but for space constraint reduced to its current capacity, is designed to provide reliable and environmentally sustainable electricity to support the University's academic, administrative, research, and student welfare functions while reducing dependence on the national electricity grid and fossil fuel-powered backup generators. The development forms part of the Federal Government of Nigeria's strategic effort to improve energy security within public tertiary institutions, increase the contribution of renewable energy to the national electricity mix, and support the country's transition towards a low-carbon economy in accordance with national and international climate commitments.

The project shall involve the design, supply, installation, testing, and commissioning of a Solar Hybrid 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 1 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 University's beneficiary loads; and
- Site fencing, and other civil infrastructure within the project footprint.

The National Open University of Nigeria (NOUN) Main Campus, Jabi, Abuja, is situated within the Guinea Savannah ecological zone, which is characterized by abundant solar resources. Empirical solar radiation data for the Federal Capital Territory indicate average global horizontal irradiance levels in the range of 5.5 – 6.5 kWh/m²/day *(Oladokun & Asemota, 2015; Okonkwo, 2003; Mbah et al., 2018)*. These values demonstrate that Abuja possesses sufficient solar insulation to support the technical and economic viability of utility-scale and institutional solar photovoltaic (PV) deployment. Accordingly, the proposed at NOUN is environmentally and technically justified, offering a sustainable alternative to fossil fuel-based generation. The project is expected to have a design life of approximately 25 years.

1.3 Project Proponent

The project proponent is the Rural Electrification Agency (REA), established by the Electric Power Sector Reform Act (2005) to promote, support, and provide rural electrification programs across Nigeria. REA's responsibilities include development of renewable energy mini-grids and embedded generation systems, electrification of federal universities and public institutions, implementation of sustainable off-grid energy solutions, and coordination with federal and state regulatory agencies. For this project, REA is responsible for:

- Project conceptualization.
- Procurement of engineering, procurement, and construction (EPC) contractor
- Compliance with environmental and social safeguard requirements.
- Oversight of ESMP implementation.

1.4 Project Location

The Federal Capital Territory (FCT) positioned within the North-Central geopolitical zone of Nigeria and serves as the administrative capital of the Federal Republic of Nigeria while Abuja

Municipal Area Council (AMAC) is the most urbanized Area Council in the FCT and serves as the administrative, commercial, and institutional hub of the Territory.

The proposed project shall be sited within the premises of the National Open University of Nigeria (NOUN), Jabi, in Abuja Municipal Area Council (AMAC) Abuja - FCT. NOUN is Nigeria's specialist open and distance learning university. It was established by the National Open University Act on 22nd July 1983, suspended in April 1984 and resuscitated in 2002. The University's central operations moved to Plot 91, Cadastral Zone, University Village, Jabi, Abuja, in March 2016. The official NOUN website currently reports 133,000 active undergraduate students and 52,138 active postgraduate students nationally. These figures describe the University system as a whole; the Jabi headquarters is principally an administrative and institutional campus rather than a conventional residential teaching campus. The Economic and Financial Crimes Commission Headquarters is the nearest prominent landmark. Its compound lies directly opposite the NOUN compound, with the EFCC/NOUN access road separating the two institutional properties.

Due to the unavailability of a contiguous land area, two parcels of land were designated for the proposed project. Together, the two sites have a reported area of approximately 6,494.89 m², equivalent to about 0.65 ha. Site 1 is located between the Faculty of Management Sciences and the Faculty of Social Sciences, adjacent to the University's substation. The site, a reclaimed and sand-filled area, occupies approximately 2,093.25 m² (0.21 ha). The second site (Site 2) is situated within the University's Car Park which is proximate to the school gate. This site is surrounded by prominent administrative, academic and institutional facilities. The site is also proximate to the school main gate and covers approximately 4,401.64 m² (0.44 ha). The sites are approximately 218 m apart, with Site 1 located north of Site 2.

The National Open University of Nigeria Main Campus is accessible through its main entrance and back gate. These institutional access points are shown in Plates 1.1 and 1.2, respectively.

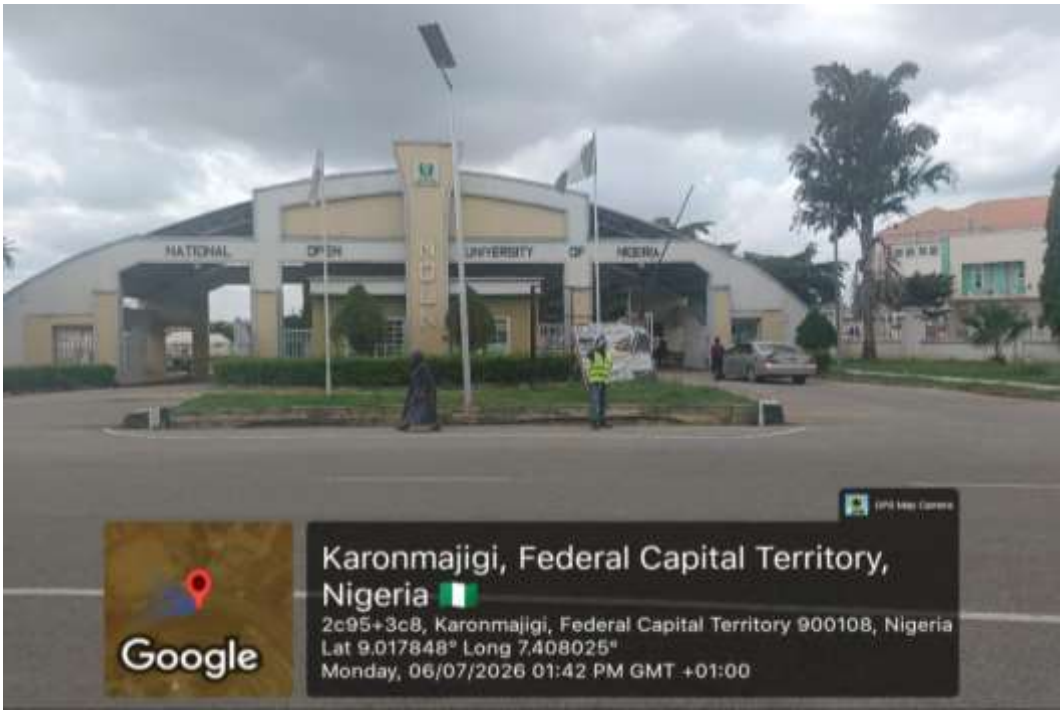


Plate 1.1: Main Entrance of the National Open University of Nigeria (NOUN), Main Campus, Jabi, Abuja.



Plate 1.2: NOUN Back Gate Adjacent to Proposed Project Site 1.

1.4.1 Detailed Description of Site 1

Site 1 is a reclaimed parcel located near the northern part of the NOUN Main Campus, close to the University's back gate. The area was formerly a trench that has been backfilled, resulting in a relatively homogeneous sand-filled surface. It is generally open and vegetated mainly by grasses and other pioneer plant species associated with previously disturbed ground.

The Faculty of Science is located to the left of the site, approximately 13 m away, while the Faculty of Management Sciences is positioned further to the left of the site, at a distance of about 17 m. The University back gate is located to the right of the site, providing convenient access through the adjoining internal back road, while the existing power-house/substation is situated opposite the site. A constructed drainage channel borders the site and conveys runoff toward the campus boundary, ultimately discharging into an unnamed river located approximately 48 m beyond the rear perimeter fence.

The boundary coordinates of Site 1, as recorded during the field reconnaissance visit, are presented in ***Table 1.1***.

Table 1.1 Boundary Coordinates of Site 1 — Reclaimed Land Area

Boundary Point	Latitude (N)	Longitude (E)	Location Reference
Point A	9.022678	7.410200	Second Gate entrance area
Point B	9.022764	7.410244	Northeast boundary
Point C	9.023094	7.410253	Far northeast corner
Point D	9.023211	7.409917	Eastern boundary
Point E	9.023269	7.409814	Southeast corner
Point F	9.023072	7.409700	Southern boundary
Point G	9.022983	7.409853	Southwest area
Total Area	**2,093.25 m²**	**0.21 ha**	**Reclaimed land**

1.4.2 Detailed Description of Site 2

Site 2 is located within the University's central/main car park. This parcel of land is larger than Site 1 and is surrounded by prominent administrative, academic and institutional facilities. Gabriel Afolabi Ojo Central Library is approximately 36 m to the north; the Convocation Arena, with blocks of shops attached behind its eastern wing, lies approximately 13 m to the west; the Senate Building is approximately 13 m to the southwest; while Directorate of Physical Planning and Development (DPP) Building is approximately 49 m to the east. A borehole taps serving the area is approximately 24 m southwest of Site 2 within the campus garden and seating park. Vegetation around Site 2 is primarily characterised by ornamental trees planted within the open spaces bordering the central car park. Unlike Site 1, the vegetation here occurs mainly as deliberately planted landscaping associated with the surrounding institutional environment.

The boundary coordinates of the site, as recorded during the field reconnaissance visit, are set out in Table 1.2.

Table 1.2 Boundary Coordinates of Site 2 — Central Car Park

Boundary Point	Latitude (N)	Longitude (E)	Location Reference
Point A	9.020278	7.408347	Northwest corner
Point B	9.020114	7.408700	Southwest corner
Point C	9.021006	7.409156	Southeast corner
Point D	9.021153	7.408861	Northeast corner
Total Area	**4,401.64 m²**	**0.44 ha**	**Existing car park**

***Source**: BOLBEN LTD Fieldwork Survey,,2026.*

1.4.3. Existing Campus Infrastructure and Utilities

1.4.3.1 Electricity Supply and Distribution

The NOUN headquarters receives electricity from the national grid through an existing MVA injection substation/power station with every of the campus building being connected to it. Site 1 is approximately 26 m south of the existing MVA injection substation/power station. The campus also has 18 diesel generator sets, with one generator serving each building.

1.4.3.2 Water, Wastewater and Solid Waste

Water is supplied from a combination of campus boreholes and municipal supply, with local storage and distribution points serving academic and administrative areas. The existing drainage and gutter network receives wastewater and stormwater and ultimately discharges westward toward the river system bounding the campus. The active open waste-disposal and burning area near the main drainage channel is the principal solid-waste feature identified in the vicinity of the proposed sites.



Figure 1.1: Map of Nigeria showing the 36 States and FCT (highlighting FCT).
Source - Google Maps

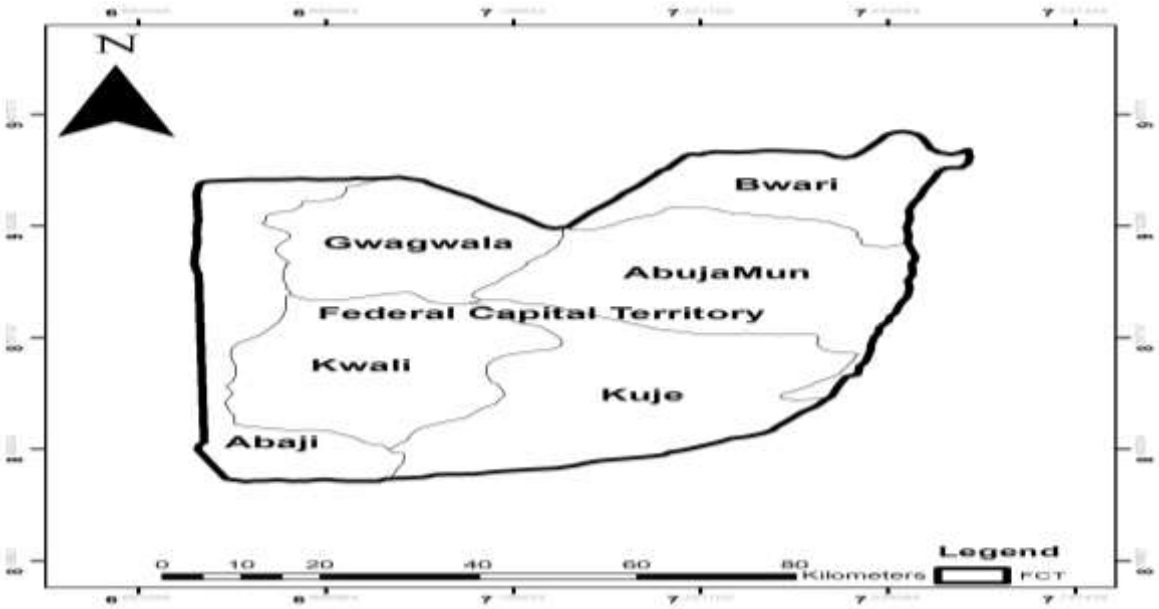


Figure 1.2: Administrative Map of the Federal Capital Territory showing the six Area Councils including Abuja Municipal Area Council (AMAC).
Source - Google Maps



Figure 1.3: Aerial View of NOUN (Main Campus) showing the locations of the proposed sites.
Source – Google Imagery

1.5 Rationale and Objectives for the ESIA

The proposed 1-MW Solar Hybrid Power Plant project falls under infrastructure developments for power facilities requiring environmental 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 prior to implementation. In addition, compliance is required with Federal Ministry of Environment EIA Procedural Guidelines, National Environmental Standards and Regulations Enforcement Agency Regulations, Climate Change Act, and AfDB Integrated Safeguards System.

The ESIA is therefore undertaken to:

- Establish the existing state of the environment and identify sensitive components of the existing environment within the project area and Area of Potential Project Influence (APPI);
- Identify sensitive components of the existing environment within the project area and its environs;
- Assess the scope of the proposed program, and the likely impacts associated with same;
- Appraise the project activities and determine any potential negative and positive impacts on the environment;
- Identify existing and expected environmental regulations that will affect the development and advise on standards, consents and targets;
- Bring all relevant information to the stakeholders, including Project Affected Persons (PAPs) and other interested parties and ensure their participation in the project design;
- Contribute to optimization of the project design and planning by identifying those aspects of the construction location and operations which may cause adverse environmental, social, health, and economic effects;

- Recommend measures during construction, commissioning, and operations to avoid and/or ameliorate these effects and increase beneficial impacts;
- Recommend an environmental and social management program for the project life cycle, including compliance, monitoring, auditing, and contingency planning; and
- Provide the basis for co-operation and consultation with regulatory and non-regulatory authorities and the public.

The assessment fully takes into account the relevant international safeguard standards to ensure that environmental and social risks have been anticipated, avoided, mitigated and eventually compensated.

1.6 Scope of the Study/Terms of Reference

The rationale for the ESIA and Scope of this study aligns with the objectives outlined in the ToR documented for this project which includes : -

- Establish the existing state of the environment and identify sensitive components of the existing environment within the project area and area of potential project influence (APPI);
- Recommend an environmental construction, commissioning and operation plan to avoid and ameliorate negative effects and increase beneficial impacts;
- Recommend an environmental management program for the lifespan of the project including compliance monitoring, audit and contingency planning;
- Provide the basis for co-operation and consultation with regulatory and non-regulatory authorities and the public;
- Appraise the project activities and determine any potential negative and positive impacts on the environment;
- Prepare an ESIA report presenting clear and concise information on the environmental impact of the current state of the project and developing project activities.

In line with the Terms of Reference (TOR), the scope of the ESIA study covers the following:

- Prepare an ESIA report presenting clear and concise information on the environmental impact of the current state of the project and developing project activities.
- Description of all actions/activities that will be carried out in the course of the Project development and implementation.
- Review of applicable local and international laws, regulations, standards and industry codes that apply to the proposed project.
- Desktop review of relevant documents pertaining to the Project and the environment where the Project would be located. These documents include the Nigerian Electrification Project (NEP) environmental and social management framework (ESMF), amongst others.
- Perimeter survey of the Project site, including development of survey maps.
- Field data gathering covering biophysical and socio-economic components of the Project's Area of Influence.
- Consultations with relevant stakeholders including government institutions, project affected persons, University management representatives
- Laboratory analysis of field samples and data analysis
- Impacts identification and evaluation, and development of appropriate and practicable mitigation measures and EMP.
- Report preparation and disclosure.

1.6.1 Spatial Scope

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

1.6.2 Temporal Scope

This covers the all aspects of the project from the Pre-construction, through to the Construction, Operation (25-year lifespan) and Decommissioning phases.

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 (dry 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 Methodology

The ESIA methodology is consistent with FMEnv procedural guidelines. It also considers the requirements of relevant and applicable international standards and best practices such as the AfDB Integrated Safeguard System. The approach and methodology applied for undertaking the environmental and social impact assessment is a combination of multidisciplinary studies (Figure 1.4). These include:

- Project Screening and development of Terms of Reference (ToR) in accordance with regulatory guidelines, as well as project site verification;
- Scoping and consultations with regulators and other relevant stakeholders concerned with the proposed project;
- Review of national and international regulations and project documents specific to the project site to obtain background information on the environmental characteristics of the area; Baseline studies and a one-season field data gathering exercise, as approved by the FMEnv, to establish environmental and social conditions specific to the project area;
- Impact identification, prediction, interpretation, and evaluation from project activities. Information on the project area, project design, as well as past project experience, was also used for impact identification and evaluation, as well as to establish mitigation and enhancement measures;
- Development of effective mitigation/ ameliorative measures and monitoring programs for significant impacts; and
- Development of a robust Environmental and Social Management Plan covering the project life cycle.

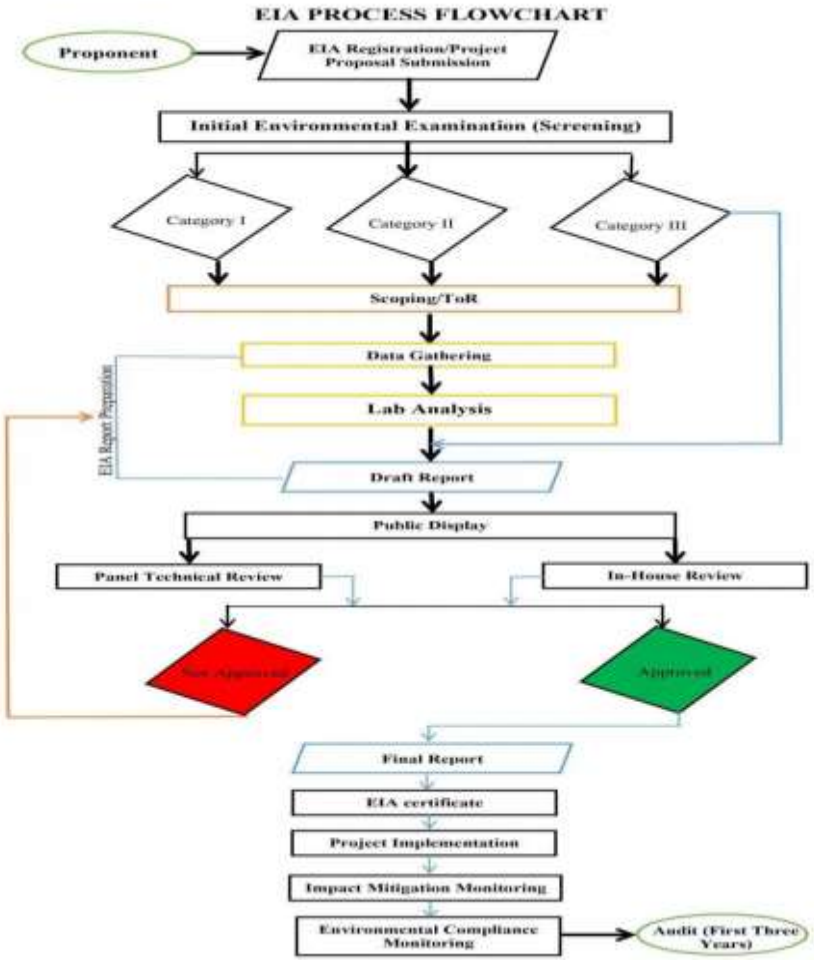


Figure 1.4: Federal Ministry of Environment EIA Flowchart
***Source**: Environmental Assessment Department, Federal Ministry of Environment, Nigeria.*

For the proposed development, the primary AoI comprises the project footprint and its immediate surroundings within the NOUN Main Campus, where site preparation, installation of solar PV modules, battery storage systems, electrical infrastructure, and ancillary facilities will be undertaken. The secondary AoI includes adjacent university facilities, internal access roads, utility corridors, nearby academic and administrative buildings, and other sensitive receptors that may experience temporary impacts such as noise, dust generation, traffic movement, and construction-related disturbances. Given the relatively small footprint and low-impact nature of solar photovoltaic technology, the project's environmental impacts are anticipated to remain localized, with no significant adverse effects beyond the university campus when the recommended mitigation measures and Environmental and Social Management Plan (ESMP) are effectively implemented.

1.8 Policy, Legal and Institutional Framework

This section provides an overview of the relevant international and national policies, laws, regulations, administrative instruments, and institutional arrangements governing the proposed 1-MW Solar Hybrid Power Plant project at National Open University of Nigeria (NOUN), to be implemented by the Rural Electrification Agency (REA) under the Desert to Power Initiative (Phase II). The section also identifies the statutory basis for the ESIA; establishes environmental approval obligations; clarifies roles of regulatory institutions; demonstrates compliance pathways;

and integrates multilateral safeguard requirements where applicable. A number of institutions have been identified and will be involved in the overall implementation of this program. These include the Federal Government of Nigeria (FGN), Rural Electrification Agency (REA), Federal Ministry of Environment (FMEnv), Federal Ministry of Power, National Environmental Standards and Regulatory Enforcement Agency (NESREA), Abuja Environmental Protection Board (AEPB) and Abuja Municipal Area Council.

1.8.1 National Policy, Guidelines and Regulations

1.8.1.1 Federal Ministry of Environment (FMEnv)

The FMEnv is the principal authority for the regulation and enforcement of environmental laws in Nigeria. The Act establishing the Ministry places on it the responsibilities of ensuring that all development and industry activity, operations and emissions are within the limits prescribed in the national guidelines and standards and comply with relevant regulations for environmental pollution management in Nigeria as may be released by the Ministry. In furtherance of its mandate, the FMEnv developed laws/guidelines on various sectors of the national economy. The specific policies, acts, guidelines enforced by FMEnv that are applicable to the proposed Project are summarized as follows:

❖ **National Policy on the Environment, 1989 (revised in 1999 and 2016)**

The National Policy on the Environment provides for "a viable national mechanism for cooperation, coordination and regular consultation, as well as harmonious management of the policy formulation and implementation process which requires the establishment of effective institutions and linkages within and among the various tiers of government that is, federal, state and local government". The Policy was formulated and published in 1991, then revised in 1999 to incorporate new environmental concerns such as desertification, biodiversity loss, and industrial pollution. It was further updated in 2016 to incorporate and address issues related to climate change, disasters, biosafety, and modern environmental governance. The project must promote sustainable development, pollution prevention, biodiversity conservation and climate resilience throughout its lifecycle. The objective of the policy is to achieve sustainable development in Nigeria pertaining to:

- Secure a quality environment adequate for good health and well-being;
- Conserve the environment and natural resources for the benefit of present and future generations;
- Raise public awareness and promoting understanding of the essential linkages between the environmental resources and developments and encouraging individual and community participation in environmental improvement efforts;
- Maintain and enhance the ecosystems and ecological processes essential for the functioning of the biosphere to preserve biological diversity;
- Co-operate with other countries, international organizations and agencies to achieve optimal use and effective prevention or abatement of trans-boundary environmental degradation.

This Solar PV Power project directly aligns with this Policy by promoting clean energy, lowering greenhouse gas emissions, and supporting Nigeria's climate commitments. The project will also incorporate measures for safe disposal of solar panels and batteries, and efficient land use.

❖ **National Climate Change Policy (2021–2030)**

The Federal Ministry of Environment developed the National Climate Change Policy (2021 – 2030) to provide a coordinated national framework for addressing the causes and consequences of climate change while supporting sustainable socio-economic development. The Policy recognizes climate change as one of the most significant environmental and developmental challenges confronting

Nigeria and one of the major objectives of the Policy is to mainstream climate change into development planning by ensuring that climate risks and opportunities are considered during project identification, design, implementation, operation, monitoring, and decommissioning.
By generating electricity from solar energy, the project will significantly reduce reliance on diesel-powered standby generators and fossil fuel-based electricity sources that contribute to greenhouse gas emissions and local air pollution. The project therefore represents a practical climate mitigation measure within Nigeria's education sector,

- **Environmental Impact Assessment (EIA) Act CAP E12 LFN 2004**

The EIA Act provides the primary legal framework for environmental assessment in Nigeria. It is the primary Act governing the environmental and social assessment of developmental Project or activity in the country. Section 2(1) prohibits the commencement of any project likely to significantly affect the environment without prior environmental assessment and approval while 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.
Based on the provisions of the EIA Act, the proposed 1-MW Solar PV Power project falls under Category II projects (moderate impacts). This necessitates the development of this ESIA to identify and manage the potential impacts of the project throughout its life cycle. This Act is applicable because the construction of a utility-scale solar power facility is a prescribed activity requiring prior environmental approval before implementation.

- **National Environmental Impact Assessment Procedural and Sectoral Guidelines.**

Following the promulgation of the EIA Act, the FMEnv developed National EIA Procedural Guidelines and other set of guidelines on various sectors of the National economy. The ESIA must follow the nationally approved procedures for scoping, baseline studies, public consultation, impact assessment, disclosure and approval. To ensure compliance with the approved EIA process, the following are applicable to the proposed project:

Environmental Impact Assessment (EIA) Procedures and Charges Regulations, 2021 (published in Nigeria's Official Gazette No. 105): The Environmental Impact Assessment (EIA) Procedures and Charges Regulations, 2021, published in Federal Republic of Nigeria Official Gazette No. 105, provide the administrative and procedural framework for implementing the EIA Act. The Regulations prescribe procedures for project registration, screening, scoping, Terms of Reference approval, preparation and submission of ESIA reports, public consultation, technical review, certification, environmental auditing, and post-approval monitoring. Compliance with these regulations is mandatory for obtaining environmental approval for the proposed project.

FMEnv EIA Guidelines for Renewable Energy Projects 2017: The Federal Ministry of Environment's EIA Guidelines for Renewable Energy Projects provide sector-specific guidance for assessing the environmental and social impacts associated with renewable energy developments, including solar photovoltaic facilities, hybrid power systems, battery energy storage systems, transmission infrastructure, and associated facilities. These guidelines ensure that renewable energy projects are implemented in an environmentally sustainable and socially responsible manner. This applies because the proposed project falls within the renewable energy sector and the Guidelines provide sector-specific requirements for environmental assessment, impact prediction, mitigation, environmental monitoring, stakeholder consultation and reporting during project planning, construction, operation and decommissioning.

FMEnv Environmental and Social Management Plan (ESMP) Guidelines for Solar Mini-grid Projects in Nigeria 2021: The FMEnv Environmental and Social Management Plan (ESMP) Guidelines for Solar Mini-grid Projects in Nigeria provide detailed guidance for the preparation and implementation of Environmental and Social Management Plans for solar energy projects and associated battery storage facilities. The Environmental and Social Management Plan developed for this Project has been structured to align with the requirements of these Guidelines and shall be implemented throughout the project lifecycle, including construction, operation, maintenance, and decommissioning phases. The Guidelines are applicable as they prescribe a simplified environmental and social assessment process for eligible solar-based projects, including ESMP preparation, stakeholder engagement, environmental monitoring, mitigation measures and post-approval compliance requirements. They were developed as an abridged version of the EIA Procedures Guidelines to streamline approval for lower-risk solar mini-grid projects.

FMEnv EIA Guidelines for the Power Sector, 2013*:* The Federal Ministry of Environment (FMEnv) EIA Guidelines for the Power Sector, 2013 provide sector-specific requirements for the environmental assessment of electricity generation, transmission, distribution, and associated power infrastructure projects in Nigeria. The Guidelines supplement the Environmental Impact Assessment Act and establish procedures for identifying, predicting, evaluating, and mitigating environmental and social impacts associated with power sector developments.

The Guidelines are applicable to conventional and renewable power generation projects, substations, transmission lines, distribution systems, energy storage facilities, and associated infrastructure. Consequently, they are directly relevant to the Environmental and Social Impact Assessment (ESIA) and Environmental and Social Management Plan (ESMP) for the proposed Project which have been prepared to ensure environmentally sustainable development and regulatory compliance throughout the project lifecycle.

- **National Adaptation Plan (NAP) Framework (2020)**

Nigeria's National Adaptation Plan (NAP) Framework (2020) provides a strategic approach for integrating climate adaptation into national, sectoral and sub-national development planning in accordance with the objectives of the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC). The Framework promotes climate-resilient infrastructure, disaster preparedness, sustainable resource management, institutional capacity building, and risk-informed planning to reduce the vulnerability of communities and public infrastructure to climate-related hazards.

Climate resilience measures incorporated into the project include appropriate drainage design, flood protection, corrosion-resistant materials, lightning protection systems, wind-resistant mounting structures, battery fire protection systems, and emergency preparedness procedures. These measures will improve the long-term resilience of the facility against projected climate variability.

1.8.1.2 National Environmental Standards and Regulation Enforcement Agency (NESREA)

The National Environmental Standards and Regulations Enforcement Agency (NESREA) was established in 2007 by the FGN as a parastatal of the FMEnv. The Agency is charged with the responsibility of enforcing the environmental laws, guidelines, standards and regulations in Nigeria, specifically during the operational phase of development projects. It is expected that during implementation, the project complies with national environmental standards relating to air quality, noise, waste management, pollution control, hazardous substances and environmental monitoring. The applicable NESREA's regulations to the proposed project include:

- ***S.I. 28 National Environmental (Sanitation and Wastes Control) Regulations, 2009***

The purpose of this regulation is the adoption of sustainable and environment friendly practices in environmental sanitation and waste management to minimize pollution. This is applicable to wastes generated during project activities including construction waste; packaging waste; scrap materials; domestic.

- ***S.I. 35 National Environmental (Noise Standards and Control) Regulations, 2009***

This regulation highlights the permissible noise levels to which a person may be exposed, control and mitigation of noise, permits for noise emissions in excess of permissible levels, and enforcement.

- ***S.I. 22 National Environmental (Surface and Groundwater Quality Control) Regulations, 2010***

The purpose of this regulation is to enhance and preserve the physical, chemical and biological integrity of the groundwater and surface water resources.

- ***S.I. 63 National Environmental (Energy Sector) Regulations, 2014***

The purpose of this regulation is to prevent or minimize pollution and encourage energy efficiency in all operations and ancillary activities of the energy sector in achieving sustainable economic development in Nigeria.

- ***National Environmental (Battery Control) Regulations, 2024.***

This regulation provides control measures for the handling, storage, transportation, recycling, and disposal of batteries in Nigeria. It is aimed at reducing environmental contamination from hazardous substances such as lead, lithium, and acid contained in batteries. It is particularly relevant to renewable energy and hybrid systems where battery energy storage is used, ensuring safe end-of-life management and prevention of soil and water pollution.

- **National Environmental (Permitting and Licensing System) Regulations, S.I. No. 29, 2009**

This regulation establishes the framework for environmental permitting and licensing of activities that may have significant environmental impacts. It requires project developers to obtain necessary permits from NESREA before commencement of regulated activities. It ensures that environmental compliance is formally approved, monitored, and enforced throughout the project lifecycle.

- **National Environmental (Control of Vehicular Emissions from Petrol and Diesel Engines) Regulations, S.I. No. 20, 2011**

This regulation sets emission standards for vehicles using petrol and diesel engines to reduce air pollution from transport sources. It establishes permissible emission limits and promotes regular inspection and maintenance of vehicles. It is relevant to construction and operational phases of projects where vehicular movement contributes to air quality impacts.

- **National Environmental (Electrical/Electronic Sector) Regulations, S.I. No. 79, 2022**

This regulation governs the management of electrical and electronic equipment waste (e-waste) in Nigeria. It promotes environmentally sound management, recycling, and extended producer responsibility (EPR) for electronic products. It is relevant to solar projects due to components such as inverters, panels, control systems, and other electrical equipment that may become waste at end-of-life.

- **National Environmental (Noise Standards and Control) Regulations, S.I. No. 35, 2009**

This regulation establishes permissible noise levels for different categories of areas such as residential, industrial, and commercial zones. It aims to protect human health and the environment from excessive noise pollution. It is relevant during construction and operation phases where machinery, generators, and transport activities may generate noise impacts.

- ***National Environmental (Plastic Waste Control) Regulations, 2026***

This regulation focuses on the reduction, control, and management of plastic waste in Nigeria through waste minimization, recycling, and restrictions on certain plastic products. It promotes sustainable plastic use and proper waste disposal practices to reduce environmental pollution. It is relevant to project activities that generate packaging waste, construction materials, and single-use plastics.

- ***National Environmental (Electrical/Electronic Sector) Regulations, 2022, S.I. 79***

The main purpose of this regulation is to ensure that best practices are applied and maintained in the operation of electrical and electronic equipment in order to safeguard the Nigerian environment against pollution hazards. These regulations are directly relevant due to the installation of PV modules; inverters; transformers; electrical cables; etc. Solar modules, inverters, batteries and electrical equipment become regulated electronic waste during replacement and decommissioning.

- ***National Environmental (Construction Sector) Regulations, 2011***

These regulations apply to construction activities associated with site clearing, civil works, installation of mounting structures, transformer installation. Key compliance requirements include dust suppression measures, noise control, safe waste handling, occupational health standards, pollution prevention.

- ***National Environmental (Soil Erosion and Flood Control) Regulations 2011, S. I. 12:***

The overall objective of this regulation is to regulate all earthing-disturbing activities, practices or developments for non-agricultural, commercial, industrial and residential purposes.

- ***National Environmental (Air Quality Control) Regulations, S. I. 64, 2013:***

The objective of this regulation is to ensure the control of air pollutants that may affect the ambient environment.

1.8.1.3 Federal Ministry of Power

The Federal Ministry of Power is the Nigerian federal government ministry responsible for formulating policies, coordinating the electricity sector, and promoting reliable power supply nationwide. The ministry oversees national policy for the electricity sector and works with key agencies responsible for generation, transmission, distribution, rural electrification, technical standards, and market regulation. The Ministry is guided by the provisions of the Electricity Act 2023, the National Electric Power Policy, 2001, the Electric Power Sector Reform Act, 2005, the Roadmap for Power Sector Reform, 2010, the National Energy Policy, 2013 and the National Energy Efficiency Action Plans, 2015.

- ***Electric Power Sector Reform Act 2005***

The Electric Power Sector Reform Act No. 6 of 2005 provides for the licensing and the regulation of the generation, transmission, distribution and supply of electricity. Part IV of the Act contains requirements for licensing and stipulates that no person may construct, own or undertake any of the

following activities without a license, unless the generating capacity and distribution capacity is below 1 MW and 100 kilowatts (KW) respectively for electricity. generation, excluding captive generation, electricity transmission, system operation, electricity distribution and trading in electricity.

- ***Electricity Act, 2023***

The Electricity Act governs electricity generation and distribution in Nigeria. Although this project is embedded within the university's internal network, compliance obligations include technical interconnection standards; electrical safety standards; and protection systems compliance. It is the principal legislation regulating generation, distribution and supply of electricity and is applicable because the project entails the construction and operation of a 1-MW Solar Hybrid Power Plant project and associated distribution infrastructure.

- **Renewable Energy and Energy Efficiency Policy (NREEEP, 2015)**

The National Renewable Energy and Energy Efficiency Policy (NREEEP) provides Nigeria's principal policy framework for accelerating the deployment of renewable energy technologies and improving energy efficiency across all sectors of the economy. Developed by the Federal Ministry of Power, the Policy promotes the deployment of grid-connected and distributed renewable energy systems in public institutions, educational facilities, healthcare centres, commercial establishments and rural communities. It also encourages the adoption of energy storage technologies to improve the reliability and flexibility of renewable energy systems.
The proposed 1 MW hybrid renewable power system integrating solar PV, battery storage and the existing utility grid is an implementation of the strategic objectives of the NREEEP as it directly contributes to renewable electricity generation, increased clean energy penetration and reduced dependence on diesel generation.

- ***Nigeria Energy Transition Plan (ETP), 2022***

Developed under the leadership of the Federal Ministry of Power in collaboration with the Energy Commission of Nigeria and other national and international stakeholders, the Plan provides a comprehensive framework for transforming Nigeria's energy sector in a manner that simultaneously promotes economic growth, industrial development, environmental sustainability and social inclusion. The Plan sets out a pathway towards universal access to electricity by 2030 while supporting Nigeria's commitment to achieve net-zero greenhouse gas emissions by 2060, consistent with the national Net-Zero Emissions Pledge and the Climate Change Act, 2021
The proposed Solar Hybrid Power Plant project shall contribute to the ETP's objective of improving energy access and cause reduction in diesel generator usage which will lower fuel consumption, air pollutant emissions and noise levels, thereby improving the environmental quality of the university campus.

1.8.1.4 Rural Electrification Agency Act 2005

The REA is legally empowered to promote off-grid and distributed renewable energy; implement rural electrification programs; and mobilize funding for renewable projects. The proposed project is consistent with REA's statutory mandate.

- ***Rural Electrification Agency HSE Policy***

The Rural Electrification Agency was set up by Section 88 of the Electric Power Sector Reform Act 2005 as the Implementing Agency of the FGN tasked with electrification of rural and unserved communities. The mission is to provide access to reliable electric power supply for rural dwellers irrespective of where they live and what they do, in a way that would allow for reasonable return on

investment through appropriate tariff that is economically responsive and supportive of the average rural customer. 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.

Other National Policies/Acts applicable to the project include:

❖ **Land Use Act CAP L5 LFN 2004**

Relevant sections of these laws that may relate to this project with respect to land ownership and property rights, resettlement and compensation are summarized in this section. Section 1 of the Act vests the entire land in any state in the Governor of the State. The Act also stipulates the procedures the State must follow to clear the land and define the compensatory measures the State must implement to compensate any affected person. The PV panels of the proposed solar power project will be installed on an allocated land within the NOUN - Main Campus, hence, no compensation or resettlement shall be required.

❖ **Climate Change Act, 2021**

This Act applies to the Ministries, Departments and Agencies (MDAs) of the Application. Federal Government of Nigeria, and to public and private entities within the territorial boundaries of Nigeria for the development and implementation of mechanisms geared towards fostering low carbon emission, environmentally sustainable and climate resilient society. The Act provides a framework for Nigeria to achieve low Green House Gas emissions (GHG) through inclusive green growth and sustainable economic development and the implementation of Nigeria's commitment to net zero emissions declared at COP26 in 2021. It establishes the National Council on Climate Change, which will be tasked with implementing the countries Climate Action Plan. The project contributes to national climate mitigation objectives and supports implementation of Nigeria's Net-Zero commitments.

❖ **Renewable Energy Master Plan (REMP)**

The Renewable Energy Master Plan (REMP) was developed by the Energy Commission of Nigeria (ECN), in collaboration with the United Nations Development Programme, to provide a comprehensive road-map for the accelerated development and deployment of renewable energy technologies across Nigeria. The Master Plan encourages deployment of renewable energy technologies with particular emphasis on the utilization of solar photovoltaic technology because

Nigeria receives abundant solar radiation (depending on geographical location), making solar energy one of the country's most economically viable renewable resources.
The project will contribute to the diversification of Nigeria's electricity supply and practical application of modern renewable energy technologies in the country.

- **Labour Act CAP L1, LFN 2004**

The Labor Act is the primary law protecting the employment rights of individual workers. The Act covers protection of wages, contracts, employment terms and conditions, and recruitment; and classifies types of workers and special workers. This law is applicable to the project because the contractors and REA will employ construction workers and must comply with labour welfare, working conditions and employment requirements..

- **Nigerian Urban and Regional Planning Act CAP N138 LFN, 2004**

This Act establishes a Development Control Department (DCD) charged with the responsibility for matters relating to development control and implementation of physical development plans at Federal, State and Local Government levels within their respective jurisdiction.

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

The Harmful Waste (Special Criminal Provisions) Act CAP H1 LFN 2004 prohibits, without lawful authority, all activities relating to the purchase, sale, importation, transit, transportation, deposit, storage of harmful wastes. Appropriate penalties for contravention are prescribed. The Regulation is applicable to the project because spent batteries, contaminated oils and hazardous wastes generated during operation or decommissioning require environmentally sound management.

- **Endangered Species Act, CAP E9, LFN 2004**

The Act encapsulates the provisions for the conservation, management and protection of the country's endangered species. Section 1 of the Act prohibits the hunting, capture and trade of endangered species

- **National Policy on Solid Waste Management (NPSWM), 2020**

The National Policy on Solid Waste Management (NPSWM) was approved by the Federal Executive Council of the Nigerian Government on 15th of July 2020 as a shared national vision of how solid waste should be managed more sustainably with relative and loose uniformity across states of the Federation. Developed in close consultation with stakeholders, the policy is expected to increasingly garner the active participation of numerous players in the management of solid waste including governments at all levels, the private sector, NGOs, CBOs, FBOs, and partnerships resulting in projects and programmes implementation.

- **Penal Code (Northern States) Federal Provisions Act, CAP P3 LFN 2004**

The Act contains the basic criminal law offences relating to endangering the life of people from various activities in the Northern region of Nigeria. These include offence relating to the public health and safety, among others.

- **Employee Compensation Act, 2010**

The Act provides compensation to employees who suffer from occupational diseases or sustain injuries arising from accidents at the workplace or in the course of employment. Payment of compensation (to the worker or his dependents in case of death) by the employer is as enshrined in the accepted principle that the employer has a duty of care to protect the health, welfare, and safety of workers at work. It is necessary as the workers engaged during construction and operation must be insured against occupational injuries and diseases.

- **The National Gender Policy 2021 - 2026**

The 1999 Constitution the Federal Republic of Nigeria prohibits discrimination based on places of origin, sex, religion, status, ethnic or linguistic association. Successive governments have always demonstrated commitment to upholding this and to promote gender equality and women's empowerment in varying degrees. To facilitate gender equality and women's empowerment, the FGN created favourable national legal and policy frameworks and put in place institutional mechanisms in this regard. Moreover, Nigeria, as a member of the United Nations, signed and ratified the various relevant international instruments, treaties and conventions without reservation. These instruments have always emphasized that member nations put in place the necessary mechanisms needed to eliminate gender discrimination, ensure equality and human dignity to all men and women.

- **National Energy Policy (Revised 2013)**

The Policy was developed by the Energy Commission of Nigeria to promote renewable energy diversification. The project advances energy security; institutional energy independence; as well as decentralized generation.

The project supports Nigeria's strategy for diversifying the national energy mix, increasing renewable electricity generation, strengthening institutional energy security, promoting energy efficiency, reducing greenhouse gas emissions and developing indigenous technical capacity in renewable energy technologies.

- **Violence Against Persons (Prohibition) Act 2015.**

This Act prohibits all forms of violence against persons in private and public life and provides maximum protection and effective remedies for victims and punishment of offenders. It is also applicable because labour influx may expose host communities to GBV/SEA/SH risks requiring prevention, reporting and response mechanisms

- **Public Health Act, Cap. P16, Laws of the Federation of Nigeria (LFN), 2004**

The Public Health Act provides the legal framework for safeguarding public health through the prevention and control of conditions that may constitute a nuisance or pose risks to human health. The Act empowers relevant public health authorities to ensure that development activities do not create environmental conditions capable of adversely affecting surrounding communities through poor sanitation, pollution, waste accumulation, contaminated water, excessive dust, noise, offensive odours or disease vectors.

REA shall ensure appropriate environmental sanitation measures, dust suppression, noise control, waste management, wastewater management, traffic management and emergency response procedures throughout the project lifespan.

- **National Policy on Occupational Safety and Health 2020**

The National Policy on Occupational Safety and Health (OSH) (2020) was developed by the Federal Ministry of Labour and Employment to establish a national framework for the prevention of occupational injuries, diseases and fatalities across all sectors of the Nigerian economy. This aligns with section 17(3c) of the constitution of the Federal Republic of Nigeria (1999) which stipulates that the health, safety and welfare of all persons in employment must be safeguarded and not endangered or abused. The Policy seeks to promote safe and healthy working environments by integrating occupational safety and health considerations into workplace planning, management and operations. It emphasizes employers' responsibility to provide safe systems of work, adequate training, hazard identification and risk assessment, emergency preparedness, workers' participation in OSH matters, continuous monitoring and compliance with applicable occupational health and

safety legislation. The Policy also promotes the prevention of occupational illnesses through appropriate workplace health surveillance, use of personal protective equipment (PPE), incident reporting and investigation, and continuous improvement of OSH performance. With respect to this project, the National Policy on Occupational Safety and Health (2020) is applicable because project activities during construction, commissioning, operation and decommissioning involve occupational hazards associated with civil works, excavation, working at heights, lifting operations, electrical installations, battery energy storage systems, heavy equipment operation, welding, etc.

- **National Commission for Museums and Monuments Act, Cap. N19, Laws of the Federation of Nigeria (LFN), 2004**

The Act established the National Commission for Museums and Monuments (NCMM) and provides for the identification, protection, preservation and management of Nigeria's archaeological, historical, cultural and national heritage resources. It prohibits the unauthorized destruction, removal, excavation or alteration of protected monuments, archaeological relics and cultural heritage sites and *requires that any archaeological discoveries made during development activities be reported to the Commission for appropriate investigation and preservation*.
The proposed project is located within the National Open University of Nigeria - Abuja, where no designated national monuments, archaeological sites or protected cultural heritage resources have been identified within the proposed project footprint. Nevertheless, minor excavation activities associated with the project could result in the accidental discovery of archaeological materials, historical artefact or cultural objects. REA shall implement a Chance Find Procedure, whereby if there is any discovery, all construction activities in the affected area will cease until the National Commission for Museums and Monuments is notified for appropriate investigation and guidance before work resumes.

1.8.2 FCT Policy, Guidelines and Regulations

1.8.2.1 Federal Capital Territory Administration (FCTA)

The Federal Capital Territory Administration (FCTA) is the administrative authority responsible for the governance, development and management of the Federal Capital Territory pursuant to the provisions of the Constitution of the Federal Republic of Nigeria and the Federal Capital Territory Act. The FCTA is responsible for ensuring that all public and private developments within the Territory are undertaken in accordance with approved planning standards, environmental requirements and sustainable urban development principles.
The proposed 1-MW Solar Hybrid Power Plant project falls under the administrative jurisdiction of the Federal Capital Territory Administration. REA shall ensure implementation of the project is undertaken in accordance with applicable FCTA policies governing land use, physical planning, environmental sanitation, public health, traffic management and infrastructure development.

1.8.2.2 Federal Capital Development Authority (FCDA)

The Federal Capital Development Authority (FCDA) is the principal agency responsible for the planning, development and physical implementation of infrastructure within the Federal Capital Territory. The FCDA is mandated to implement the Abuja Master Plan, coordinate physical development, provide engineering infrastructure and ensure orderly urban growth within the Territory as well as supervise development projects to ensure consistency with approved layouts, infrastructure corridors, zoning regulations and engineering standards.
The proposed Solar PV power project will be constructed within an existing institutional development already designated for educational purposes under the Abuja Master Plan and will not involve a change of land use.

1.8.2.3 Abuja Environmental Protection Board (AEPB)

The Abuja Environmental Protection Board (AEPB) is the principal environmental regulatory agency of the Federal Capital Territory Administration (FCTA), established to protect and improve the quality of the environment within the Federal Capital Territory. The Board is responsible for implementing environmental policies, enforcing environmental regulations, monitoring environmental quality, promoting sustainable waste management, controlling environmental pollution, regulating sanitation services, and ensuring compliance with environmental standards throughout the FCT. The AEPB collaborates with the Federal Ministry of Environment (FMEnv), the Federal Capital Territory Administration (FCTA), Area Councils within the FCT and other relevant institutions to ensure that development projects are implemented in an environmentally responsible manner.

The proposed project is subject to the environmental oversight responsibilities of the Abuja Environmental Protection Board to ensure continued compliance with applicable environmental standards within the FCT.

1.8.2.4 Abuja Municipal Area Council (AMAC)

The Abuja Municipal Area Council (AMAC) is one of the six Area Councils established within the Federal Capital Territory to administer local government functions within its jurisdiction. AMAC is responsible for the provision and coordination of certain municipal services including environmental sanitation, waste management, public health administration, local roads, markets, community liaison, and other statutory local government functions.

The National Open University of Nigeria Main Campus is situated within the jurisdiction of the Abuja Municipal Area Council. Accordingly, implementation of the proposed project will require appropriate coordination with the Area Council regarding environmental sanitation, construction waste management, public health, traffic management and other municipal services that may be affected during project implementation.

1.8.2 International Convention and Agreements, Best Practice Standards and Guidelines

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 such conventions, treatises and agreement are:

- **The African Development Bank (AfDB) Integrated Safeguards System (ISS) 2023 - *African Development Bank Environmental and Social Safeguards Policies:***

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 complies with the safeguard requirements of the ISS during project implementation. The safeguards aim to:

i. Avoid adverse impacts of projects on the environment and affected people, while maximizing potential development benefits to the extent possible.
ii. Minimize, mitigate, and/ or compensate for adverse impacts on the environment and affected people when avoidance is not possible.

iii. 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 1-MW Solar Hybrid Power Plant project at NOUN Main Campus are highlighted as follows:

- **OS 1** - Assessment and Management of Environmental and Social Risks and Impacts: This safeguard governs the process of determining a project's environmental and social category and the resulting environmental and social assessment requirements. This Operational Safeguard is triggered as the project will have environmental interactions with its attendant negative impacts on the people and the environment, thus, requires ESIA/ESMP, risk categorization, and mitigation planning. The ESIA and ESMP align with OS1, covering construction impacts (dust, noise, waste) and operational risks.
- **OS 2** - Labour and Working Conditions: This Operational Safeguard is triggered because the construction and operation of the project will involve contractors, subcontractors and project workers. The project shall ensure fair labour practices, non-discrimination, prohibition of child and forced labour, occupational health and safety, workers' grievance mechanism, emergency preparedness and compliance with national labour legislation.
- **OS 3** - Resource Efficiency and Pollution Prevention and Management: The construction and operation phases will consume water, energy and construction materials while generating dust, noise, wastewater, solid waste, used oils and end-of-life batteries hence this Operational Safeguard is triggered. Measures shall be implemented to promote efficient resource use, pollution prevention, hazardous waste management and greenhouse gas emission reduction.
- **OS 4** - Community Health, Safety and Security: This Operational Safeguard is triggered because construction activities may expose surrounding communities to traffic hazards, dust, noise, public safety risks, labour influx, communicable diseases, Gender-Based Violence (GBV), Sexual Exploitation and Abuse (SEA), Sexual Harassment (SH), emergency incidents and electrical hazards. Appropriate traffic management, community health programs, emergency preparedness and security management shall be implemented.
- **OS 5** - Land Acquisition, Restrictions on Access to Land and Land Use, and Involuntary Resettlement: This safeguard consolidates the policy commitments and requirements set out

in the Bank's policy on involuntary resettlement and incorporates a few refinements designed to improve the operational effectiveness of those requirements. It ensures avoidance or minimizes displacement and ensure fair compensation. This Operational Safeguard is not triggered as the project will be sited on university land and no form of displacement is expected.

- **OS 6** - Habitat and Biodiversity Conservation and Sustainable Management of Living Natural Resources: This safeguard aims to conserve biological diversity and promote the sustainable use of natural resources. It also translates the commitments in the Bank's policy on integrated water resources management into operational requirements. Although site preparation may result in vegetation clearing, this Operational Safeguard is not triggered because the project is on a piece of land with limited sensitive ecological receptors. The project shall minimize habitat loss, conserve biodiversity, restore disturbed areas and prevent unnecessary damage to flora and fauna while promoting sustainable land management.
- **OS 7** - Vulnerable Groups: This Operational Safeguard is not triggered as the project will be sited on university land and vulnerable persons, including women, youth, elderly persons, persons with disabilities and economically disadvantaged households are not expected to be impacted negatively.
- **OS 8** - Cultural Heritage: This Operational Safeguard is not triggered because the project will be sited within a university land and no known cultural heritage resources have been identified within the project area but it is a safe bet to incorporate a Chance Finds Procedure into construction contracts and implemented throughout excavation work as construction activities may uncover archaeological or cultural materials.
- **OS 9** - Financial Intermediaries: This safeguard is triggered as AfDB channels funds through banks or intermediaries.
- **OS 10** - Stakeholder Engagement and Information Disclosure: This Operational Safeguard is triggered because continuous stakeholder engagement is required throughout planning, construction, operation and decommissioning. The project shall implement a Stakeholder Engagement Plan (SEP), maintain an accessible Grievance Redress Mechanism (GRM), disclose relevant environmental and social information and ensure meaningful consultation with affected communities and other stakeholders.

❖ **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 Program (UNEP).

Some of the guiding principles that are relevant to the1-MW Solar Hybrid Power Plant project at NOUN Main Campus, showing how they apply across the construction, operation, and decommissioning phases of the project are on Table 1.3:

Table 1.3 - 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	Efficient use of solar energy reduces fossil fuel	Recycling of panels and metals protects resources.

Principle	Construction Phase	Operation Phase	Decommissioning Phase
	minimized.	reliance.	
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.
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.

- **The <u>Paris Agreement 2015</u>**

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 NOUN 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.

- **<u>Nationally Determined Contributions (NDCs)</u> 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.

❖ ILO Conventions and Core Labor Standards

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**.**

- **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.

- **Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa, 2003**

The Protocol to the African Charter on Human and Peoples' Rights on the Rights of Women in Africa, better known as the Maputo Protocol, is an international human rights instrument established by the African Union was adopted in Maputo in July 2003 and went into effect in 2005. It guarantees comprehensive rights to women including the right to take part in the political process, social and political equality with men, and improved autonomy in their reproductive health decisions.

- **Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW), 1979**

Adopted December 18, 1979, and entered into force on September 3, 1981, the Convention on the Elimination of All Forms of Discrimination Against Women (CEDAW) is an international legal instrument that requires countries to eliminate discrimination against women and girls in all areas and promotes women's and girls' equal rights.

- **United Nations Convention on Climate Change (UNFCCC):**

The Convention on the Climate Change was signed in 1992 during the Rio Earth Summit but was put into force in 1994. The Convention called on developed countries and economies in transition to limit their emissions of the greenhouse gases which cause global warming, although it does not impose mandatory emissions on developing countries. The UNFCCC is the umbrella treaty under which later agreements like the Kyoto Protocol (1997) and the Paris Agreement (2015) were adopted.

- **Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal**

The Basel Convention was adopted on 22 March 1989 in Basel, Switzerland, and opened for signature on 23 March 1989. Nigeria signed the Convention in 1989 and ratified it on 13 March 1991. Nigeria is therefore a legally bound Party to the Convention and obligated to (1) Regulate hazardous waste management; (2) Prevent illegal import/export of hazardous waste; (3) Ensure environmentally sound management (ESM) of hazardous materials; and (4) Prohibit trans-boundary movement without prior informed consent.

Although the proposed project is a renewable energy installation, the Basel Convention becomes relevant as the Solar PV system contains: (i) PV modules (which may contain trace heavy metals); (ii) Inverters and power electronics; (iii) Cabling and electrical control panels; (iv) Batteries, etc which, at their end-of-life, may qualify as Hazardous wastes; or Controlled electronic waste under national regulations aligned with Basel provisions. For this project, REA commits to:

- Procuring certified PV modules compliant with IEC standards;
- Implementing an End-of-Life Management Plan;
- Engaging licensed waste handlers approved by national authorities;
- Preventing uncontrolled disposal of electronic components.
- Use of long-life (25-year) modules;
- Minimizing the use of hazardous materials;
- Deployment of modular inverter systems to reduce replacement volumes;
- Requiring suppliers to provide take-back guarantees; and
- Inclusion of contractual clauses for recycling·

These satisfy the Convention as it requires environmentally sound waste management and Waste Minimization Principles.

- **World Bank Environmental and Social Safeguards (or Standards) (ESS) 2018**

The term "Environmental and Social Safeguards (or Standards)" (ESS) refers to policies, standards, and operational procedures designed to identify, mitigate, and minimize adverse environmental and social impacts that may arise during the implementation of development projects. Compliance with the ESS ensures the project is bankable under World Bank or AfDB financing. It also strengthens the credibility of your ESIA by aligning with international best practices as while as demonstrating that the project is environmentally sustainable, socially responsible, and institutionally transparent.

In Nigeria, certain ESS Instruments such as Environmental Impact Assessment (EIA), Environmental Auditing (EA), Environmental Protection and Rehabilitation Program (EPRP), Decommissioning Planning, Environmental Compliance Monitoring Program and Community Development Agreement (CDA) are used to avoid, mitigate and compensate for the impacts associated with the mining sector. Each of the aforementioned safeguards instruments is administrated by one oversight government agency or the other. Importantly, applicable ESS safeguards instruments are documented in reports which are submitted, reviewed and cleared by the appropriate regulators.

- The World Bank's Environmental and Social Framework (ESF), which introduced the Environmental and Social Standards (ESS) in 2016. However, the official adoption of the ESS was in 2018, which is highly relevant to the proposed 1-MW Solar PV Power project at NOUN Main Campus. These standards provide the safeguard requirements that projects must meet to qualify for World Bank financing or alignment. Key ESS Provisions and Application to the project are:

- ESS1 – Assessment and Management of Environmental and Social Risks: Requires a comprehensive Environmental and Social Impact Assessment (ESIA). In conformance with the stipulations, of the EIA Act CAP E12 LFN 2004, REA conducted an ESIA with baseline studies, stakeholder consultations, and an Environmental and Social Management Plan (ESMP). This ensures risks like dust, noise, waste, and occupational hazards are identified and mitigated
- ESS2 – Labor and Working Conditions: Protects workers' rights, health, and safety. Workers must have PPE, fair contracts, grievance mechanisms, and safe working conditions. It shall align with the OHS plan for the project.
- ESS3 – Resource Efficiency and Pollution Prevention: The project shall minimize pollution while promoting efficient use of energy and materials. The adoption and installation of the Solar PV Power shall ensure reduction of greenhouse gas emissions. A robust Waste Management Plan shall also be incorporated for the project to ensure compliance.
- ESS4 – Community Health and Safety: Addresses risks to surrounding communities. Noise and dust during construction, electrical safety, and fire prevention measures shall be adequately covered in the ESMP. Stakeholder consultations with the students and staff of NOUN address community concerns.
- ESS5 – Land Acquisition, Restrictions on Land Use, and Involuntary Resettlement: This applies when land acquisition or displacement occurs but is not triggered here, since the project is on institutional land with no displacement.
- ESS6 – Biodiversity Conservation and Sustainable Management of Living Natural Resources: This requires protection habitats and species. Baseline studies show no endangered species or critical habitats on site. Compliance is straightforward.
- ESS7 – Indigenous Peoples/Sub-Saharan African Historically Underserved Traditional Local Communities: Ensures respect for indigenous peoples' rights. ESS 7 is not triggered, as the project is within a university campus.
- ESS8 – Cultural Heritage: Requires the protection of cultural heritage resources in the project area. ESS 8 is not triggered, as no cultural heritage sites were identified within the project footprint.
- ESS9 – Financial Intermediaries: Recognizes that strong financial markets and financial institutions are important for economic development. It therefore requires Financial Intermediaries to establish systems for identifying, assessing, managing and monitoring the environmental and social risks of the subprojects they finance.
- ESS10 – Stakeholder Engagement and Information Disclosure: This requires meaningful consultation and disclosure. The ESIA ensured that stakeholder consultations with the university management, staff, students, host community, the Federal and Abuja Environmental Protection Board was carried out.

❖ 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 programs, 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: Protecting and conserving biodiversity (including genetic, species, and ecosystem diversity) and its ability to change and evolve, is fundamental to sustainable development. Although site preparation may result in vegetation clearing, this PS is not triggered because the project is on a piece of land with limited sensitive ecological receptors. REA shall ensure minimal habitat loss, conserve biodiversity, restore disturbed areas and prevent unnecessary damage to flora and fauna while promoting sustainable land management.
- PS7 – Indigenous Peoples: Indigenous Peoples are recognized as social groups with identities that are distinct from other groups in national societies and are often among the marginalized and vulnerable. Their economic, social, and legal status may limit their capacity to defend their interests and rights to lands and natural and cultural resources. Even though the project

will be sited within the university, REA ensure that the project activities respect the identity, culture, and natural resource-based livelihoods of Indigenous Peoples and reduce exposure to impoverishment and disease.

- 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 a university land and no known cultural heritage resources have been identified within the project area. It is a safe bet to incorporate a Chance Finds Procedure into construction contracts and implemented throughout excavation work as construction activities may uncover archaeological or cultural materials.

Just as with the World Bank ESS, the project conforms with most of the IFC PS.

1.8.3 FGN Requirements and Relevant Legislation

The Constitution of the Federal Republic of Nigeria (1999), as the national legal order, recognizes the importance of improving and protecting the environment and making provision for it. The relevant sections are:

- Section 20 makes it an objective of the Nigerian State to improve and protect the air, land, water, forest and wildlife of Nigeria;
- Section 12 establishes that international treaties (including environmental treaties) ratified by the National Assembly should be implemented as law in Nigeria; and
- Sections 33 and 34 which guarantee fundamental human rights to life and human dignity, respectively, have also been argued to be linked to the need for a healthy and safe environment to give these rights effect.

The proposed Solar PV Power project and the ESIA study are in compliance with these constitutional mandates.

1.9 Structure of ESIA Report

The format of this report is essentially in line with the recommended format and guidelines by the Federal Ministry of Environment (FMEnv). Accordingly, the report is organized into the nine main chapters and is structured as follows:

Chapter One: *Introduction*
This chapter provides background information about the proposed project and highlights objectives, scope of work for the environmental assessment as well as the applicable legal and administrative framework for the project.

Chapter Two: *Project Justification*
This chapter outlines the project justification, including the need; value/benefits of the project and project development options and alternatives.

Chapter Three: *Project Description*
This chapter describes the proposed project location, project activities and processes involved including exploration, construction, project operation, maintenance and schedule.

Chapter Four: *Description of Existing Project Environment*
This chapter describes the existing (baseline) environmental conditions of the project area including the socio-economic and health status of the inhabitants in the area. Also included are records of consultations held with the stakeholders notably the elders, youths and women in the host communities.

Chapter Five: *Potential and Associated Environmental Impacts*
In this chapter, potential and associated environmental impacts of project activities are identified and evaluated.

Chapter Six: *Mitigation Measures*
This chapter proffers mitigation and ameliorative measures that would be adopted to eliminate or reduce to acceptable levels significant adverse impacts identified.

Chapter Seven: *Environmental and Social Management Plan (ESMP)*
This chapter presents the Environmental and Social Management Plan (ESMP) that will be adopted throughout the project life cycle. It also includes the Environmental Management System (EMS) plan that will ensure the effectiveness of the mitigation measures and the remediation plan after decommissioning. It also presents the activities carried out during the ESIA and an overview of the grievance redress mechanism.

Chapter Eight: *Remediation/Decommissioning Plan*
This chapter briefly presents the details of decommissioning plan at the end of the project life cycle.

Chapter Nine: *Summary and Conclusion*
This chapter presents conclusions and recommendations

CHAPTER TWO

PROJECT JUSTIFICATION

2.1 Introduction

This chapter presents the justification, need, values, benefits, and sustainability measures for the proposed 1-MW Solar Hybrid Power Plant project at the National Open University of Nigeria (NOUN) Main Campus, 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

Nigeria continues to experience a significant electricity supply deficit relative to its growing population and economic demand. Despite an installed generation capacity exceeding 12,000 MW, actual delivered capacity remains substantially lower due to transmission constraints, distribution losses, gas supply limitations, and aging infrastructure. The resulting supply gap has led to widespread dependence on self-generation using diesel and petrol generators, particularly within institutions, commercial establishments, and rural communities. This reliance has contributed to high operating costs, greenhouse gas (GHG) emissions, noise pollution, and localized air quality deterioration. In response, the Federal Government Nigeria set targets to expand electricity access to 75% by 2020 and 90% by 2030, and increasing the minimum renewable energy contribution, as outlined in the National Electric Power Policy (NEPP, 2001) and the Rural Electrification Policy (2005) (RESIP, 2016). In line with these goals, the Rural Electrification Agency (REA) proposes the installation of a 1-MW Solar Hybrid Power plant at the National Open University of Nigeria Main Campus, Abuja - FCT.

Also, access to electricity is a critical driver of poverty reduction and economic development. 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.

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.

2.2.2 Economic Justification

Although the initial capital cost for the installation of a 1-MW 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 NOUN'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.

Also, 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.

2.2.3 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 a university 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 NOUN Main Campus, Abuja 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.

2.3 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 Expected Benefits of the Project

The potential benefits of the proposed project include but are not necessarily limited to the following:

- Improved electricity reliability.
- Reduction in reliance on diesel generators.
- Temporary employment during construction i.e civil construction workers, electrical installation technicians, site engineers, security personnel.
- Renewable energy capacity building.
- Stimulation of academic and research activities within the University as a result of access to constant and reliable power supply.
- Potential improvement in livelihood enhancing activities within the University creating or enhancing education quality, research capacity, campus services etc.

2.5 Sustainability of the Project

The sustainability of this project is discussed under environmental, social, economic and technical sustainability pillars.

2.5.1 Technical Sustainability

Technical sustainability refers to the ability of the project to operate safely, efficiently, and reliably over its intended lifespan (at least 25 years). For the proposed 1 MW solar hybrid plant project at NOUN, the technical sustainability is embedded in the project's procurement structure (ensuring certified equipment/materials are used), engineering oversight, operational framework, and capacity development strategy led by the Rural Electrification Agency (REA).

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 Program (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.

Capacity building opportunities will be also available to University staff who will manage day-to-day operations long-term. After construction, an O&M contractor will operate and maintain the project in collaboration with the relevant university departments, which provides opportunities for the additional training for university staff. Students from related departments could also receive hands-on training on power plant construction, operation, and maintenance' into discussion on the technical sustainability of the project.

2.5.2 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 relevant stakeholders are given the opportunity to contribute their perspectives at an

early stage. This participatory approach enhances inclusiveness, builds trust, and lays a foundation for long-term relationships with the university community, local residents, and other stakeholders.

The preparation of a Stakeholder Engagement Plan (SEP) further reinforces social sustainability by institutionalizing continuous dialogue throughout the project lifecycle. This ensures that stakeholders remain informed, involved, and able to influence decisions that may affect them, thereby promoting transparency, accountability, and project legitimacy.

A Grievance Redress Mechanism (GRM) will also be implemented by the Rural Electrification Agency (REA) to provide a structured platform for receiving and resolving stakeholder concerns in a timely and fair manner. This mechanism will help prevent and manage conflicts, thereby strengthening social cohesion and community trust in the project.

In addition to stakeholder engagement, the project incorporates Occupational Health and Safety (OHS) measures to protect workers during construction and operation phases. These measures include the implementation of a site-specific Health, Safety and Environment (HSE) management plan, routine risk assessments, provision and mandatory use of Personal Protective Equipment (PPE), safety induction and regular training for workers, incident reporting systems, and emergency preparedness and response procedures. Contractors will be required to comply with applicable national regulations and international best practices on occupational safety.

Community Health and Safety (CHS) considerations are also integrated into project planning to protect surrounding communities and university users. Mitigation measures will include control of site access and security, traffic management during construction, dust and noise control, electrical safety precautions, safe handling and storage of materials, and proper waste management practices. These measures are designed to minimize potential risks such as accidents, exposure to construction hazards, and public disturbances.

Overall, the combination of stakeholder engagement, grievance management, occupational health and safety, and community health and safety measures ensures that the project is socially sustainable. These interventions promote inclusiveness, safety, responsiveness, and accountability, while strengthening the project's social license to operate and long-term acceptance within the host community.

2.5.3 Economic Sustainability

The proposed 1-MW Solar Hybrid Power Plant project is economically sustainable because it provides a long-term, reliable and cost-effective electricity supply to the National Open University of Nigeria (NOUN) while significantly reducing dependence on diesel generators and the associated recurrent expenditure on fuel, lubricants and maintenance. Although the project requires a relatively high initial capital investment, the operating costs are comparatively low due to the absence of fuel requirements, limited routine maintenance needs and the long service life of photovoltaic modules, which are typically designed to operate efficiently for 25–30 years. The project will utilize Lithium-Ion batteries which are preferred due to their longer lifespan compared to Lead-Acid batteries, while cheaper upfront, have shorter life cycles and higher maintenance needs.

During construction, the project will also generate short-termed employment opportunities for approximately 31–45 workers with priorities given to locals while on the long term, it shall support capacity building.

The economic sustainability of the project is founded on its ability to deliver long-term dividends including predictable energy pricing, reduced operational expenditure, and enhanced institutional financial stability. In conclusion, by maximizing the utilization of solar energy, reducing peak demand on the national grid and improving overall energy resilience, the project is an economically sustainable investment that will deliver long-term value to the University, the Rural Electrification Agency, and the Federal Government of Nigeria.

2.5.4 Environmental Sustainability

The project has been conceived and designed with environmental sustainability as a fundamental consideration. Unlike conventional thermal power plants, photovoltaic systems generate electricity without combustion, resulting in negligible operational emissions of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM), or other criteria air pollutants. Water requirements during operation are minimal and largely limited to periodic cleaning of photovoltaic modules. The project will also incorporate environmental protection measures including stormwater management, waste minimization, occupational health and safety provisions, emergency preparedness measures, and end-of-life equipment management in accordance with applicable environmental regulations and international good industry practice. These measures are intended to ensure that adverse environmental and social impacts remain minimal, localized, and effectively managed throughout the project lifecycle.

2.6 Project Alternatives

The establishment of the proposed solar power project at NOUN Main Campus -Abuja, requires careful selection of an environmentally and economically suitable site, taking into account land characteristics, meteorological conditions, existing infrastructure, grid connectivity, water availability, accessibility, and shading considerations. Prior to determining the most appropriate solar system for this location capable of matching daily demand with renewable energy generation a comprehensive review of measured data was undertaken by the Front-End Engineering Design (FEED) Consultant. Accordingly, this section focuses specifically on the alternatives evaluated for the proposed project. Since the project is conceptualized as a renewable energy source utilizing Solar Photovoltaic Power (SPV) Systems, discussions on conventional power generation options such as coal-fired, oil-fueled, or natural gas plants have been excluded.

SPV systems utilize semiconductor-based materials (solar cells) which directly convert solar energy into electricity. SPV systems have many attractive features, including modularity, no fuel requirements, zero emissions, no noise and there is no emphatic need for grid connection. SPV systems can be classified according to three principal applications:

- Stand-alone solar devices purpose-built for a particular end use, such as solar High Frequency (HF) radios, solar home lighting systems, or solar coolers. These dedicated SPV systems can either be configured to include some energy storage capacity or directly power electrical or mechanical loads, such as pumping or refrigeration;
- Stand-alone solar power plants, basically small power plants designed to provide electricity from a centralized SPV power plant to a small locality like village or a building; and
- SPV power plants, which are equivalent to any other generator supplying power to the electricity grid.

The PV technology is favourable for project financing due to relatively lower costs than other solar technologies. Also, the existing transmission infrastructure is adequate to deliver the energy produced from the plant and the process involves a simple design with few technical components which reduces operation and maintenance costs and in general makes the plant more efficient. Table 2. 1 indicates

Table 2.1: Potential SPV System Configurations and Design Assumptions based on 4.8 daily hours of peak power output.

Description	SPV Systems		SPV Mini-grid	Large Grid-connected
			Power Plants	SPV Power Plant
Module Capacity	50 W_p	300 W_p	25 kW	5 MW
Life Span Modules	20 Years	20 Years	25 Years	25 Years
Life Span Batteries	5 Years	5 Years	5 Years	NA
Capacity Factor	20%	20%	20%	20%

*(**Source**: REA FEED Projections)*

The discussion on the options considered include Alternative Sites considered and Justification for selection, Alternative to Power Generation, Alternative technology and Battery Selection Options, as well as the Do-nothing option.

2.6.1 Alternative Sites Considered for the Project

The following alternatives were considered during site selection:

Rooftop Solar Installation: Rooftop installations were evaluated but found limited due to irregular roof geometry, limited available contiguous area, and increased installation complexity.

Ground-mounted installation was selected because it offer greater efficiency, scalability as well as easier and safer access for inspection, cleaning and repairs.

Distributed Micro-Solar Installations: A dispersed system across multiple buildings was considered but would increase wiring complexity and complicate maintenance.

A centralized ground-mounted configuration was deemed technically superior, hence, the option for a distributed micro-solar installation was rejected.

The sites were considered good for the project based on the following factors on Table 2.2.

Table 2.2 - Factors for site consideration and selection

Factors	Suitability
Technical Suitability	Both sites 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 combined land area is sufficient for a 1-MW installation.
Environmental Sensitivity	The sites are 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;

Factors	Suitability
Screening	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 locations will not require resettlement, compensation, or livelihood restoration because the sites: Are within university-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 sites 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 1-MW installation, designating and utilizing both locations will ensure that the project remains feasible and actualized.

Source *- Bolben Energy & Environmental Services Limited*
(EIA for the proposed 1MW Solar Hybrid Power Plant at NOUN)

Table 2.3 Environmental Trade-Off Analysis

Option	Environmental Risk	Technical Efficiency	Cost	Social Impact	Overall Suitability
Off-Campus	Moderate	Moderate	High	Moderate	Low
Rooftop	Low	Moderate	Moderate	Low	Moderate
Distributed Micro-Solar Installations	Low	Moderate	High	Low	Moderate
On-Campus (Selected)	Low	High	Moderate	None	High

Source *- Bolben Energy & Environmental Services Limited*
(EIA for the proposed 1MW Solar Hybrid Power Plant at NOUN).

2.6.2 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.

Option C - Installation of Solar Photovoltaic (PV) – Proposed Option: The proposed option involves installation of a 1-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 2.4: 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 (EIA for the proposed 1MW Solar Hybrid Power Plant at NOUN).*

'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.

2.6.3 Panel Technology Alternatives Considered

The panel technologies considered for this project are the mono-crystalline, polycrystalline and thin film panels, this is as a result of its peculiar technology advancement

Option A – Monocrystalline Panels:

- Features: Made from single-crystal silicon, giving them a uniform dark coloured appearance.
- Efficiency: Highest: (18–22%), meaning more power per square meter.
- Pros: Space-efficient, long lifespan, better performance in low light.
- Cons: Higher upfront cost compared to other types.

Option B – Polycrystalline Panels:

- Features: Made from multiple silicon crystals, with a bluish speckled appearance.
- Efficiency: Moderate (15–17%).
- Pros: Lower cost, simpler manufacturing process.
- Cons: Less efficient, requires more land area for the same capacity.

Option C – Thin-film Panels:

- Features: Made by depositing photovoltaic material on glass, plastic, or metal.
- Efficiency: Lower (10–12%), but improving with new materials.
- Pros: Lightweight, flexible, easier installation, good performance in hot climates.

- Cons: Larger area required, shorter lifespan, faster degradation.

Table 2.5: Comparative Analysis between Solar Panel Technology for the project

Panel Type	Monocrystalline	Polycrystalline	Thin Film
Efficiency	High	Medium	Low
Cost	High	Medium	low
Lifespan	Long	Long	Short
Land Requirement	Low	Medium	High

Source *- Bolben Energy & Environmental Services Limited (EIA for the proposed1MW Solar Hybrid Power Plant at NOUN).*

Based on the above comparative analysis, Monocrystalline Solar PV panels is the preferred due to their efficiency, durability, and requiring the least land space. It is therefore the selected alternative.

2.6.4 Solar Batteries Alternatives Considered:

2.6.4.1 Lead-Acid Batteries

Lead-acid batteries are the oldest form of battery with technology dating back more than a century. As a result, lead-acid batteries are a tried-and-true when it comes to storage. Lead-acid batteries are categorized into two types: flooded lead-acid and sealed lead-acid batteries. Compared with newer battery chemistries such as lithium-ion and sodium-ion batteries, lead-acid batteries generally have a lower initial capital cost, making them one of the least expensive rechargeable battery technologies for solar energy storage applications (IRENA, 2017). However, their use is associated with several limitations, including a relatively short service life—typically 3 to 7 years under solar photovoltaic cycling conditions, although service life may reduce to 2 to 6 years under harsh operating conditions or poor maintenance practices (NREL, 2021; Sandia National Laboratories, 2020). In addition, lead-acid batteries generally have a lower permissible depth of discharge (DoD), typically between 50% and 80%, lower round-trip efficiency, lower energy density and higher maintenance requirements than lithium-ion batteries, particularly in the case of flooded lead-acid systems (Rahn & Wang, 2013; IRENA, 2017)

2.6.4.2 Lithium-Ion Batteries

Lithium-ion batteries are a relatively newer rechargeable battery technology compared with traditional lead-acid and nickel-cadmium batteries (Linden & Reddy, 2011; Nitta et al., 2015). Owing to their advanced electrochemical design, lithium-ion batteries offer several performance advantages, including high energy density, high round-trip efficiency, low self-discharge rates, long cycle life and minimal maintenance requirements, making them well suited for renewable energy storage applications (Linden & Reddy, 2011; IRENA, 2017). Their compact size, lightweight construction and superior energy-to-weight ratio have also made lithium-ion batteries the preferred energy storage technology for portable electronic devices such as mobile phones, laptop computers, tablets and electric vehicles (Goodenough & Park, 2013; IEA, 2024). They are efficient, compact and lightweight. One downside to it is, if not properly installed, lithium-ion batteries could experience thermal runaway and catch fire (Finegan et al., 2015; NFPA, 2023).

Lithium-ion (Li-ion) batteries have become the dominant energy storage technology for modern solar photovoltaic (PV) systems owing to their superior technical performance, high efficiency and declining lifecycle costs (IRENA, 2022; IEA, 2024). Compared with traditional lead-acid and nickel-cadmium batteries, lithium-ion batteries offer significantly higher energy density, allowing more electrical energy to be stored within a smaller footprint and lower weight, which is particularly advantageous where installation space is limited, such as institutional campuses

(Goodenough & Park, 2013; Linden & Reddy, 2011). They also have a more mature global manufacturing base, extensive operational experience, higher energy density and broader commercial deployment across residential, commercial and utility-scale Battery Energy Storage Systems (BESS) (IEA, 2024).

2.6.4.3 Nickel Cadmium Batteries

Historically, nickel-cadmium batteries were widely deployed in industrial and utility-scale energy storage applications because of their durability, long cycle life and ability to operate under harsh environmental conditions. However, they have largely been superseded by lithium-ion batteries in modern utility-scale solar photovoltaic projects due to environmental concerns associated with cadmium and the superior technical and economic performance of lithium-ion technology (IRENA, 2017; IEA, 2024).

2.6.4.4 Flow Batteries

Flow batteries are an emerging electrochemical energy storage technology that has reached commercial deployment for stationary energy storage applications, although their market penetration remains considerably lower than that of lithium-ion batteries (IRENA, 2022; IEA, 2024). Similar to sodium-ion batteries, flow batteries are expected to play an increasingly important role in future renewable energy systems, particularly for utility-scale and long-duration energy storage where high durability and operational flexibility are required (IRENA, 2022). One of the principal advantages of flow batteries is their ability to operate at nearly 100% depth of discharge (DoD) without causing significant degradation to the battery system, thereby allowing virtually all stored energy to be utilized while maintaining long operational life (IRENA, 2022; Weber et al., 2011). Furthermore, flow batteries differ fundamentally from lithium-ion batteries because energy capacity and power output are independently scalable.

Although their long cycle life, high safety profile, non-flammable aqueous electrolytes and modular scalability make flow batteries a promising technology for future utility-scale renewable energy storage applications, their relatively high capital costs and lower energy density currently limit widespread deployment compared with lithium-ion battery systems (IEA, 2024; IRENA, 2022).

Table 2.6: Comparison between battery alternatives for the project

Battery Type	Lifespan (Years)	Efficiency	Cost Trend	Best Use Case
Lead-Acid	3 - 5	Moderate	Low	Small off-grid backup
Lithium-Ion	10 - 15	High	Moderate - High	Utility-scale + residential
Flow	15 - 20	Moderate	High	Large-scale, long-duration storage
Nickel Cadmium	15–20	Moderate	High	Large-scale
Sodium - Ion	8 - 12	Moderate	Low	Utility-scale

Source *- Bolben Energy & Environmental Services Limited*
(EIA for the proposed 1MW Solar Hybrid Power Plant at NOUN).

Based on the comparison above, Lithium-ion batteries are the preferred due to their efficiency, availability and applicability (best-use-case). It is therefore the selected alternative.

2.7 Project Development Options:

2.7.1 No Project Option:

The No-Project Alternative assumes that the proposed 1-MW Solar Hybrid Power Plant at the National Open University of Nigeria (NOUN), to be implemented by the Rural Electrification

Agency (REA), will not be developed. Under this scenario, the university would continue relying on existing grid supply supplemented by diesel-powered generators and lose other benefits that accompany the project.

2.7.2 Technical Implications of the No-Project scenario:

- The university would remain dependent on an unstable national grid supply;
- Power outages and voltage fluctuations would persist;
- Diesel generators would continue to serve as backup or primary energy sources;
- Research laboratories, ICT systems, water supply, and security infrastructure would remain vulnerable to power interruptions.

This would compromise energy reliability and constrain academic and operational performance.

2.7.3 Environmental Implications of the No-Project scenario:

- Continued Greenhouse Gas Emissions: Ongoing diesel generator use would produce substantial CO_2, NOx, SO_2, and particulate matter emissions.
- Air Quality Degradation: Persistent combustion emissions may affect local air quality within the campus environment.
- Noise Pollution: Diesel generators produce high noise levels that may disrupt academic activities.
- Fuel Handling Risks: Continued storage and transfer of diesel fuel present risks of spills, soil contamination, and fire hazards

Although the No-Project option avoids temporary construction-related impacts (e.g., minor land disturbance), it results in significant long-term environmental costs. By contrast, the proposed solar PV system produces negligible operational emissions and eliminates on-site fuel handling.

2.7.4 Economic Implications of the No-Project scenario:

- High and volatile fuel expenditures;
- Generator maintenance and overhaul costs;
- Financial exposure to fuel price fluctuations;
- Unplanned operational costs due to equipment failures.

Over a 20–25 year period, cumulative diesel fuel costs would likely exceed the capital investment required for the solar PV plant. Therefore, the No-Project option is economically inefficient in the long term.

Additionally, failure to implement the project would make the university forgo the opportunity to serve as another demonstration site for renewable energy deployment in northern Nigeria and reduce opportunities for renewable energy training and technical capacity building. Furthermore, the No project scenario does not align with Nigeria's commitment to expanding renewable energy and reducing greenhouse gas emissions.

2.7.5 Go ahead with the Project Option:

The proposed 1-MW Solar Hybrid Power Plant at the National Open University of Nigeria should proceed because it will significantly improve electricity reliability for academic, research, and essential campus operations. It will reduce long-term energy costs by displacing expensive and fuel-dependent diesel generation, thereby strengthening institutional financial sustainability. The project will substantially lower greenhouse gas emissions and eliminate on-site fuel handling risks, supporting Nigeria's renewable energy and climate commitments. It also incorporates structured capacity building and technical knowledge transfer to ensure long-term operational sustainability. Overall, the project delivers clear environmental, economic, technical, and social benefits that outweigh its minor and manageable impacts.

Summarily, while the No-Project Alternative avoids short-term construction disturbances, it perpetuates long-term environmental degradation, economic inefficiency, energy insecurity, and missed sustainability opportunities. From environmental, economic, technical, and policy perspectives, the No-Project Alternative is less desirable than the implementation of the proposed 1-MW Solar Hybrid Power Plant project. The assessment therefore justifies project development as the preferred and more sustainable option.

CHAPTER THREE
PROJECT DESCRIPTION

3.1 Introduction

This Chapter provides a comprehensive engineering-level description of the proposed 1-MW Solar Hybrid Power Plant to be developed at National Open University of Nigeria (NOUN) by the Rural Electrification Agency (REA) under the Desert to Power Initiative (Phase II).

The proposed development involves the engineering design, procurement, construction, installation, commissioning, operation and maintenance of a 1-MW Solar Hybrid Power Plant with an integrated Battery Energy Storage System (BESS) within the Main Campus of the National Open University of Nigeria (NOUN), located along the Nnamdi Azikiwe Expressway, Jabi, Abuja, Federal Capital Territory (FCT). The facility will be interconnected with the University's existing electrical distribution network to provide a reliable and sustainable source of electricity for academic, administrative and ancillary facilities across the campus. Based on the high solar resource potential of the Federal Capital Territory, the proposed solar PV system is expected to generate approximately 1.6–1.9 gigawatt-hours (GWh) of clean electricity annually, depending on the final system design and operational performance**.**

The proposed plant would use a renewable method of generating electrical power by converting solar radiation into direct current electricity using silicon panels that exhibit the photovoltaic effect. 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.

3.2 Key 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 power plant will use solar panels fitted on fixed structures (mounts). Photovoltaic (PV) power generation employs solar panels composed of a number of solar cells containing silicone. The solar panels generate electricity in the form of direct current (DC). This DC power cannot be used directly by most appliances or fed into the grid, which requires alternating current (AC). Inverters are installed to perform the conversion from DC to AC. The DC output from multiple panels is first collected and routed through combiner boxes. From the combiner boxes, the DC power flows into the inverter system. The inverter electronically switches the DC at high speed to create a sinusoidal AC waveform. This AC output is synchronized with grid frequency and voltage standards. The converted AC power is then passed through transformers to step up or step down voltage as

required. Once conditioned, the AC electricity is suitable for distribution across the university's internal network. A simple flow diagram Power flow sequence is illustrated as follows:

PV Modules → DC Combiner → Inverters → AC Panel → Step-up Transformer → 11kV Switchgear → Campus Distribution Network.

The main characteristics of the fixed mounted structure is stated in 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
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 Desert to Power Initiative (Phase II) FEED)*

Table 3.2 gives a summary of the project's characteristics and Figure 3.1 shows the electrical configuration of the PV plant.

Table 3.2 Summary of the project's characteristics

Main characteristics	
Location	National Open University of Nigeria, Main Campus, Jabi, Abuja
Rated power (AC)	4180.0 kWac
Peak Power (DC)	5018.3 kWdc
Ratio DC/ AC	1.20
Civil characteristics	
Suitable plot area	0.21 + 0.44 Hectares
Structure type	Fixed structure
Pitch distance	3.04m
Electrical characteristics	
PV modules rating 335.0 - 550 (Wp)	At least 2,000 modules
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 channeled and discharged to natural watercourses as appropriate.
Noise	≤ 15 dB(A) at nearest noise sensitive premises and plant boundary
Roads	An existing single road offering access to the plant will be rehabilitated within the university to link the plants perimeter.

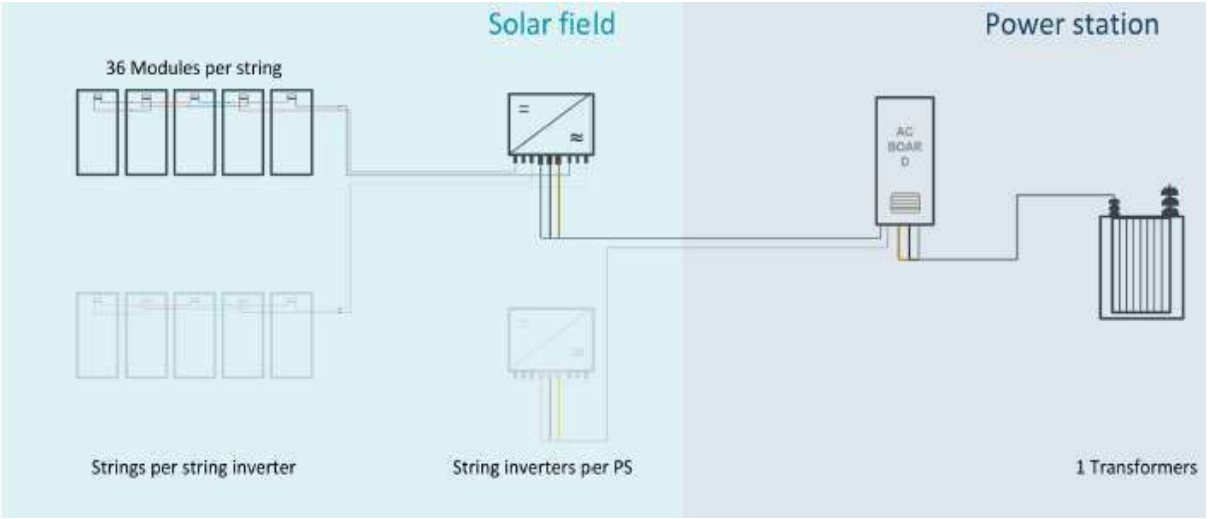


Figure 3.1: Simplified electrical configuration diagram
*(**Source**: REA Desert to Power Initiative (Phase II) Front End and Engineering Design)*

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 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 proposed development will comprise ground-mounted arrays of high-efficiency monocrystalline photovoltaic (PV) modules installed on galvanized steel support structures anchored to suitable foundations within the project site. The PV arrays will be configured to deliver approximately 1 MW of power to the University's electrical distribution network. The specific number of modules would be confirmed during the detailed engineering design.

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 3.2.

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

*(**Source**: REA Desert to Power Initiative (Phase II) FEED)*



Figure 3. 2: Example of a Monofacial Si-poly photovoltaic module
*(**Source**: REA Desert to Power Initiative (Phase II) 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. The inverter adapts itself to the photovoltaic string to get the maximum electrical energy available. This method is called Maximum Power Point Tracking (MPPT). In Figure 3.3, 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 3.4.



Figure 3.3: Example of string photovoltaic inverter
*(**Source**: REA Desert to Power Initiative (Phase II) 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 Desert to Power Initiative (Phase II) FEED)*

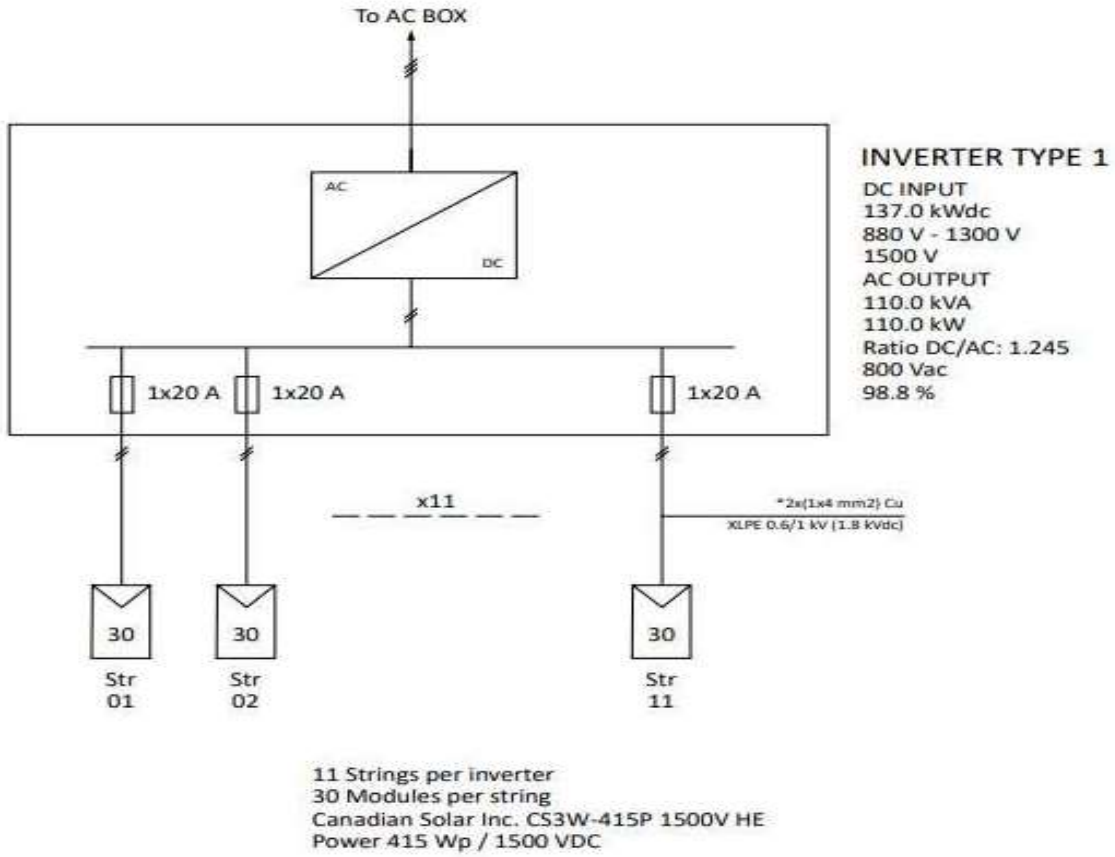


Figure 3.4: String Inverter Single Line Diagram
(Source: Desert to Power Initiative (Phase II) FEED)

Transformers

The proposed 1-MW Solar Hybrid Power Plant will incorporate a step-up transformer to which all inverters will be connected. The role of the transformer is to step- up the voltage from an inverter. 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 transformer will be equipped with appropriate protection systems, including overcurrent, earth fault and surge protection devices, to ensure safe and reliable operation (IEC, 2021; IEEE, 2015; NREL, 2021).An example of a power transformer is shown in Figure 3.5.



Figure 3.5: Example of Transformer

(Source: REA Desert to Power Initiative (Phase II) 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 Desert to Power Initiative (Phase II) FEED)

Power Station - Control room/powerhouse structure.

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 3.5.



Figure 3.6: Example of a power station
*(**Source**: REA Desert to Power Initiative (Phase II) FEED)*

The power station shall be supplied with medium voltage switch-gears that include one transformer protection unit, one direct incoming feeder unit, one direct out-coming 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 3.6 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 Desert to Power Initiative (Phase II) FEED)*

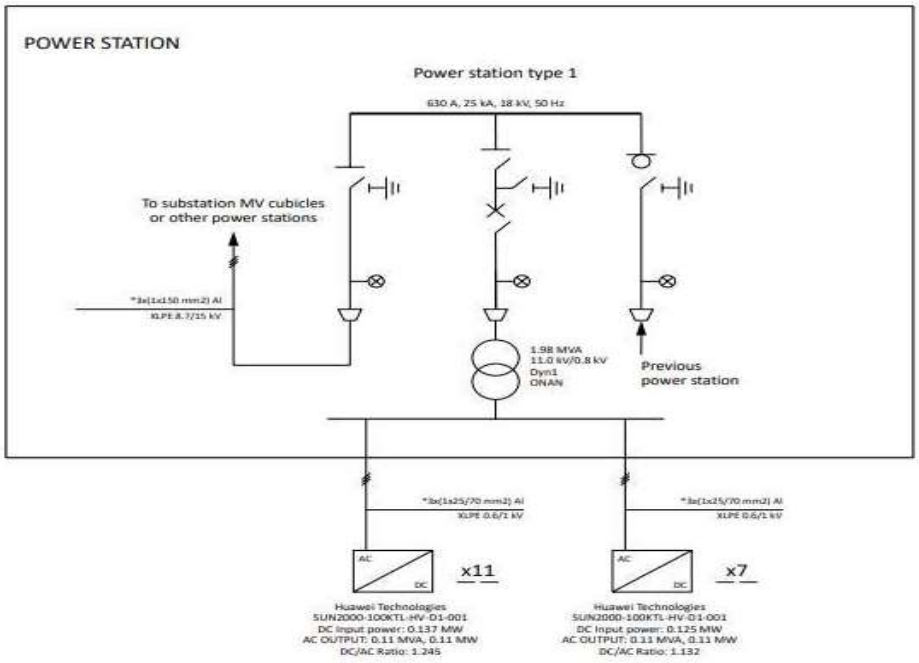


Figure 3.7: Power station Single line Diagram
*(**Source**: Desert to Power Initiative (Phase II) FEED*

Access Roads

Gravel paved earth access roads will be created only within Site 1. Site 2, being an already existing car park, is interlocked. Both proposed project sites are readily accessible through the existing internal road network of the National Open University of Nigeria (NOUN) Main Campus. **Site 1**, located within the northern part of the campus, is served by the adjoining internal campus road and can be accessed through the existing route connecting the surrounding Faculty buildings and the nearby power/substation area. **Site 2**, situated within the University's central/main car park, has direct access from the paved internal road network serving the Senate Building, Central Library, Convocation Arena and other adjoining facilities. Consequently, construction of new access roads is not anticipated, although temporary traffic-control arrangements may be required during equipment delivery and construction activities. At the wider project-area level, access to the University is provided through the **NOUN Main Entrance and the NOUN–EFCC Road**, which connects with Abdulrasheed Na'Allah Way and the adjoining Kado–Galadima road network. These existing roads provide adequate vehicular access for personnel, construction materials and equipment associated with the proposed project.
A typical road cross-section illustrating the general configuration of the existing/project access arrangement is presented in Figure 3.8 below.

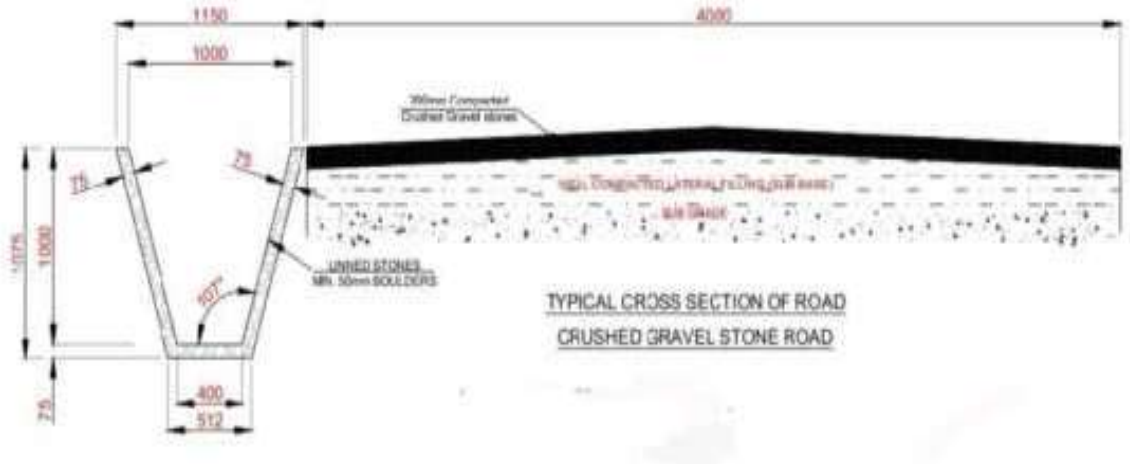


Figure 3.8: Typical Road Cross Section
*(**Source**: REA NEP 3 FEED)*

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.

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.

Transmission Line

The following are the existing utilities currently serving NOUN Main Campus:

- Number of distribution transformers: 8
- 500 kVA transformers: 7 units
- 300 kVA transformers: 1 unit
- Total installed transformer capacity: 3,800 kVA (3.8 MVA)
- Primary supply voltage: 11 kV
- Secondary distribution voltage: 415 V
- Incoming utility supply: 33/11 kV Injection Substation feeding the campus through Ring Main Units

The proposed 1-MW Solar Hybrid Power Project will be integrated into the existing 11-kV campus distribution network. The existing transformer arrangement provides multiple distribution points, enabling the solar plant to inject power into the campus network without requiring extensive modification of the downstream low-voltage infrastructure, subject to a detailed load-flow, protection coordination and interconnection study. The power generated from the proposed solar power plant would be evacuated through the 11-kV transmission line to the university load center through underground cable. The path for the underground cable will be beside the existing road. Each transformer supplies a feeder pillar, which then distributes electricity through the campus low-voltage network to clusters of buildings. Figure 3.8 is single line diagram showing the distribution network layout at NOUN, Main Campus indicating that these feeders collectively serve the University's:

- Administrative buildings
- Senate and Registry complex
- Faculties/Departmental Buildings
- Library
- ICT/Data Centre
- Staff offices
- Utility buildings
- Worship Centres
- Other ancillary campus infrastructure.

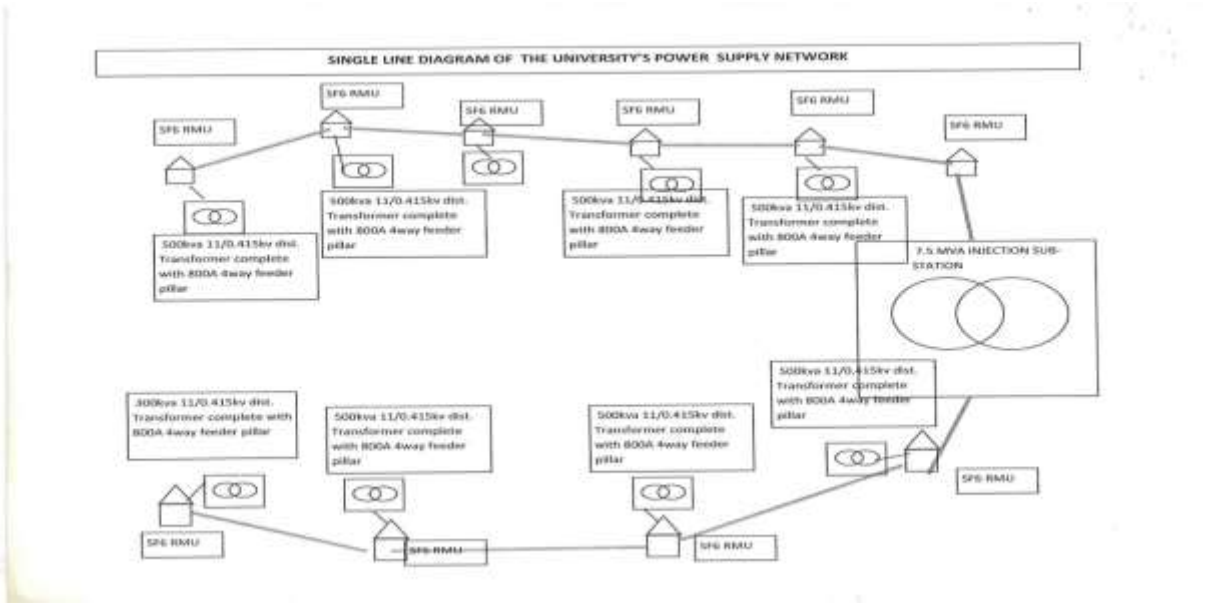


Figure 3.9: NOUN 11kv Distribution Network Layout
*(**Source**: Desert to Power Initiative (Phase II) FEED)*

3.3 Project Phases for Implementation

The project will be implemented in four major phases:

3.3.1 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 university operations and ensure compliance with environmental and safety requirements.

Table 3.7: 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.

3.3.2 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.

3.3.3 Operational Phase

***Electricity generation*:**

During the operation phase, the 1-MW Solar Hybrid Power facility at National Open University of Nigeria 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.

Preventive and corrective maintenance:

To enhance the performance and reliability of the plant during the system's estimated 25-year life cycle, maintenance of the system would be required. 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 (5nos) 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.

Additionally, 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.

3.3.4 Decommissioning Phase

Although the proposed 1-MW Solar PV facility at the National Open University of Nigeria 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 3.8: Breakdown of the Estimated Workforce for 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 Requirement

During the pre-construction and construction phases, water demand for the proposed project is expected to be relatively low compared with conventional infrastructure developments. Water will primarily be required for domestic use by the construction workforce, dust suppression on access routes and work areas, preparation and curing of concrete for module mounting structures and equipment foundations, and occasional cleaning of construction equipment and photovoltaic (PV) modules prior to commissioning. As the proposed development involves predominantly modular installation works with limited reinforced concrete construction, overall water consumption is anticipated to be modest.

During the operational phase, water will be required primarily for cleaning of the photovoltaic (PV) modules to remove dust, bird droppings and other deposits that may reduce energy generation efficiency. The quantity of water required will depend on the level

of soiling, prevailing weather conditions, module configuration and the adopted cleaning schedule. Water requirement is approximately 2–5 litres per module per bi-monthly.

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. 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. 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..

3.7 Health, Safety and Environment (HSE)

Health, Safety and Environment considerations shall be integrated into the planning, construction, operation, maintenance and eventual decommissioning of the proposed solar-hybrid power project. The principal objective of the project HSE framework is to prevent occupational injuries and illnesses, protect workers, contractors, National Open University of Nigeria staff, students, visitors and other stakeholders, prevent environmental pollution, and ensure compliance with applicable Nigerian legislation, Rural Electrification Agency requirements and international good industry practice.

Engineering, procurement and construction (EPC) contracts are the most common form of contracts for the construction of solar PV power plants. Occupational health and safety (OHS) is an issue shall be properly managed during construction in order to minimize the risk of preventable accidents leading to injuries and/or fatalities. Proper OHS risk identification and management measures should 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 Health, Safety and Environment (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.

Detailed occupational health and safety requirements for project implementation are presented in the Occupational Health and Safety Plan under **Section 7.5.4** of this report.

3.8 Emergency Shut-Down Measures

Solar PV facilities are generally low-risk installations but the presence of high DC voltages, grid interconnection infrastructure, inverters, battery energy storage systems necessitates 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 University Safety Unit and local fire services to ensure familiarity with the facility layout and shutdown procedures.

3.9 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 3.9: 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)*

3.9.1 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 3.10: 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 m³	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 3.11: 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 3.12: 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
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

3.10 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 3.13 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 3.10 is a typical EPC Construction Phase to Handover Protocol.

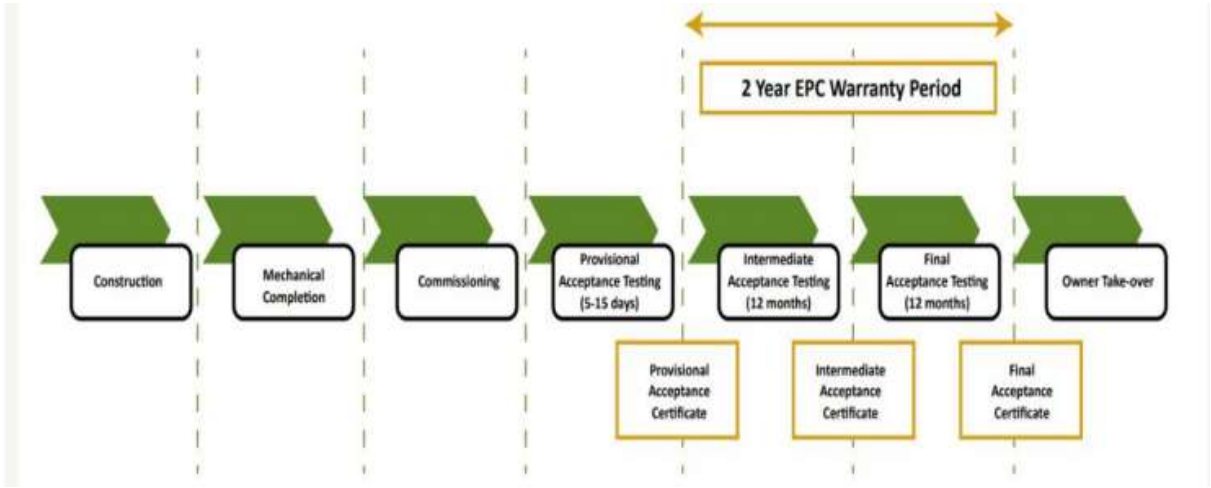


Figure 3.10: Typical EPC Construction Phase and Handover Protocol
*(**Source**: Desert to Power Initiative (Phase II) FEED)*

CHAPTER FOUR
DESCRIPTION OF THE EXISTING ENVIRONMENT

4.1 Background

This chapter presents a description of the environmental and social (biophysical, health and social) setting of the study area and its environs for the proposed 1-Megawatt (MW) Solar Hybrid Power project which shall be sited within the premises of the National Open University of Nigeria (NOUN, Main Campus), Jabi, Abuja against which the potential and associated impacts of the proposed Project have been assessed. The field and desktop investigations are detailed in each relevant section.

4.2 The ESIA Study Approach

A multi-disciplinary approach was adopted in gathering the environmental and socio-economic data of the proposed project area. The data sources for the environmental and socio-economic characteristics of the proposed project area were obtained using desktop research, field observation, review of online sources and analytical measurement of the soil, water, air and noise components using in situ-measuring instruments and laboratory analysis. Data for the environmental description of the project area were based on field data gathering (primary data) as well as a desk-based review of relevant literature (secondary data). Data from literature review were obtained from the existing reports of environmental studies around the proposed project area.

4.2.1 Desktop Research

The desktop research reviewed published literature including previous reports, existing studies, sources from websites, data portals by the governments, and academic and research institutions. The research collected recent information on studies and activities in the proposed project area. The demographics of the population and the biodiversity were also complemented by information gathered from literature, the survey that was carried out and that gathered from University Staff. The data obtained include maps, demographic data and climate data of the area.

4.2.2 Field Visit and Data Gathering Exercise

In line with the activities recommended by the Federal Ministry of Environment and for Environmental & Social Impact Assessment (ESIA), a field visit was planned in order to meet with the stakeholders, view the proposed site and carry out environmental baseline studies of the project area. A socioeconomic survey was conducted within the school premises to evaluate how the project could affect the local environment and people as well as their perception, fears and expectations.

A one-season fieldwork was embarked upon during the wet season for the biophysical as well as social and health studies and complemented with secondary data for dry season obtained from the FMEnv approved, Final Environmental & Social Management Plan for the Construction of Africa Centre for Excellence on Technology Enhanced Learning (ACETEL) Centre Jabi Abuja by Africa Higher Education Centers Of Excellence in conjunction with National Open University Of Nigeria, 2022. Sampling locations were identified using a satellite imagery of the project area and were selected to cover the land area as much as possible for the proposed project. The basis of the sampling design was informed by a preliminary characterization of the project area through desktop research and nearby sensitive receptors. This was to ensure a proper representativeness of the field samples collected, the sampling approach employed included simple random and systematic sampling,

based on the environmental components to be surveyed. The environmental components covered include topography, climate/meteorology, air quality and noise levels, soil, vegetation, geology, socio-economics, health status assessment and waste management. The sampling points were geo-referenced using Global Positioning System.

Being a 1-MW Solar Hybrid Power facility, the Area of Influence (AoI) is expected to be limited and localized, given the small footprint and low-impact nature of solar technology. The primary AoI comprises the project footprint, temporary construction areas, equipment laydown areas and immediately adjoining portions of the NOUN campus expected to experience direct physical disturbance during project implementation. The secondary AoI encompasses surrounding academic buildings, administrative facilities, internal roads, pedestrian walkways, utility corridors, drainage channels and other institutional infrastructure that may experience temporary impacts associated with construction traffic, noise, dust generation or utility integration. A 1-km radius spatial boundary was established for the bio-physical and socio-economic aspects of the EIA study.

4.2.2.1 Minutes of Stakeholder Consultation Meetings

These minutes document the reconnaissance visit and site-verification engagements held with NOUN management, regulatory representatives, and the ESIA consultant team in relation to the proposed 2 MW Solar Photovoltaic Power Project at the NOUN Jabi Campus, Abuja-FCT.

DAY 1: RECONNAISSANCE VISIT	
Date	Friday, 3 July 2026
Time	10 a.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 Director of Project and Planning, NOUN, Jabi, Abuja-FCT.
Participants	• Director of Project and Planning, NOUN • Principal Architect, NOUN • ESIA consultant team
PROCEEDINGS	

Introduction

The consultant **team**, led by **Ms. Mariam Mopelola M**., conducted a scheduled reconnaissance visit to the proposed project location at the NOUN Jabi Campus as a preliminary site-familiarization exercise. The team met with the institution's management, led by the Director of Project and Planning, **Dr. Sadiq O. Shuaib**, and the meeting was held in his office.

Aim

The aim was to establish a working relationship with the institution's management, assess the suitability of the proposed site for the project, and gather relevant project information ahead of the formal site analysis to be witnessed by the Federal Ministry of Environment (FMEnv).

Welcome Address/Presentation

The DPP, giving a welcome address on behalf of the Vice-Chancellor (VC), thanked the Rural Electrification Agency (REA) and the consultant, BOLBEN LTD, for the initiative. He stated that the proposed project would support the institution in several ways, particularly by reducing the cost of fuel purchases for its approximately 18 generators. He also expressed the institution's excitement that the project would provide constant and clean energy, among other benefits. The DPP further briefed the team on the institution's system and management hierarchy, infrastructure, energy infrastructure, and energy consumption. He then invited the Principal Architect, **Arc. Aisha Alfa**, to present the institution's Master Plan showing the proposed project sites and other relevant information.

The Principal Architect presented the university's Master Plan showing the proposed project sites with brief explanation.

Afterward, the consultant presented an overview of the proposed project, including its objectives and benefits. The presentation focused on the relevance of the Environmental and Social Impact Assessment (ESIA) to the project, covering the ESIA process, objectives, and relevant institutional considerations.

Afterward the team proceeded to the proposed sites for an inspection.

Observations.

Site **1** is about 0.44 ha, a reclaimed land, located directly opposite the faculty of management sciences. The **Site 2** is about 0.21 hectares, it is a car pack, fully interlocked located directly opposite the Admin Block 2. It is about 218m away from Site **1.**

The team observed that the 2 proposed sites are not up to the 10 hectares land requirement for the proposed project, hence the project capacity and design as to be re-evaluated to suit the available land size. Perhaps, consider roof top option.

Resolutions

The teams returned to the meeting venue for a recap. The institution's management was reminded of the next scheduled activities, namely the site-verification and data-gathering exercises to be witnessed by the Federal Ministry of Environment (FMEnv) and the relevant Abuja environmental regulatory agency.

DAY 2: SITE VERIFICATION	
Date	Monday, 6th July 2026.
Time	10 a.m.
Venue	Office of the Director of Project and Planning, NOUN, Jabi, Abuja-FCT.

Participants	• Vice Chancellor, NOUN • Director of Project and Planning, NOUN • Principal Architect, NOUN • Representatives of the Federal Ministry of Environment (FMEnv) • Representative of Abuja Environmental Protection Board (AEPB) • ESIA Consultant team

Introduction

On arrival for the site-verification and baseline-data-collection exercises, the team held a brief meeting at the DPP office where each team was introduced by their team lead. The **regulator's team** (FMEnv & AEPB), The **consultant team** (BOLBEN LTD), and the **NOUN Management** team.

Aim

The aim is to gather relevant information both desktops review and existing social and environmental information of the existing proposed project location. To as well enlighten the institution on the processes, procedures and importance of the ESIA.

Welcome Address/Presentation

The DPP formally welcomed the teams on behalf of the Vice-Chancellor and explained that the Vice-Chancellor was attending to official management duties but would meet with the team shortly.

The regulator team led by **Mrs. Esther Njoku** presented an overview of the ESIA, including its requirements, objectives, aims, and processes. She stated that the project aligns with the Ministry's mission on clean-energy and climate-change agenda among others. She then requested a presentation of the proposed project.

The Consultant presented the project overview covering environmental and technical matters. This includes the project design, components of the solar facility, proposed layout and installation of solar panels, plant generating capacity, associated infrastructure, and the university's existing infrastructure, site conditions, operational environment, current electricity demand and consumption. The master plan was showing the proposed project sites including the total land size was further presented by the **Architect**.

The **teams** then proceeded to the sites for verification and data gathering.

At 1 p.m., while the site assessment was ongoing, the meeting with the **Vice-Chancellor** was conducted. The consultant team leader again presented an overview of the ESIA and the proposed project. The Vice-Chancellor assured the team of his commitment and support for the successful implementation of the project. The meeting was brief and ended at about 1:20 p.m.

Outcomes / Resolutions

Baseline investigations were successfully carried out without hindrance. The assessments covered air quality, noise, water, soil, traffic, and socioeconomic conditions. The team returned to the **DPP's office** for a debriefing, where the **consultant** expressed appreciation to the institution's management for its support and participation in the exercise. She further stated that she would remain in contact with the management.

This marks the close of the day's activities. After which the **consultant team** departed.

Key action points arising from the engagements were as follows:

- the project capacity and design should be reviewed against the available land area;
- the rooftop option should be considered as a possible alternative or complement; and
- the consultant team should maintain communication with NOUN management as the ESIA process progresses.



Plate 4.1: Reconnaissance Visit Meeting (NOUN Representative Team and Bolben Ltd Team)



Plate 4.2: Site Verification Visit Meeting (NOUN Representative Team and Bolben Ltd Team at the office of the DPP)



Plate 4.3: Site Verification Visit Meeting (NOUN Vice-Chancellor, DPP and Bolben Ltd Team)

See ***Appendix VI*** for more photographs of stakeholder engagements.

4.2.2.2 Field Sampling Equipment and Materials

The environmental baseline survey was undertaken using appropriate field sampling, measurement, documentation and safety equipment. The principal equipment and materials used included handheld Air Quality meters, digital camera, measuring tapes, field notebooks, water-sampling bottles, cooler box, a multiparameter water-quality meter, soil augers, hand trowel, sample-storage bags, questionnaires and personal protective equipment. These items supported the accurate identification of sampling locations, collection and preservation of environmental samples, in-situ measurement of selected parameters, field documentation and protection of personnel during the survey.

The complete list of the field sampling equipment and materials, together with their respective purposes, is presented in **Appendix XI**.



Plate 4.4: Photograph of Sampling Equipment

4.2.3 Laboratory Analysis of Field Samples

Samples were transported to Bio-Metrics Geo Consult, at 4, Rachael T. Owolabi Street, Gaduwa, Abuja, for analyses after the fieldwork exercises. Samples were analyzed using standard analytical methods. The synoptic descriptions of the laboratory analytical methods and procedures employed for the various physical, chemical and biological parameters as well as the detection limits of these parameters are documented in this report. Also documented is a synopsis of the QHSE plan adopted in both field data collection and laboratory analysis.

General Quality Assurance and Quality Control Measures in Field Survey

Quality Control remains an integral part of environmental assessments, reinforcing the credibility of the collected data and subsequent analytical results. The Quality Assurance and Quality Control (QA/QC) procedures adopted in this study were designed to prevent errors arising from improper sampling techniques, inadequate sample preservation, incorrect labeling and transportation issues. These procedures were applied to every stage of the study, including sample collection, handling, laboratory analysis, data coding and processing, statistical analysis, and the presentation and communication of results. The analytical methods used followed Federal Ministry of Environment guidelines and other internationally recognized procedures, ensuring the reliability and integrity of the data obtained.

- **Sample Collection and Handling**

Sample collection and handling procedures to maintain the integrity of samples and enhance the quality of the results, were in accordance with Federal Ministry of Environment. Following procurement, all samples were immediately labeled indelibly, giving details of sampling point, location of sampling, date and time of sampling, name of personnel sampling, etc. To reduce sampling errors, measurements were replicated and a number of spatially distributed samples were composited before sub sampling for analysis. The sample collection and handling procedures are summarized as follows:

- Standard field procedures and methods approved FMEnv were adopted.
- All sampling equipment was maintained in excellent condition, calibrated against international standards and adequate steps were taken to ensure that they function normally.
- Only new and thoroughly washed, rinsed and sterilized sampling containers were used.

- For heavy metal determination, sampling bottles were used and were rinsed with a solution of one-part nitric acid to four parts water, followed by copious amounts of distilled water. Water samples for BOD_5 determination were collected in black oxygen bottles and kept away from light source.
- All parameters without holding time were measured in situ on the field. Samples for other parameters were preserved as soon as they were collected. Dissolved oxygen samples were fixed with Winkler's Reagents; while heavy metal samples were acidified to a pH of about 2 with concentrated H_2SO_4 respectively.
- All samples were adequately labeled to preserve their identity. Label included sample reference code number, source, sampling date, etc.
- All samples were safely packed and transported to the laboratory base.

❖ **Sample Preservation**

To prevent sample contamination and deterioration, all sampling tools and containers were pre-sterilized. Samples were pre-treated and kept in ice-cooled chests (<4°C) during transport to the laboratory, then stored at that temperature in refrigerators until analysis. To ensure accuracy and reliability, parameters with short holding times, such as pH and temperature, were measured on-site, while samples for delayed analyses were preserved by refrigeration (for general water chemistry) and by pH adjustment and chemical pre-treatment (for heavy metals, total hydrocarbons, and dissolved oxygen). Dissolved oxygen samples were acidified to a pH of 2 with concentrated H_2SO_4 and HNO_3, and samples for microbiology were properly stored.

4.3 Physical Characteristics of the Proposed Project Area

The project comprises two designated sites located within the National Open University of Nigeria Main Campus, Jabi, Abuja. Site 1 is a reclaimed and sand-filled area characterized by relatively open ground and vegetation associated with previously disturbed land. Site 2 is situated within the University's existing car park, close to one of the campus access gates. The site is surrounded by prominent administrative, academic and institutional facilities and forms part of an already developed section of the campus.

The existing physical conditions and surrounding features of both proposed project sites are shown in Plates 4.2a and 4.2b.



Plate 4.5a: View of the proposed project site (Site 1).




Plate 4.5b: View of the proposed project site (Site 2).

4.3.1 General Overview of FCT's Location, Climate and Weather Patterns

This section presents an overview of the climate and meteorological (macroclimatic) data for the project area, including relative humidity, temperature, cloud cover, solar irradiation, surface pressure, rainfall, and wind speed and direction. It also includes microclimatic data such as air quality, noise levels, topography, geology, surface water, and groundwater. The macroclimatic data covering the period from 2004 to 2025 was obtained from the Nigeria Meterological Agency (NiMet).

The Federal Capital Territory (FCT) is located in the North-Central geopolitical zone of Nigeria - between latitudes 8°25′N and 9°20′N and longitudes 6°45′E and 7°39′E - and occupies a strategic position near the geographical centre of the country. It is adjacent to Niger State to the west, a portion of Kaduna State to the north, and Nassarawa State to the east. The FCT covers an area of approximately 8,000 km² and comprises six Area Councils: Abuja Municipal Area Council (AMAC), Bwari, Gwagwalada, Kuje, Kwali and Abaji. AMAC serves as the seat of the Federal Government and is the most urbanized Area Council of the six. (National Bureau of Statistics, 2023; Federal Capital Development Authority, 2024). The FCT lies within the Northern Guinea Savannah ecological zone, characterized by gently undulating terrain, isolated granitic inselbergs and broad plains drained by several seasonal and perennial streams. The vegetation consists predominantly of open woodland interspersed with tall grasses and scattered deciduous tree species, reflecting the transitional nature of the Guinea Savannah ecosystem. The climate of the FCT is tropical wet-and-dry (Aw) under the Köppen climate classification and is characterized by two distinct seasons: a wet season, generally extending from April to October, and a dry season, which typically occurs between November and March. The dry season is influenced by the dry north-easterly Harmattan winds originating from the Sahara Desert, while the wet season is associated with the moist south-westerly maritime air mass from the Atlantic Ocean. Seasonal shifts between these air masses largely determine rainfall distribution, humidity and temperature patterns within the Territory (NiMet, 2025). The FCT receives relatively high levels of solar radiation throughout the year, owing to its tropical location, with average daily global horizontal irradiance generally exceeding 5 kWh/m²/day, together with a well-defined dry season characterized by prolonged sunshine hours, provides favourable conditions for infrastructure development, including renewable energy projects such as ground-mounted solar photovoltaic (PV) installations.

4.3.2 Discussions on the Macro-climate of the FCT

4.3.2.1 Relative Humidity and Temperature

Relative humidity is defined as the ratio of the amount of water vapour present in the atmosphere to the maximum amount the air can hold at a given temperature. Temperature is the measure of the degree of hotness or coldness of the atmosphere and is one of the most important climatic variables influencing the performance, efficiency and longevity of solar photovoltaic (PV) systems. Air temperature directly influences the operating temperature of photovoltaic modules, battery energy storage systems (BESS), inverters and other electrical components, thereby affecting energy conversion efficiency, equipment reliability and maintenance requirements (REA, 2023; IEC, 2016).

From the climatic data for the FCT obtained from the Nigeria Meteorological Agency (NiMet), relative humidity levels in the project area demonstrate a strong correlation with the onset of the rainy season, climbing from a dry pre-rainfall average of around 40% in February during the hot season to upwards of 85% at the peak of the rainy months. This high atmospheric moisture content plays a critical role in determining the cooling requirements for infrastructure and the prevalence of specific micro-climatic conditions.

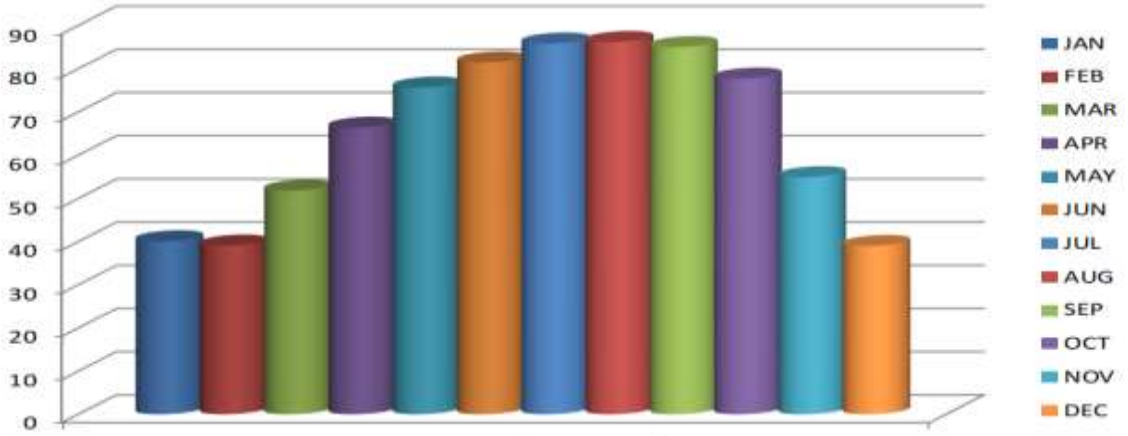


Figure 4.1 - Average Relative Humidity of the FCT (2004 - 2025)
***Source**: NiMet, 2026*

Regarding temperature fluctuations, the average maximum temperature consistently reaches its zenith in March, frequently hovering around 36°C - 37°C, creating high evapotranspiration demands across the FCT. Conversely, the average minimum temperature drops to its lowest point in January around 18°C–21°C, reflecting a temperate shift that affects soil moisture retention and vegetation dormancy periods.
Maximum air temperature is an important design consideration for solar photovoltaic facilities because it influences module operating temperature, conversion efficiency and equipment cooling requirements.

(^{0}c)

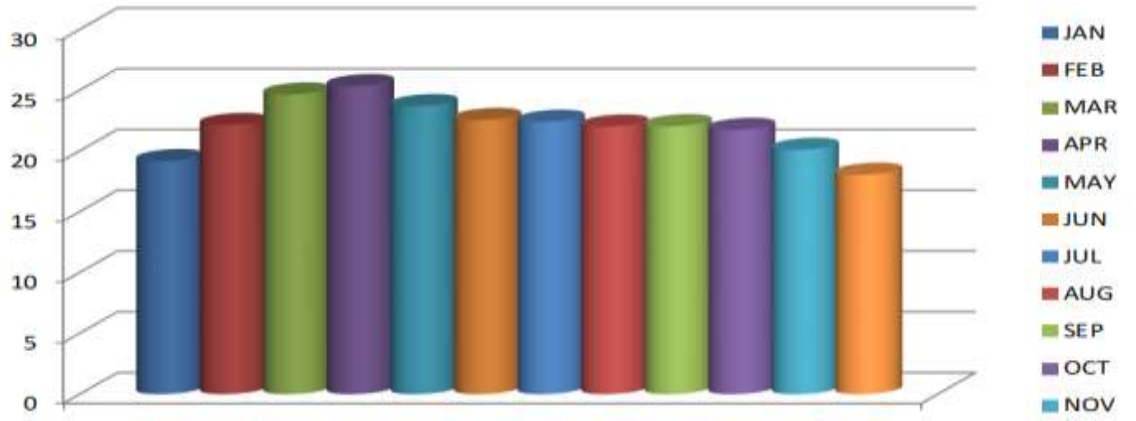


Figure 4.2a - Average Minimum Temperature of the FCT (2004 - 2025)
***Source**: NiMet, 2026*

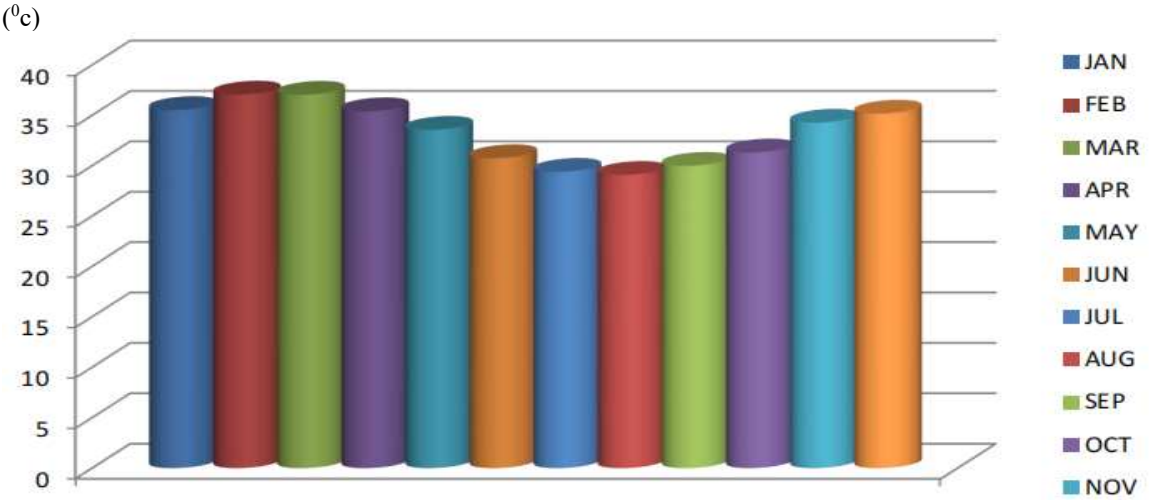


Figure 4.2b - Average Maximum Temperature of the FCT (2004 - 2025)
***Source**: NiMet, 2026*

An inverse relationship exists between temperature and relative humidity. Relative humidity increases progressively with the onset and advancement of the rainy season due to increased atmospheric moisture content, while temperatures decline correspondingly. Conversely, during the dry season, particularly the Harmattan period, temperatures increase as relative humidity decreases under the influence of dry continental air masses. This seasonal pattern reflects the dominance of moisture-laden maritime air during the wet season and dry Saharan air during the dry season.

4.3.2.2 Rainfall

Rainfall is the predominant form of precipitation and is one of the principal climatic variables influencing hydrological processes, stormwater runoff, soil erosion and vegetation dynamics within the Federal Capital Territory (FCT). From historical data, the rainfall regime of the FCT is characterized by a distinct wet season extending from approximately April to October, with maximum rainfall generally occurring between July and September often exceeding 250 mm per month, while little or no rainfall is experienced during the dry season between November and March, with December and January being almost completely dry (NiMet). This cyclical variation significantly influences the local hydrological cycle and groundwater

recharge rates. The total annual rainfall ranges between 1,100 mm and 1,600 mm, with a long-term mean of about 1,350–1,500 mm.

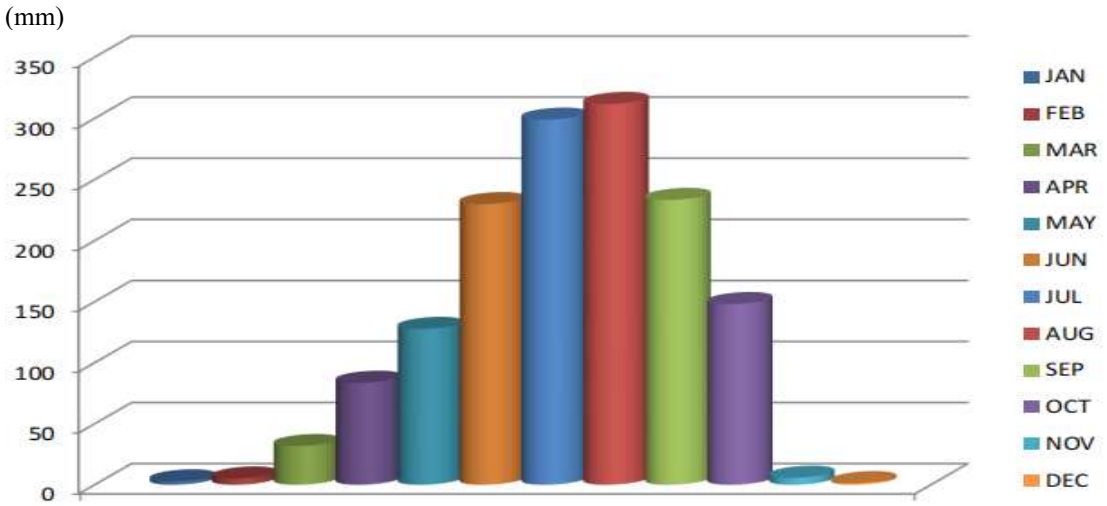


Figure 4.3 - Average Monthly Rainfall of the FCT (2004 - 2025)
***Source**: NiMet, 2026*

4.3.2.3 Sunshine Hours

Sunshine hours refer to the cumulative duration during which direct solar radiation reaching the Earth's surface equals or exceeds the threshold established by the World Meteorological Organization (WMO), and are usually expressed as the number of hours of bright sunshine received in a day. Sunshine duration in the study area exhibits strong seasonal variation, closely tied to cloud cover and rainfall distribution. During the rainy season, heavy cloudiness significantly reduces the number of bright sunshine hours, while in the dry season, clear skies allow for prolonged sunshine exhibiting a bi-modal distribution. This therefore indicates that insolation is relatively constant and sunshine hours high during the dry season and relatively low in the wet season due to large cover of thick convective clouds which pervade the sky during this period.

Long-term climatic data for Abuja indicate that the mean monthly sunshine hours range from a minimum of about 4.6 hours in August (the peak rainy month with heavy cloud cover) to a maximum of about 8.6 hours in November (the early dry season with clear skies). On average, Abuja receives between 6 – 7 hours of bright sunshine per day annually. The abundance of sunshine in the dry months, coupled with relatively high annual averages, provides significant potential for solar energy utilization.
(hrs)

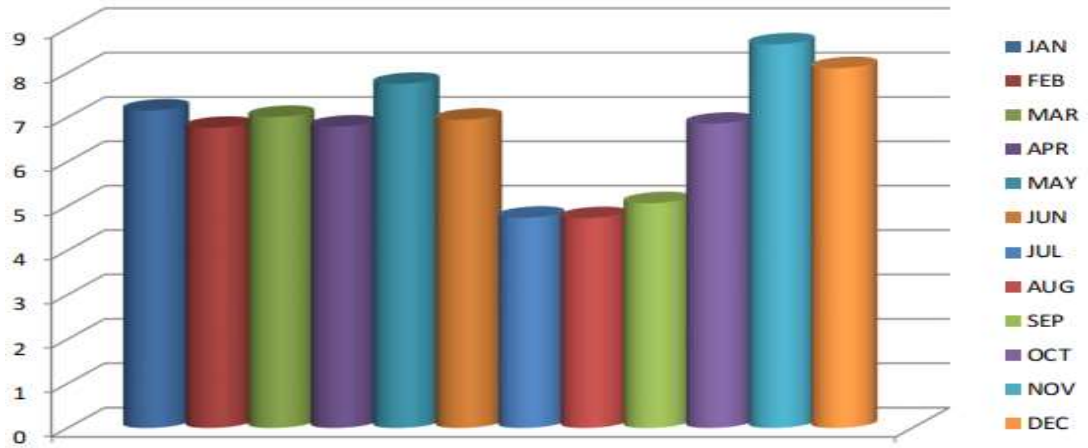


Figure 4.4 - Average Monthly Sunshine Hour of the FCT (2004 - 2025)
***Source**: NiMet, 2026*

Sunshine hours, cloud cover and solar irradiance are interrelated meteorological parameters that collectively have an effect on the quantity of solar energy available for photovoltaic (PV) electricity generation. Cloud cover represents the proportion of the sky obscured by clouds and is an important indicator of atmospheric cloudiness while solar irradiance refers to the amount of solar energy received per unit area of the Earth's surface per day and is expressed in kilowatt-hours per square metre per day (kWh/m²/day). Solar irradiance in the project area shows clear seasonal variability, largely controlled by cloud cover, solar angle, and day length.

Nigerian Meteorological Agency (NiMet), State of the Climate in Nigeria 2024 — reports Abuja averages of 6 –7 sunshine hours daily, with cloud cover ranging from ~20–30% (dry season) to ~45–55% (rainy season) and an average solar irradiance is ~5.2–5.5 kWh/m²/day, confirming strong PV potential. The quantity of sunshine hours, cloud cover and solar irradiance experienced in the FCT indicate that the environment would have sufficient resource for a solar power project including the proposed for NOUN Main Campus, Abuja.

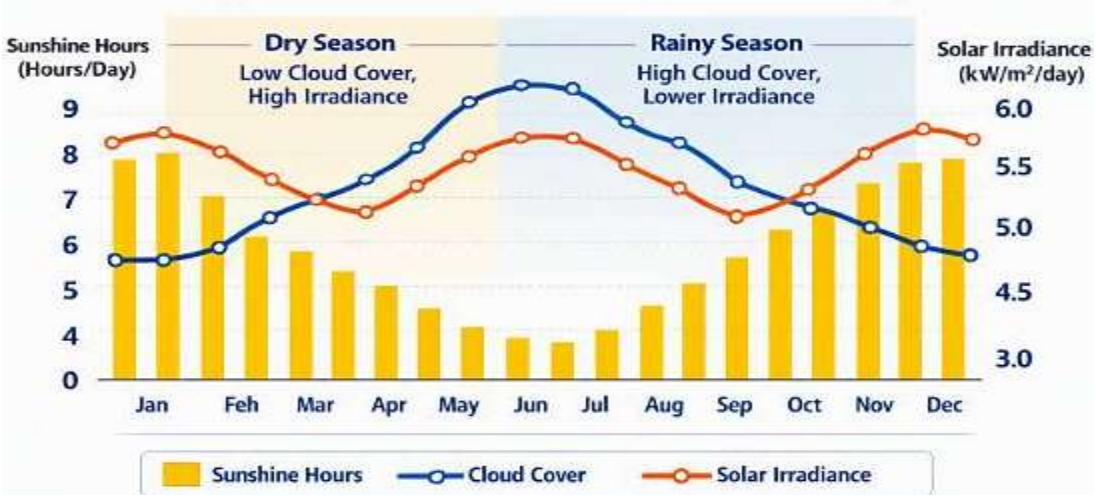


Figure 4.5: A graphical illustration of the Sunshine hours, Cloud Cover and Solar Irradiance in the FCT.
***Source**: NiMet, 2026.*

4.3.2.4 Wind Speed and Direction

Wind speed analysis indicates a steady profile with occasional gusts during the transitional seasons; however, the long-term average remains moderate, facilitating natural ventilation without posing extreme structural risks. These synthesized meteorological parameters from 2004 to 2025 provide a robust baseline for assessing climate resilience and optimizing the engineering design parameters for the upcoming development phases. Unlike other weather elements, wind velocity at the project area is relatively steady. However, there seems to be a slight increase in wind velocity at the onset and cessation of rainfall. This is largely due to the thunderstorms and squally activities associated with the systems. Diurnal wind variation is only of climatological importance if it occurs frequently and regularly. Wind speed direction over Abuja follows the distinctive patterns of the T_c (Northeast) and Tim (Southwest) directions depending on the apparent location of the sun and the dominant of the two. The moisture laden and rain bearing southwesterly wind from the Atlantic predominates during the wet season. The T_c is of less intensity and prevails between December and March. The two major wind patterns are however modified marginally by the warm Benguela Current and the North-East Harmattan winds. Wind velocity is higher over the nights than the days. It ranges mostly between 2ms^{-1} in the morning to about 5ms^{-1} in the night. A mean value of 4.72ms^{-1}, force range of 2-3 beautifort and about 32.5% of calm were recorded. Highest speed is recorded at the onset and offset of seasons when squalls, lightning and thunder accompany torrential rains. Occasionally, this could be in the excess of 10ms^{-1}.

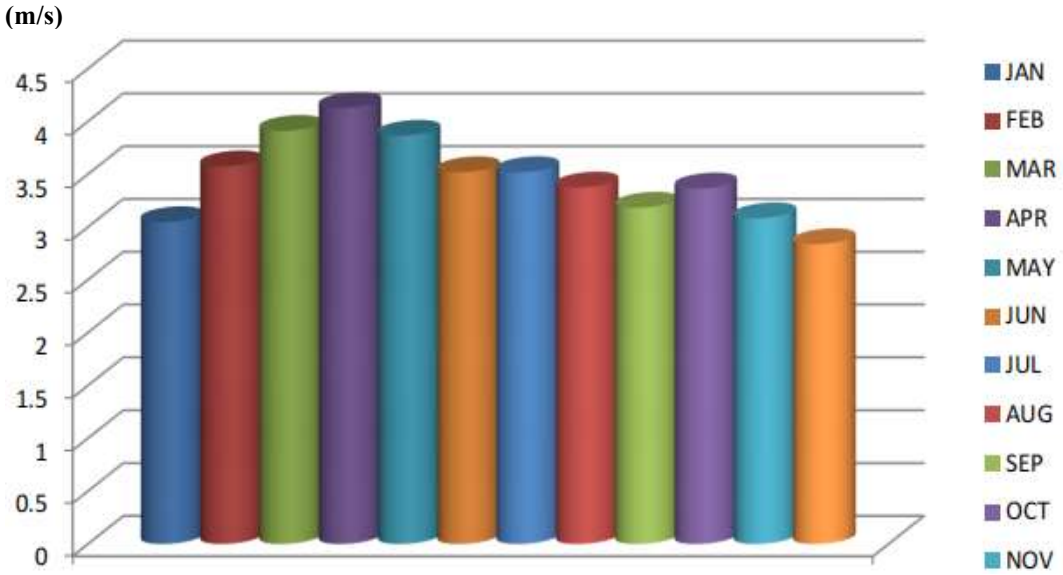


Figure 4.6 - Average Monthly Wind Speed in the FCT (2004 - 2025)
***Source**: NiMet, 2026*

The wind rose diagram for the project site illustrates the distribution of wind speed and direction over the monitoring period. The analysis indicates that the prevailing wind direction is predominantly from the east to east-northeast sector, accounting for the highest proportion of total wind occurrences, with additional significant contributions from the east-southeast direction. This pattern reflects a dominant easterly wind regime, consistent with the influence of continental air masses that characterize northern Nigeria, particularly during the dry season.

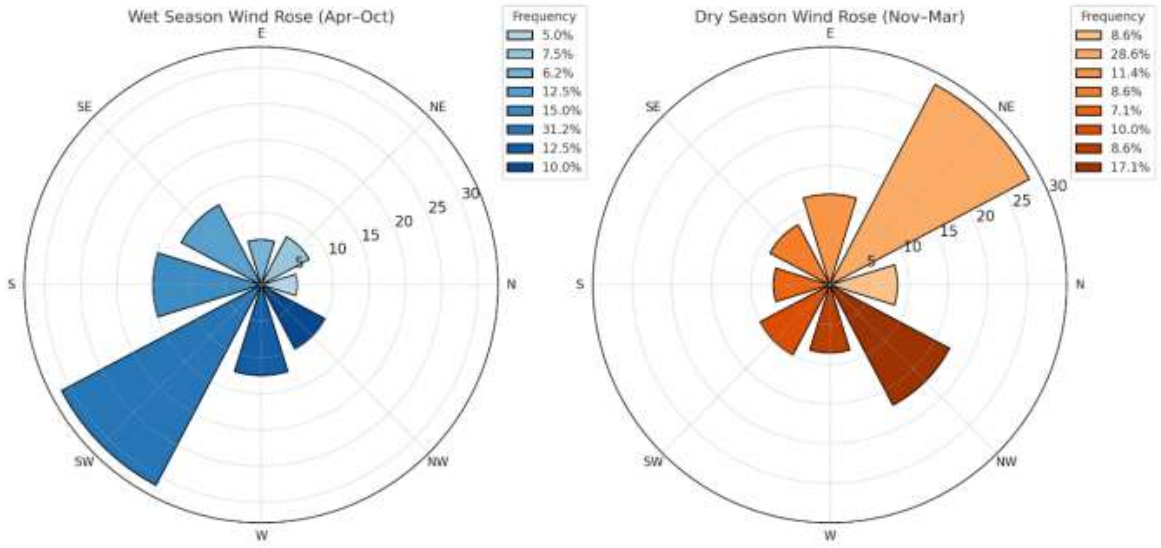


Figure 4.7: Illustration of the Frequency of Direction in the FCT (2004 – 2025)
***Source**: NiMet, 2026.*

For the proposed 1-MW Solar Hybrid Power Project, the prevailing climatic conditions within the FCT provide a suitable environment for reliable solar electricity generation. Although seasonal increases in cloud cover during the rainy season may temporarily reduce photovoltaic output, the incorporation of a Battery Energy Storage System (BESS) and integration with the existing campus electrical network will enhance system reliability by storing excess electricity generated during periods of high irradiance and supplying power during periods of reduced solar availability. This hybrid configuration is therefore expected to provide a stable and resilient electricity supply for the National Open University of Nigeria throughout the year.

4.4 Baseline Study of the Project Area

The baseline study was conducted to establish the existing environmental, ecological, and socio-economic conditions prior to project implementation. Detailed field surveys and sampling were carried out to assess soil quality, vegetation cover, hydrology, and land use patterns within the study area. Maps generated from the sampling exercise provide spatial representation of key features, while photographs document the current state of the terrain and surrounding environment. Findings from this baseline assessment serve as a reference point for predicting and evaluating environmental impacts during construction and operation. The sampling maps and pictures enhances the clarity of the study, ensuring that stakeholders can visualize the existing conditions of the project site.



Figure 4.8: Sampling Map Indicating Groundwater and Surface Water Sampling Locations.



Figure 4.9: Sampling Map Indicating Air Quality and Noise Level Measurement Locations.



Figure 4.10: Sampling Map Indicating Soil Sampling Locations.



Plate 4.6: Air Quality Measurement

See ***Appendix IX*** for more photographs of Air Quality Measurement

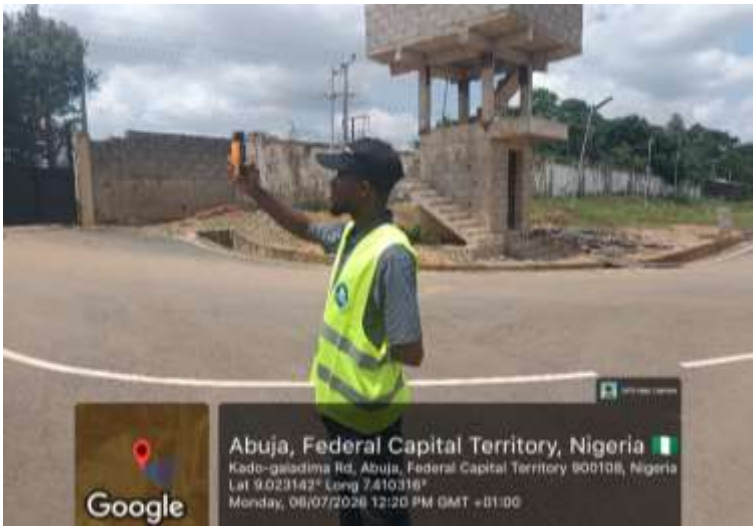


Plate 4.7: Noise Level Measurement

See ***Appendix IX*** for more photographs of Air Quality Measurement



Plate 4.8: Soil Sampling Activities

See ***Appendix VIII*** for more photographs of Soil Sampling Activities



Plate 4.9: Collection and In-situ Measurements of Groundwater.

See ***Appendix X*** for more photographs of Groundwater Measurement



Plate 4.10: Collection of Surface water

See ***Appendix X*** for more photographs

In addition to meteorological data from literature presented in subsections 4.3.2.1 - 4.3.2.4, on-site measurements of relative humidity and temperature were measured recorded during fieldwork. The micro-climatic conditions were assessed through direct field measurements ***(see Table 4.1)***. Data collection was conducted between 10:00 AM and 5:00 PM, coinciding with peak afternoon heat. During the monitoring exercise, the weather was generally cloudy to partly cloudy. This seasonal cloud cover reduced direct solar radiation at several sampling points. Wind conditions reflected the steady south-west monsoon circulation, with light to moderate breezes observed across open sections of the campus. The prevailing airflow contributed to effective atmospheric ventilation, minimizing the risk of ground-level pollutant buildup around the project boundaries. The data revealed a clear inverse relationship between ambient temperature and relative humidity across the fifteen sampling locations. As afternoon temperatures rose, the air's moisture-holding capacity increased, resulting in lower relative humidity values. Built-up areas with concrete and paved surfaces, and limited shading, retained more heat and therefore recorded lower humidity. In contrast, shaded and vegetated areas remained cooler and more humid.

Ambient temperatures ranged from 88.9°F (31.6°C) at AQ1 and AQC1 to 101.0°F (38.3°C) at AQ4, situated between the Faculty of Science and the Faculty of Management Science. Relative humidity values ranged from 63.8% to 73.4%, with an overall campus mean of 69.5%. The lowest humidity (63.8%) was recorded at AQ4, which also registered the highest temperature. Conversely, AQ1 and AQC1 recorded the highest humidity (73.4%) alongside the lowest temperature (88.9°F). This pattern highlights the consistent high-moisture baseline typical of the wet season, providing important context ahead of construction and installation of the solar infrastructure.

Table 4.1: Values for Relative Humidity and Temperature Measured in the Study Area

Latitude	Longitude	Temperature (°F)	Relative Humidity (%)
9.023061	7.410082	88.9	73.4
9.022742	7.410250	100.0	64.9
9.023109	7.410326	95.5	68.6
9.023438	7.409639	101.0	63.8
9.022080	7.410049	97.1	67.2
9.020950	7.409181	93.9	69.9
9.020714	7.408832	93.1	70.6
9.020395	7.408362	91.7	71.8
9.021039	7.408178	95.0	68.6
9.019422	7.408302	94.7	69.1
9.020049	7.407122	93.4	70.3
9.023219	7.410464	88.9	73.4
9.017986	7.408031	94.3	69.5
9.015769	7.410119	90.7	72.8
9.016417	7.412200	92.1	71.4

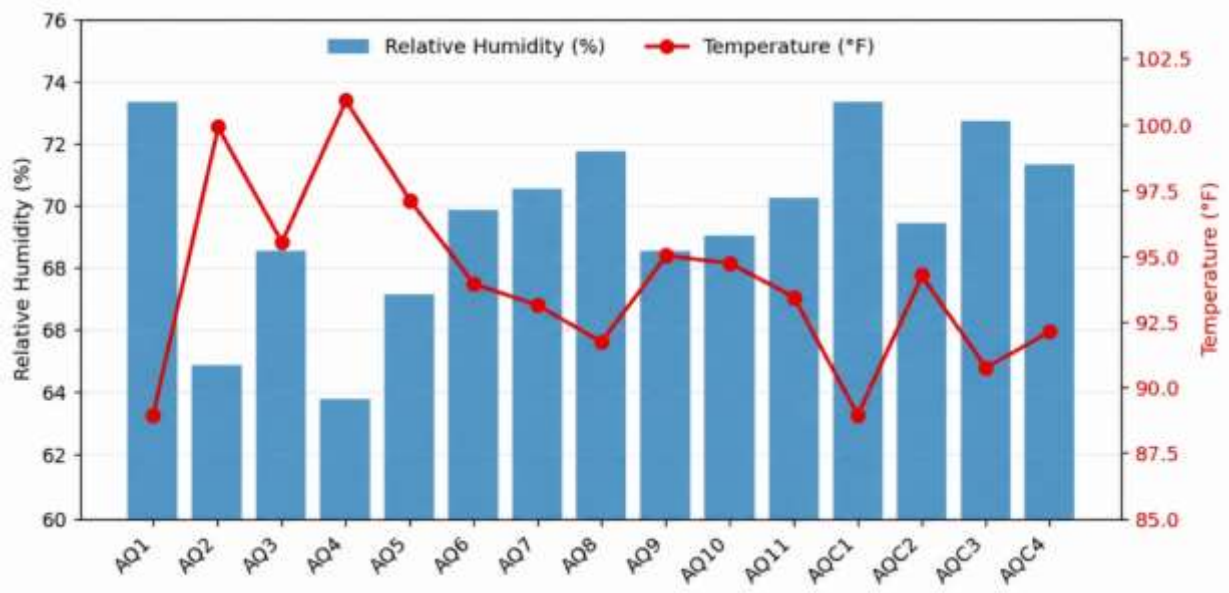


Figure 4.11: Graphical Illustration of Relative humidity and Temperature Measured in the Study Area

4.4.1 Air Quality and Noise Assessment

The quality of air within the project AoI was measured *in-situ* using the equipment listed on Table 4.2. The equipment was calibrated, and each sensor for measuring specific air gases was attached and held at arm's length facing the prevailing wind at each sampling point. After five minutes, the atmospheric concentration of each gaseous pollutant was recorded directly from the equipment's display.

Table 1.2 Detection Limits of 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)

The air quality readings along with the locations and coordinates of each sampling point within the project area and surrounding host communities, are presented on ***Table 4.3.*** The ambient ground-level air quality was assessed using the Air Quality Index (AQI) rating equation established by the United States Environmental Protection Agency (USEPA).

Table 4.3: Ambient Air Quality Level 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	Longitude
AQ1	Soil Sample point one	47	88.9	73.4	0.02	0.11	14.7	25.4	2195	411	20.9	9.023061	7.410082
AQ2	Soil Sample point two	24	100.0	64.9	0.03	0.11	6.9	12.2	1096	445	20.9	9.022742	7.410250
AQ3	Tri-junction between second gate, substation and site A.	38	95.5	68.6	0.04	0.18	9.3	16.1	1383	411	20.9	9.023109	7.410326
AQ4	Between Faculty of social science & Faculty of management science.	44	101.0	63.8	0.02	0.11	10.8	19.1	1692	409	20.9	9.023438	7.409639
AQ5	Besides the open dumpsite and campus main drainage.	46	97.1	67.2	0.01	0.09	11.2	19.2	1793	425	20.9	9.022080	7.410049
AQ6	Soil Sample point one - site B	30	93.9	69.9	0.03	0.13	7.9	13.7	1254	406	20.9	9.020950	7.409181
AQ7	Soil Sample point two	43	93.1	70.6	0.02	0.11	12.3	21.8	2023	431	20.9	9.020714	7.408832
AQ8	Soil Sample point three	43	91.7	71.8	0.02	0.09	10.4	17.3	1607	407	20.9	9.020395	7.408362
AQ9	Centre of the NOUN convocation ground	40	95.0	68.6	0.01	0.03	9.8	17.4	1598	414	20.9	9.021039	7.408178
AQ10	Besides the campus network mast and faculty	41	94.7	69.1	0.01	0.03	8.4	15.0	1405	401	20.9	9.019422	7.408302
AQ11	Between NOUN course material warehouse & media building.	41	93.4	70.3	0.01	0.05	9.9	17.6	1574	410	20.9	9.020049	7.407122
CONTROL													
AQC1	NOUN 2nd Gate	47	88.9	73.4	0.02	0.11	14.7	25.4	2195	550	20.9	9.023219	7.410464
AQC2	NOUN Main Gate	49	94.3	69.5	0.02	0.03	11.8	20.7	1822	406	20.9	9.017986	7.408031
AQC3	NOUN/EFCC Junc./check point	48	90.7	72.8	0.01	0.04	11.8	20.7	1822	2235	20.9	9.015769	7.410119
AQC4	Main Junc. (Kado-Galadima Expressway)	56	92.1	71.4	0.01	0.04	14.5	24.5	2123	2643	20.9	9.016417	7.412200

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	Longitude
Mean		42.47	94.02	69.69	0.02	0.08	10.96	19.07	1705.47	693.60	20.90		
Standard Deviation		7.74	3.50	2.83	0.01	0.05	2.42	4.07	337.80	713.75	0.00		
FMEnv. Limit							250.00	250.00					
WHO Guideline Value							25.00	50.00					
USE-EPA Guideline Value										1000.00			

Source: BOLBEN LTD Fieldwork for the EIA of the proposed 1-MW Solar Hybrid Power Plant at NOUN Main Campus, Abuja, 2026

Results and Discussions on Air Quality Measurement

- ***Gaseous Pollutants and Volatile Organics***

Direct measurements of ambient trace gases indicated a generally clean atmospheric profile across the university environment.

- Formaldehyde (HCHO): Baseline concentrations ranged from 0.01 mg/m³ to 0.04 mg/m³, with a campus average of 0.022 mg/m³. The recorded values were within applicable international public-health reference levels.

- Total Volatile Organic Compounds (TVOC): Measured concentrations ranged from 0.03 mg/m³ to 0.18 mg/m³, with a mean of 0.103 mg/m³ for measurements within the campus. The lowest values occurred within the proposed Site A and Site B footprints, indicating limited influence from traffic or fuel-related emissions at those locations.

- Oxygen and Carbon Dioxide: Oxygen remained uniform at 20.9% at all sampling locations. Carbon dioxide within the campus interior ranged from 401 ppm to 445 ppm, with an internal mean of 413.6 ppm, well below the USEPA reference ceiling of 1,000 ppm.

External control points AQC3 and AQC4 recorded elevated carbon dioxide concentrations of 2,235 ppm and 2,643 ppm, respectively. These localized increases were associated with vehicular emissions, traffic idling and proximity to the Kado - Galadima Expressway.

The absence of hazardous gaseous pollutants (NO_2, SO_2, CO, H_2S) at measurable levels indicates that the NOUN campus environment is not subject to significant air pollution from vehicular traffic, industrial activities, or other major emission sources. This establishes a clean baseline against which construction-phase dust and emissions impacts can be assessed.

- ***Particulate Matter***

Particulate matter (PM) is a key indicator of ambient air quality, as it directly affects human health and environmental quality. Fine particulate matter (PM2.5) and coarse particulate matter (PM10) were measured at all sampling locations.

The ambient concentration of PM2.5 in the project area ranged from 6.9 to 14.7 µg/m³, with a mean concentration of 10.2 ±2.87 µg/m³. All measured PM2.5 concentrations were well below both the WHO guideline value of 25 µg/m³ for 24-hour average exposure and the FMEnv regulatory limit. These low PM2.5 levels are consistent with a campus environment with limited vehicular traffic and minimal industrial dust sources.

Coarse particulate matter (PM10) concentrations ranged from 12.2 to 25.4 µg/m³, with a mean concentration of 17.6 ±4.43 µg/m³ across the sampling locations. These readings also remain significantly below the WHO guideline value of 50 µg/m³ for 24-hour average and the FMEnv limit of 250 µg/m³. The low PM10 concentrations at the baseline reflect the relatively protected campus setting with established vegetation that helps suppress dust generation.

During the project construction phase, particulate matter concentrations are expected to increase temporarily due to site clearing, excavation, material handling, and vehicular movement. The current clean baseline provides a clear reference point for impact mitigation planning and monitoring. Dust suppression measures outlined in the ESMP will be essential to controlling PM emissions and maintaining air quality during construction.

Result of Noise Level Measurement

Ambient noise level measurements were conducted at multiple locations across the NOUN campus to establish the baseline acoustic environment. Noise readings were taken at Site 1 (reclaimed land near the Second Gate and substation), Site 2 (car park area), and at control locations outside the project area of influence.

Ambient noise levels within the proposed project area of the NOUN campus ranged from 46.7 dB(A) to 84.1 dB(A). The measured noise levels represent a mix of campus background noise (classrooms, administrative buildings, outdoor spaces) and intermittent external sources (vehicle traffic from nearby roads, particularly from the Nnamdi Azikiwe Expressway and the junction leading toward the EFCC headquarters).

At Site 1 (reclaimed land near the Second Gate), minimum recorded noise levels ranged from 48.8 to 53.5 dB(A), while maximum readings ranged from 63.6 to 76.8 dB(A). These levels are within the Federal Ministry of Environment guideline of 90 dB(A) for educational areas and are below the WHO recommendation of 70 dB(A) for daytime noise in sensitive environments.

At Site 2 (car park area), noise levels showed greater variation, with minimum readings from 46.7 to 70.7 dB(A) and maximum readings from 69.5 to 84.1 dB(A). The higher readings at control location NLC4 (65.6 to 84.1 dB(A)) reflect proximity to the Nnamdi Azikiwe Expressway and increased traffic volumes along the campus access routes.

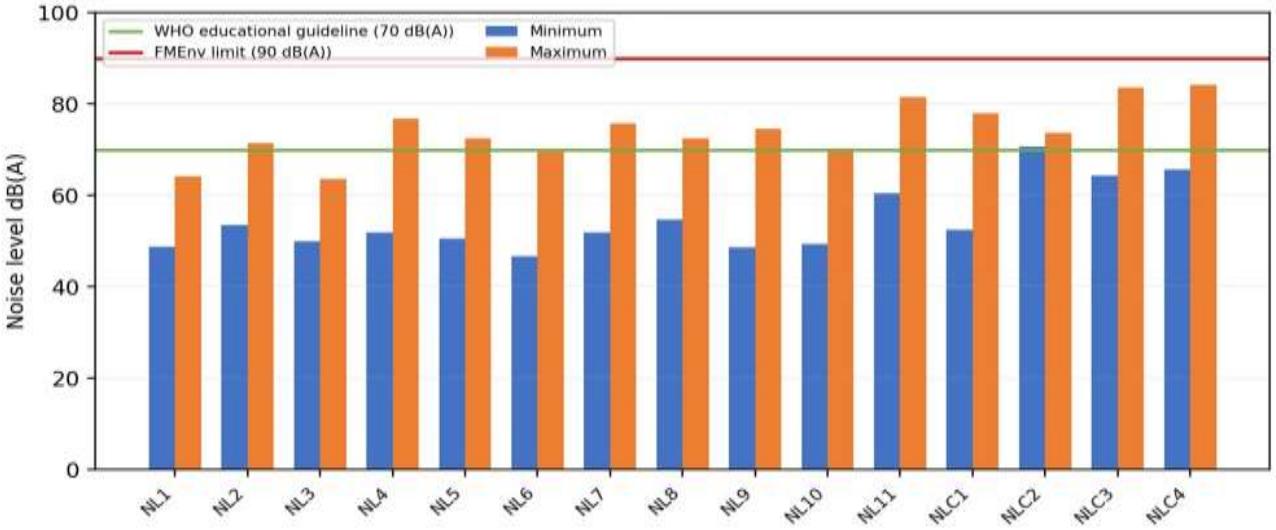


Figure 4:12: Ambient noise level within the study area

Overall, the baseline acoustic environment of the NOUN campus is consistent with that of an academic institution in a semi-urban setting with moderate traffic influence. Daytime noise levels fall within acceptable ranges for educational facilities, though elevated readings at some locations reflect traffic from surrounding roads.

Air Quality Index (AQI)

The instrument-reported AQI values indicate the broad condition at each sampling point. The rating bands and associated health implications are presented in Table 4.4, while the supplied AQI values are summarized in Table 4.5. The specific pollutant and averaging algorithm

used by the meter to generate AQI should be confirmed before the values are used for formal regulatory compliance reporting.

Table 4.4: 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

***Source**: United States Environmental Protection Agency (USEPA)*

Table 4.5: Air quality index of the project area

Sampling Code	Instrument AQI	Level of Health Concern
AQ1	47	Good
AQ2	24	Good
AQ3	38	Good
AQ4	44	Good
AQ5	46	Good
AQ6	30	Good
AQ7	43	Good
AQ8	43	Good
AQ9	40	Good
AQ10	41	Good
AQ11	41	Good
AQC1	47	Good
AQC2	49	Good
AQC3	48	Good
AQC4	56	Moderate

The instrument-reported AQI ranged from 24 to 56. Fourteen of the fifteen locations were within the "Good" category (0–50), while AQC4 recorded 56 and was therefore "Moderate" (51–100). Overall, the baseline was predominantly good at the time of measurement, with the moderate control-location result warranting confirmation and source review. Future monitoring should record the AQI basis, averaging time, instrument model and calibration status alongside the individual pollutant concentrations.

4.4.2 Geology

The geology of the Federal Capital Territory (FCT) forms an important component of the environmental baseline because it influences the engineering properties of foundation materials, groundwater occurrence, drainage characteristics, soil development, slope stability and the suitability of land for infrastructure development. The Federal Capital Territory lies almost entirely within the Precambrian Basement Complex of north-central Nigeria, which forms part of the Pan-African Mobile Belt situated between the West African and Congo Cratons. The Basement Complex was extensively reworked during the Pan-African Orogeny (approximately 600 ± 150 million years ago) and is composed predominantly of high-grade metamorphic and igneous rocks that constitute the oldest geological formations in Nigeria (NGSA, 2025). The principal rock units underlying the FCT comprise migmatite-gneiss complexes, banded gneisses, granitic gneisses, Older Granites, schists and quartzite intrusions. The migmatite-gneiss complex forms the dominant lithological unit across much of the Territory and represents the oldest basement rocks exposed in the area. Structurally, the Basement Complex rocks of the FCT have undergone multiple episodes of folding,

faulting and jointing associated with the Pan-African tectonic event. These structural discontinuities exert considerable influence on groundwater occurrence because groundwater storage within the crystalline basement is largely restricted to weathered regolith and fractured bedrock aquifers. Consequently, groundwater availability within the FCT is controlled primarily by the thickness of the weathered overburden and the degree of bedrock fracturing rather than by primary rock porosity (NGSA, 2025). The proposed project site at the National Open University of Nigeria (NOUN), Jabi, is situated within this crystalline Basement Complex terrain. These geological conditions are favourable for construction and the competent nature of the underlying basement rocks is expected to provide adequate bearing capacity for the proposed development while minimizing risks associated with excessive settlement and foundation instability.

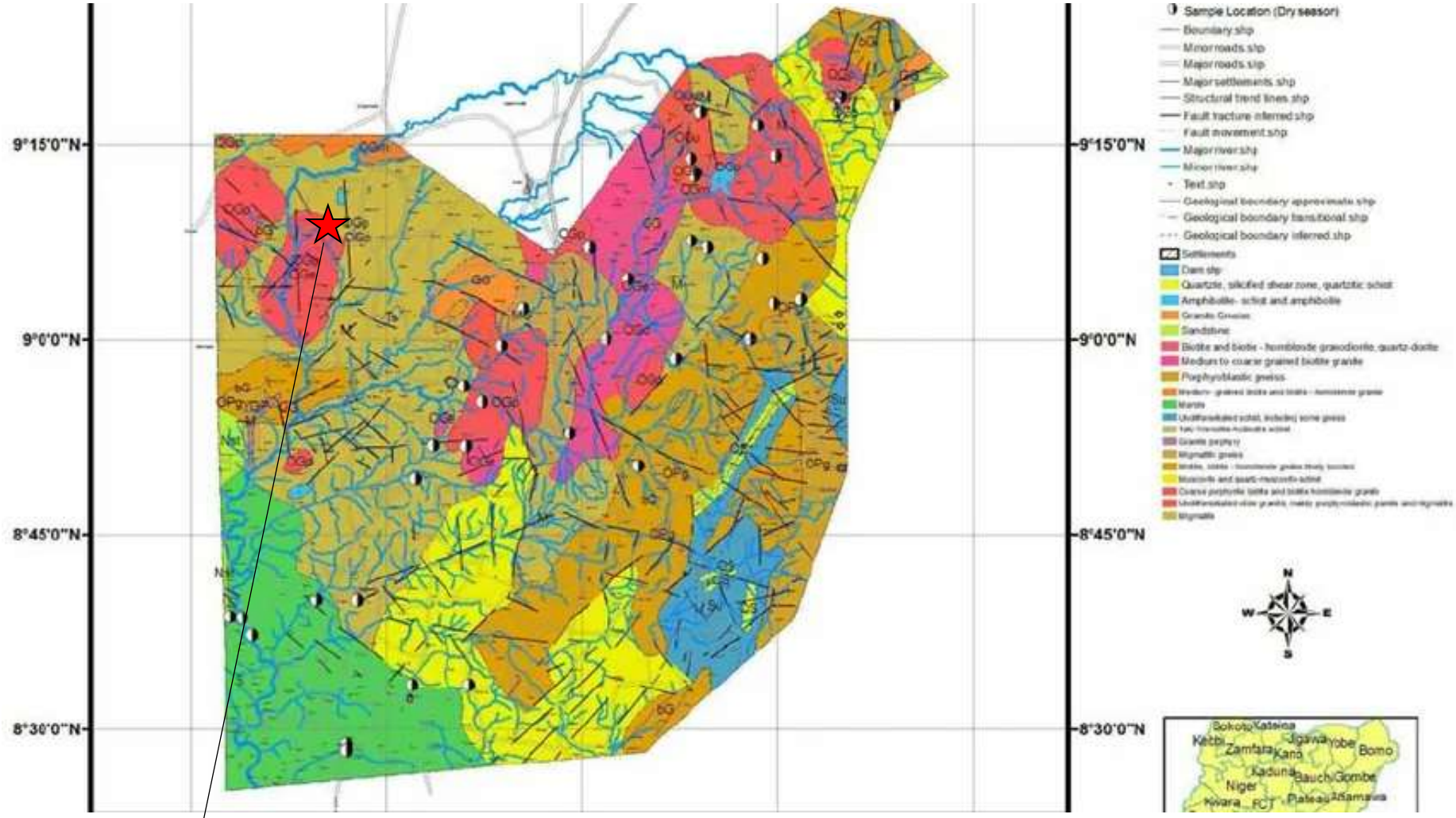


Figure 4.13: Geological Map of the FCT
***Source**: Nigeria Geological Survey Agency*

4.4.2.1 Soil Studies

The proposed project comprises two separate locations within the National Open University of Nigeria (NOUN), Abuja. Site 1 is located between the Faculty of Management Sciences and the Faculty of Social Sciences, adjacent to the University's substation, while Site 2 is situated within the University's Car Park. This site is situated in front of the Senate Building and Convocation Arena, and is opposite the Directorate of Physical Planning and Development (DPP) Building.

Site 1 occupies an area of approximately 2,093.25 m² (0.21 ha). Field observations and information provided by the University's representatives indicated that the site is a reclaimed, sand-filled area rather than a naturally occurring soil profile. Owing to the relatively homogeneous nature of the fill material, a single representative sampling location (Location 1, L1) was established near the centre of the site. Two soil samples were collected from this location, comprising a topsoil sample (0–15 cm) and a subsoil sample (15–30 cm), to adequately characterize the site's baseline soil conditions.

Site 2 covers approximately 4,401.64 m² (0.44 ha) and is located within the University's designated car park. Given the relatively larger area and anticipated spatial variability in soil conditions, soil samples were collected from three (3) strategically selected locations distributed diagonally across the site. Consequently, a total of six (6) soil samples were obtained from Site 2. The sampling points were positioned near opposite ends and at the centre of the proposed development area to ensure representative spatial coverage.

To establish the natural background soil quality for comparison with the proposed project sites, a control sampling location (Location 5, L5) was established outside the University campus near the Second Gate, beyond the potential influence of project activities. Two soil samples (top and bottom) were collected at Latitude 9°01'23.448"N and Longitude 7°24'37.86012"E. These samples serve as the baseline reference (Control Samples) for evaluating any future changes in soil quality associated with project implementation.

Overall, a total of ten (10) soil samples were collected during the baseline survey, comprising two samples from Site 1, six samples from Site 2, and two control samples taken outside the university second gate. All soil samples were appropriately labeled, preserved, sealed, and transported under standard quality assurance and quality control (QA/QC) procedures to an accredited laboratory for physicochemical and heavy metal analyses. The laboratory results of the physico-chemical and microbial analysis of soil samples from the study area are presented in Tables 4.7.

Table 4.6a: Summary of Soil Samples Collected

Location	Description	Sampling Locations	Sample Depth (cm)	Number of Samples
Site 1	Reclaimed land adjacent to the substation	1	0–15 and 15–30	2
Site 2	Car park area opposite DPP building	3	0–15 and 15–30	6
Control	Outside the Second Gate (background reference)	1	0–15 and 15–30	2
Total		**5**		**10**

Table 4.6b: Soil Sampling Locations, Coordinates and Sample Details

Sample ID	Location ID	Sampling Location	Latitude (N)	Longitude (E)	Depth (cm)	Description
S1	L1	Site 1	9°01'23.01816"	7°24'36.29628"	0–15	Topsoil sample collected from the reclaimed area adjacent to the substation.
S2	L1	Site 1	9°01'23.01816"	7°24'36.29628"	15–30	Subsoil sample collected from the reclaimed area adjacent to the substation.
S3	L2	Site 2	9°01'15.42036"	7°24'33.05052"	0–15	Topsoil sample collected from the northern section of the car park.
S4	L2	Site 2	9°01'15.42036"	7°24'33.05052"	15–30	Subsoil sample collected from the northern section of the car park.
S5	L3	Site 2	9°01'14.56896"	7°24'31.79412"	0–15	Topsoil sample collected from the central section of the car park.
S6	L3	Site 2	9°01'14.56896"	7°24'31.79412"	15–30	Subsoil sample collected from the central section of the car park.
S7	L4	Site 2	9°01'13.42036"	7°24'30.10176"	0–15	Topsoil sample collected from the southern section of the car park.
S8	L4	Site 2	9°01'13.42036"	7°24'30.10176"	15–30	Subsoil sample collected from the southern section of the car park.
S9	L5	Control Site	9°01'23.448"	7°24'37.86012"	0–15	Background topsoil sample collected outside the University's Second Gate.
S10	L5	Control Site	9°01'23.448"	7°24'37.86012"	15–30	Background subsoil sample collected outside the University's Second Gate.

Table 4.7: Laboratory Results for Soil Samples Analysis

S/N	PARAMETERS	UNIT	TEST METHODS	SITE 1		SITE 2						CONTROL	
				L 1		L 2		L 3		L 4		L 5	
				S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
PHYSICO- CHEMICAL PARAMETERS													
1	Electrical Conductivity	µS/cm	ASTM D1125	280.000	100.000	200.000	180.000	260.000	180.000	540.000	620.000	540.000	510.000
2	pH	6.800	ASTM D4972	6.690	6.930	6.670	6.410	6.410	6.510	6.420	6.480	6.640	6.870
3	Moisture Content	%	ASTM D2216	11.015	12.465	5.303	11.578	9.031	8.680	14.580	15.504	11.331	13.390
4	Porosity	%	ASTM D7263	57.600	57.867	59.130	60.254	56.900	63.131	57.680	56.789	63.507	49.573
5	Soil Texture		ASTM D422	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Sandy Clay
6	Bulk Density		ASTM D7263	1.124	1.117	1.083	1.053	1.142	0.977	1.121	1.145	0.994	1.336
7	Total Alkalinity	mg/Kg	Acid titration	200.000	200.000	200.000	200.000	200.000	200.000	400.000	400.000	400.000	400.000
8	Total dissolved Salts	mg/Kg	ASTM D1125	0.632	0.632	0.632	0.632	0.632	0.316	0.948	0.632	0.316	0.632
9	Ammonium	mg/Kg	Nesslerization / Indophenol method)	11.52	14.657	17.534	13.089	14.149	13.277	10.532	10.198	14.178	15.05
10	Ammonia	mg/Kg	Distillation + titration or colorimetric method	10.878	13.841	16.557	12.359	13.361	12.538	9.945	9.63	13.358	14.211
11	Exchangeable sodium	Cmol/Kg	Ammonium acetate extraction + AAS	0.036	0.012	0.009	0.048	0.058	0.007	0.003	0.048	0.041	0.024
12	Exchangeable potassium	Cmol/Kg	Ammonium acetate extraction + AAS	0.287	0.285	0.309	0.442	0.486	0.435	0.295	0.424	0.499	0.437

S/N	PARAMETERS	UNIT	TEST METHODS	SITE 1		SITE 2						CONTROL	
				L 1		L 2		L 3		L 4		L 5	
				S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
13	Exchangeable Calcium	Cmol/ Kg	Ammonium acetate extraction + EDTA titration	1.246	1.222	1.466	1.469	1.711	1.955	0.978	0.733	1.713	0.978
14	Exchangeable Magnesium	Cmol/ Kg	Ammonium acetate extraction + EDTA titration	0.964	1.235	1.234	1.974	1.976	0.741	1.235	1.236	0.986	0.988
15	Exchangeable Acidity	Cmol/ Kg	KCl extraction + titration with NaOH	0.058	0.022	0.042	0.083	0.05	0.037	0.019	0.053	0.653	0.062
16	Exchangeable Bases	Cmol/ Kg	Ammonium acetate extraction + summation of cations	2.594	2.754	3.02	3.933	4.212	3.139	2.512	2.441	3.239	2.437
17	Cation Exchange Cation (CEC)	Cmol/ Kg	Ammonium acetate (1N NH_4OAc, pH 7) method	2.591	2.716	3.062	4.016	4.262	3.177	2.53	2.494	3.891	2.489
18	Base saturation	%	Calculated	97.764	99.208	98.630	97.943	98.828	98.826	99.263	97.863	83.225	97.511
19	Sodium Adsorption Ratio (SAR)		Calculated	0.034	0.110	0.008	0.037	0.042	0.006	0.003	0.049	0.035	0.024
20	Exchangeable Sodium Potassium (ESP)	%	Calculated	1.428	0.420	0.308	1.233	1.365	0.232	0.130	1.986	1.264	0.994
MACRO NUTRIENTS													
21	Total Nitrogen	mg/Kg	Kjeldahl	31.398	27.335	40.856	54.965	51.994	48.039	22.379	63.211	63.682	56.445

S/N	PARAMETERS	UNIT	TEST METHODS	SITE 1		SITE 2						CONTROL	
				L 1		L 2		L 3		L 4		L 5	
				S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
			method										
22	Available Phosphorus	mg/Kg	Bray I or Bray II method	1.261	0.000	0.210	2.416	2.521	0.000	0.000	0.000	3.676	1.576
23	Total Potassium	mg/Kg	AAS after acid digestion	112.109	111.328	120.703	172.266	182.422	169.922	115.234	165.234	194.531	170.313
ORGANICS													
24	Total Organic carbon	%	Walkley–Black wet oxidation method	0.596	0.914	0.933	0.516	1.192	0.477	1.112	1.311	0.874	0.993
25	Total Organic Matter	%	Loss on Ignition	1.027	1.575	1.712	0.89	2.054	0.822	1.917	2.26	1.507	1.712
26	Total Organic Nitrogen	mg/Kg	Kjeldahl digestion method	0.03	0.046	0.05	0.026	0.06	0.024	0.056	0.066	0.044	0.05
ANIONS													
27	Chloride	mg/Kg	Argentometric titration	210.573	210.573	210.57	210.57	210.573	105.287	315.86	210.573	105.287	210.573
28	Nitrate	mg/Kg	Cadmium reduction method,	18.487	11.345	6.732	36.555	34.034	33.193	10.504	49.16	45.378	37.815
29	Nitrite	mg/Kg	colorimetric method	1.361	1.287	16.55	5.296	3.751	1.545	1.287	3.788	4.082	3.531
30	Phosphate	mg/Kg	Molybdenum blue method	3.858	0.000	0.643	7.395	7.717	0.000	0.000	0.000	11.254	4.823
31	Sulphate	mg/Kg	Turbidimetric method	193.846	64.615	78.462	95.385	481.538	240	81.535	98.412	250.769	373.846
METALS													
32	Calcium	mg/Kg	EDTA titrimetric	498.555	480.78	586.513	684.291	782.047	391.024	293.268	685.269	391.024	391.219

S/N	PARAMETERS	UNIT	TEST METHODS	SITE 1		SITE 2						CONTROL	
				L 1		L 2		L 3		L 4		L 5	
				S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
33	Magnesium	mg/Kg	EDTA titrimetric	231.241	296.463	296.462	473.748	474.341	177.878	296.462	296.462	236.577	237.17
34	Sodium	mg/Kg	AAS	8.319	2.657	2.137	11.150	13.229	1.675	0.751	11.150	9.417	5.546
35	Iron	mg/Kg	AAS	17.619	33.429	21.524	2.762	18.857	21.048	15.905	3.619	0.476	13.810
36	Copper	mg/Kg	AAS	3.705	1.013	6.612	3.631	6.899	2.839	3.365	1.239	0.579	2.535
37	Lead	mg/Kg	AAS	0.000	0.000	0.000	0.000	0.000	0.000	1.078	6.165	5.017	4.122
38	Zinc	mg/Kg	AAS	7.151	0.784	4.207	3.157	7.173	3.728	3.098	3.417	2.848	2.273
39	Aluminium	mg/Kg	AAS	15.647	5.935	11.331	22.302	13.489	10.072	5.036	14.388	176.259	16.727
40	Arsenic	mg/Kg	AAS	0.062	0.045	0.046	0.061	0.057	0.053	0.061	0.041	0.051	0.047
41	Chromium	mg/Kg	AAS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MICROBIAL ANALYSIS													
40	Total Heterotrophic Bacterial (THB)	cfu/g	Serial dilution + pour plate	3.25×10^5	3.1×10^5	2.2×10^5	1.05×10^4	2.55×10^5	1.6×10^5	3.1×10^5	2.1×10^5	6.2×10^5	4.0×10^4
41	Total Heterotrophic Fungi (THF)	cfu/g	Serial dilution + pour plate	1.5×10^4	TNTC	1.0×10^4	ND	5.0×10^3	1.7×10^5	5.0×10^3	1.0×10^4	5.5×10^4	4.0×10^4
43	Total coliform (TC)	cfu/g	Serial dilution + pour plate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NOTE:													
cfu/g = colony forming unit per gramme													
Cmol/Kg = centimole per kilogram													
NS = Not stated													
ND = Not Detected													
TNTC = Too numerous to count													

4.4.2.1.1 Interpretation and Discussion of Soil Laboratory Results

The laboratory analysis was undertaken to establish the baseline physicochemical, geochemical and microbiological characteristics of soils within the proposed project area prior to project implementation. Soil samples were collected from the two proposed project sites and a control location to evaluate the existing environmental conditions and determine any evidence of contamination, nutrient limitations or geochemical anomalies. 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. The discussion is presented according to the major analytical categories.

Physicochemical Properties

Electrical Conductivity (EC)

Electrical conductivity is an important indicator of soluble salt concentration within soils and provides an assessment of soil salinity. Elevated EC values generally indicate excessive salt accumulation, which can adversely affect plant growth, reduce soil permeability and impair microbial activity. Conversely, low to moderate EC values are characteristic of non-saline soils suitable for agricultural productivity and infrastructure development. The measured electrical conductivity values ranged from 100–280 µS/cm in Site 1 soils, 180–620 µS/cm in Site 2 soils and approximately 510 µS/cm in the control sample. These values indicate that the soils are generally non-saline and fall well below thresholds commonly associated with saline soil conditions (>2,000 µS/cm). The relatively higher conductivity observed in some Site 2 samples may reflect localized accumulation of dissolved ions resulting from landscaping practices, fertilizer application, surface runoff or natural variations in soil mineralogy. Nevertheless, the recorded values do not indicate salinity-related environmental concerns. From an engineering perspective, the low salinity suggests minimal risk of salt-induced deterioration of buried electrical infrastructure, concrete foundations or metallic components associated with the proposed project.

Soil Reaction (pH)

Soil pH is one of the most influential parameters governing nutrient availability, microbial activity, heavy metal mobility and overall soil health. Most terrestrial vegetation performs optimally within slightly acidic to neutral soils (approximately pH 6.0–7.5), where nutrient availability is generally maximized. The analyzed soils exhibited pH values ranging between 6.41 and 6.93, indicating slightly acidic to near-neutral conditions across both project sites and the control location. The relatively uniform pH distribution demonstrates that the study area possesses stable soil chemical conditions with no evidence of acidification or excessive alkalinity. The slightly acidic nature of the soils is characteristic of many tropical soils within the Guinea Savanna ecological zone and is generally considered favourable for plant growth, microbial processes and nutrient cycling. Furthermore, the near-neutral pH reduces the solubility and mobility of many potentially toxic heavy metals, thereby minimizing the likelihood of metal toxicity to plants or groundwater contamination. Overall, the observed pH conditions indicate that the proposed project area is environmentally suitable and requires no pH-related remediation prior to project implementation.

Moisture Content

Moisture content represents the amount of water retained within the soil pores at the time of sampling and significantly influences soil strength, compaction characteristics, biological activity and engineering performance. The laboratory results indicate moisture contents ranging from approximately 5.30% to 15.50% across the investigated samples. The variation observed among the sampling locations is expected and reflects localized differences in vegetation cover, drainage conditions, surface runoff, soil texture and antecedent rainfall conditions. Site 2 generally exhibited slightly higher moisture contents than Site 1, likely due to increased vegetation cover, landscaped lawns and greater organic matter accumulation, which enhance water retention. From an engineering standpoint, these moisture contents indicate relatively well-drained soils that can be readily compacted during construction without excessive drying or stabilization requirements. No evidence of prolonged waterlogging or poor drainage was observed during field investigations.

Soil Porosity

Porosity defines the proportion of void spaces within the soil matrix and governs the movement of air and water through the soil profile. High porosity generally enhances infiltration, root penetration and microbial respiration, whereas excessively low porosity may restrict drainage and increase surface runoff. Measured porosity values varied from approximately 49.57% to 63.51% across all samples. These values indicate moderately to highly porous soils, which are consistent with the predominance of sandy materials observed during field investigations. The relatively high porosity supports efficient infiltration of rainfall, minimizes surface ponding and encourages adequate soil aeration necessary for biological activity. Although higher porosity improves drainage, it may also facilitate leaching of soluble nutrients under prolonged rainfall conditions, particularly in tropical environments. Consequently, soil nutrient replenishment through natural organic matter cycling remains important for sustaining long-term soil fertility. For engineering works, the observed porosity suggests that the soils possess favourable drainage characteristics, reducing the likelihood of excessive pore-water pressure development beneath project foundations.

Soil Texture

Soil texture governs numerous physical and chemical processes, including permeability, water retention, nutrient storage, erosion susceptibility and engineering behaviour. Laboratory classification showed that virtually all project area samples consist predominantly of Silty Sand, while the control sample was classified as Sandy Clay. The predominance of silty sand indicates soils with relatively high permeability, moderate water-holding capacity and good drainage characteristics. Such soils are generally less susceptible to prolonged waterlogging and are suitable for shallow civil engineering works after appropriate compaction. However, silty sands generally possess lower nutrient retention capacity compared with finer-textured clayey soils because of their reduced surface area and cation exchange capacity. Consequently, nutrients may be more readily lost through leaching during periods of intense rainfall. The sandy clay encountered at the control location demonstrates relatively greater fine-particle content, explaining its comparatively higher bulk density and lower permeability. Overall, the textural characteristics are typical of the weathered basement complex soils commonly encountered within the Federal Capital Territory.

Bulk Density

Bulk density is an important engineering and agronomic property that reflects the degree of soil compaction and influences root penetration, infiltration and structural stability. Bulk density values ranged from approximately 0.98 to 1.34 g/cm³ across the investigated soils. These values indicate relatively loose to moderately compact soils with good structural conditions. Lower bulk density values generally correspond with higher porosity and improved root development, while the slightly higher value recorded in the control sample is consistent with its sandy clay texture. From an engineering perspective, the measured bulk densities indicate that the soils can achieve satisfactory compaction during construction using conventional earthwork procedures. No evidence of excessive compaction or restrictive soil conditions was observed.

Total Alkalinity and Total Dissolved Salts (TDS)

Total alkalinity reflects the buffering capacity of soils against changes in pH, while total dissolved salts provide an estimate of the concentration of soluble mineral constituents within the soil solution. The laboratory results show relatively consistent alkalinity values ranging from 200 to 400 mg/kg, whereas total dissolved salts remained generally low (0.316–0.948 mg/kg). The low dissolved salt concentrations corroborate the electrical conductivity results, confirming that the soils are free from excessive salt accumulation. Similarly, the moderate alkalinity values indicate adequate buffering capacity capable of maintaining relatively stable soil pH under existing environmental conditions. These findings suggest that soil chemical conditions are stable and unlikely to present constraints to vegetation establishment or the proposed infrastructure development.

4.4.2.1.2. Exchangeable Cations and Soil Fertility Indices

Exchangeable cations constitute one of the most important indicators of soil fertility and chemical quality because they determine the soil's ability to retain and supply essential nutrients required for plant growth. The major exchangeable cations assessed during this study include sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}), together with exchangeable acidity, exchangeable bases, cation exchange capacity (CEC), base saturation, sodium adsorption ratio (SAR) and exchangeable sodium percentage (ESP). These parameters collectively provide valuable information on soil fertility, nutrient availability, structural stability and the potential for sodicity-related degradation.

Exchangeable Sodium (Na^+)

Exchangeable sodium represents the proportion of sodium ions adsorbed onto soil colloids and is an important indicator of sodicity. Excessive sodium concentrations can disperse soil particles, reduce permeability, impair soil aggregation and ultimately degrade soil structure. The analyzed soils recorded exchangeable sodium concentrations ranging from 0.003 to 0.058 cmol/kg, with generally low values across both project sites and the control location. These results indicate that sodium is present only in trace quantities and is unlikely to adversely influence soil physical properties. The slightly higher values observed in some Site 2 samples may reflect localized accumulation of soluble salts from landscaping activities or surface runoff; however, the concentrations remain substantially below levels associated with sodic soils. From both agricultural and engineering perspectives, the low exchangeable sodium content is favourable

because it minimizes the risk of clay dispersion, reduced infiltration and structural instability. Consequently, no sodium-induced soil management interventions are considered necessary.

Exchangeable Potassium (K^+)

Potassium is an essential macronutrient required for enzyme activation, protein synthesis, osmotic regulation and plant resistance to environmental stress. Unlike sodium, potassium contributes positively to soil fertility and crop productivity. Exchangeable potassium concentrations varied between 0.285 and 0.499 cmol/kg, indicating moderate potassium availability throughout the study area. The relatively consistent potassium concentrations across both project sites suggest uniform nutrient distribution and limited nutrient depletion. Site 2 generally exhibited slightly higher potassium levels than Site 1, possibly reflecting the influence of landscaped vegetation and periodic fertilizer application within the campus. Overall, the potassium status indicates that the soils possess adequate reserves to support vegetation establishment and landscape sustainability without evidence of potassium deficiency.

Exchangeable Calcium (Ca^{2+})

Calcium is usually the dominant exchangeable cation in productive soils and plays a fundamental role in root development, cell wall formation, soil aggregation and structural stability. Measured exchangeable calcium values ranged between 0.733 and 1.955 cmol/kg, with Site 2 generally exhibiting slightly higher concentrations than Site 1. The predominance of calcium among the exchangeable cations is characteristic of relatively well-balanced tropical soils and contributes significantly to maintaining favourable soil structure. Higher calcium concentrations also improve soil aggregation, thereby reducing erosion susceptibility and enhancing water infiltration. The observed calcium distribution indicates satisfactory soil fertility and suggests that calcium availability is unlikely to limit vegetation growth within the project area.

Exchangeable Magnesium (Mg^{2+})

Magnesium is another essential secondary nutrient involved in chlorophyll synthesis, photosynthesis and numerous enzymatic reactions. It also contributes to soil aggregation through interactions with clay minerals and organic matter. Exchangeable magnesium concentrations ranged from approximately 0.741 to 1.976 cmol/kg across the analyzed soils. The relatively moderate magnesium concentrations complement the calcium status, indicating balanced exchangeable cation composition throughout the study area. The higher magnesium values observed in some Site 2 samples further suggest localized nutrient enrichment associated with managed landscaping. Collectively, the calcium and magnesium results demonstrate that the soils possess good nutrient reserves capable of sustaining healthy vegetation.

Exchangeable Acidity

Exchangeable acidity represents the concentration of hydrogen and aluminium ions occupying exchange sites within the soil. Elevated exchangeable acidity is commonly associated with strongly acidic soils and reduced nutrient availability. The measured exchangeable acidity values ranged from 0.019 to 0.083 cmol/kg for nearly all samples, with only one control sample recording a relatively higher value of 0.653 cmol/kg. These low values are consistent with the measured soil pH and indicate minimal soil acidification throughout the project area. The isolated higher value observed in the control location likely reflects localized soil variability rather than widespread acidic conditions. Overall, exchangeable acidity remains sufficiently low to avoid significant constraints on nutrient availability or root development.

Exchangeable Bases

Exchangeable bases represent the sum of calcium, magnesium, potassium and sodium available for plant uptake and provide an overall measure of nutrient reserves within the soil. The analyzed soils recorded exchangeable base values ranging from 2.437 to 4.212 cmol/kg. Site 2 generally exhibited slightly higher exchangeable base values than Site 1, indicating comparatively greater nutrient reserves, likely attributable to landscaping practices and accumulation of organic residues. The relatively moderate exchangeable base concentrations indicate that the soils possess satisfactory nutrient status capable of supporting vegetation establishment and ecological productivity.

Cation Exchange Capacity (CEC)

Cation Exchange Capacity is one of the most important indicators of soil fertility because it reflects the ability of soils to retain nutrient cations against leaching and gradually release them for plant uptake. The laboratory results indicate CEC values ranging from approximately 2.489 to 4.262 cmol/kg. Although these values are relatively modest compared with highly clayey soils, they are entirely consistent with the predominantly silty sand texture observed across the project area. Sandy soils naturally possess lower cation exchange capacities because of their limited clay and organic matter contents. Consequently, while nutrient retention is moderate, periodic replenishment through natural organic matter cycling or landscaping maintenance may be beneficial for sustaining long-term fertility.

Base Saturation

Base saturation expresses the proportion of the cation exchange sites occupied by basic cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) rather than acidic ions. High base saturation generally indicates fertile soils with favourable nutrient availability. The analyzed soils exhibited remarkably high base saturation values ranging from 83.23% to 99.26%. These values indicate that the overwhelming majority of exchange sites are occupied by beneficial nutrient cations rather than acidic ions. Such high base saturation is consistent with the near-neutral pH values measured across the study area and confirms that the soils possess good inherent fertility. Only one control sample recorded a comparatively lower value (83.23%), although this still represents a relatively favourable soil condition.

Sodium Adsorption Ratio (SAR)

The Sodium Adsorption Ratio is widely used to evaluate sodicity hazards by assessing the relative abundance of sodium compared with calcium and magnesium. High SAR values can adversely affect soil permeability, aggregation and engineering behaviour. The calculated SAR values ranged from only 0.003 to 0.110. These extremely low values demonstrate that sodium poses no threat to soil structural stability. The soils therefore exhibit excellent physical characteristics with minimal risk of sodium-induced dispersion or reduced infiltration. For infrastructure development, the low SAR values indicate favourable subgrade conditions with negligible sodicity-related engineering concerns.

Exchangeable Sodium Percentage (ESP)

Exchangeable Sodium Percentage represents the proportion of exchange sites occupied by sodium ions and serves as another important indicator of sodicity. The analyzed soils recorded ESP values between 0.130% and 1.986%. These values are substantially below the internationally accepted threshold of 15%, above which soils are generally classified as sodic. Accordingly, none of the investigated soils exhibit characteristics of sodic soils. The consistently low ESP values confirm the conclusions drawn from the SAR and exchangeable sodium analyses, demonstrating excellent soil structural stability and permeability throughout the study area.

4.4.2.1.3. Macronutrients

Macronutrients constitute the primary mineral elements required in relatively large quantities for plant growth, metabolic activities and ecosystem productivity. The major macronutrients analyzed during this study include total nitrogen (N), available phosphorus (P), available sulphur (S), and available silicon (Si). These nutrients are fundamental to plant development, energy transfer, protein synthesis, root establishment and overall soil productivity. Their concentrations also provide valuable insight into the fertility status of the soil and its capacity to sustain vegetation following project implementation.

Total Nitrogen (N)

Nitrogen is one of the most essential plant nutrients because it forms a major component of amino acids, proteins, nucleic acids and chlorophyll. Nitrogen availability directly influences vegetative growth, photosynthetic activity and biomass production. However, tropical soils often experience nitrogen depletion due to continuous mineralization, leaching and erosion. The analyzed soils recorded total nitrogen concentrations ranging from approximately 0.04% to 0.12%, with moderate spatial variation across the study area. The results indicate that nitrogen availability is generally low to moderate, which is typical of tropical savannah soils characterized by relatively rapid decomposition of organic matter and seasonal nutrient cycling. Site 2 exhibited slightly higher nitrogen concentrations than Site 1, likely reflecting greater vegetation density, accumulation of leaf litter and routine landscape maintenance within the developed portions of the campus. Although the measured nitrogen concentrations are not exceptionally high, they are sufficient to sustain the existing vegetation cover observed during the ecological survey. The absence of extremely low nitrogen values further suggests that the soils have not undergone severe degradation or excessive nutrient depletion. From an environmental perspective, the moderate nitrogen levels indicate a stable nutrient balance with minimal evidence of nutrient enrichment that could contribute to eutrophication or excessive nitrate leaching.

Available Phosphorus (P)

Phosphorus plays a critical role in energy transfer, cell division, root development, flowering and seed formation. Unlike nitrogen, phosphorus exhibits relatively low mobility within soils because it readily becomes fixed by iron, aluminium and calcium minerals, particularly in tropical environments. Available phosphorus concentrations ranged from approximately 7.89 mg/kg to 14.63 mg/kg across the analyzed samples. The results indicate low to moderate

phosphorus availability, with several Site 1 samples recording comparatively lower concentrations than those obtained from Site 2. This pattern may be attributed to localized differences in vegetation cover, organic matter decomposition and routine horticultural management. The generally moderate phosphorus concentrations suggest that phosphorus is likely the most limiting macronutrient within the project area. This observation is consistent with many tropical soils, where phosphorus fixation significantly reduces plant-available phosphorus despite adequate total phosphorus reserves. Nevertheless, the observed phosphorus status remains adequate for maintaining the existing vegetation communities documented during field investigations. Should future landscaping or revegetation programmes be implemented following construction, localized phosphorus supplementation may improve vegetation establishment, although no immediate nutrient deficiency requiring remediation was identified.

Available Sulphur (S)

Sulphur is an essential secondary nutrient involved in protein synthesis, enzyme activation and chlorophyll production. It also contributes to the formation of amino acids such as cysteine and methionine, which are fundamental to plant metabolism. Available sulphur concentrations ranged from approximately 4.31 mg/kg to 7.94 mg/kg. These values indicate generally adequate sulphur availability within the study area. The relatively uniform distribution across the sampling locations suggests that sulphur cycling remains relatively stable and has not been significantly affected by anthropogenic disturbances. The observed sulphur concentrations are consistent with soils supporting actively growing grasses, shrubs and ornamental trees, all of which were abundant throughout the project area during ecological surveys. No evidence of sulphur deficiency or excessive sulphur accumulation was observed.

Silicon (Si)

Silicon, although not traditionally classified as an essential nutrient for all plants, is increasingly recognized as a beneficial element that enhances plant resistance to drought, pests, diseases and mechanical stress. Silicon also improves structural rigidity and contributes to overall plant resilience. The laboratory analysis indicates available silicon concentrations ranging between approximately 15.30 mg/kg and 34.50 mg/kg. The relatively moderate silicon concentrations are characteristic of soils developed from weathered silicate parent materials, which dominate much of the Nigerian Basement Complex. These concentrations provide favourable conditions for grasses and other monocotyledonous species, several of which were identified during the flora assessment. The abundance of grasses observed across both project sites corresponds well with the measured silicon concentrations, since many grass species accumulate significant quantities of silicon within their tissues to enhance structural support and resistance against herbivory.

Nutrient Balance

Assessment of the major macronutrients indicates a relatively balanced nutrient status across the project area. Nitrogen occurs at moderate concentrations, phosphorus is comparatively lower but remains within acceptable limits for the existing vegetation, while sulphur and silicon exhibit generally adequate concentrations. The slight variations observed between Site 1 and Site 2 largely reflect differences in vegetation density, landscaping practices, organic matter accumulation and localized soil management rather than evidence of contamination or

environmental degradation. Importantly, none of the measured nutrient concentrations indicate excessive nutrient enrichment, fertilizer contamination or conditions capable of adversely affecting groundwater quality through nutrient leaching.

4.4.2.1.4 Organic Matter Characteristics

Soil organic matter constitutes one of the most important indicators of soil quality because it directly influences soil fertility, nutrient cycling, water-holding capacity, aggregation, microbial activity and carbon sequestration. Organic matter is primarily derived from decomposed plant residues, root biomass, microorganisms and other biological materials. In tropical ecosystems, organic matter is continuously mineralized due to high temperatures and microbial activity, making its assessment particularly important for evaluating baseline environmental conditions. The organic matter characteristics of the project area were assessed using Organic Carbon (OC), Organic Matter (OM), Carbon-to-Nitrogen (C:N) Ratio and Carbon Stock. These parameters collectively provide insight into soil fertility, biological productivity and ecosystem sustainability.

Organic Carbon (OC)

Organic carbon is the principal component of soil organic matter and serves as an important indicator of soil health, fertility and long-term environmental sustainability. It influences nutrient retention, microbial activity, soil aggregation and resistance to erosion. The analyzed soils recorded organic carbon concentrations ranging from approximately 0.42% to 1.29%, with moderate variation between the sampling locations. These values indicate low to moderate organic carbon contents, which are characteristic of tropical savannah soils where rapid decomposition limits long-term accumulation of organic residues. Site 2 generally exhibited slightly higher organic carbon concentrations than Site 1, reflecting the denser ornamental vegetation, landscaped lawns and greater accumulation of plant litter observed during the ecological survey. Although the organic carbon concentrations are not particularly high, they are adequate to sustain the existing vegetation communities and maintain active soil biological processes. Furthermore, the absence of extremely low organic carbon values suggests that the soils have not experienced severe degradation or prolonged disturbance. From an environmental perspective, the observed organic carbon concentrations indicate that the project area retains satisfactory ecological functioning and possesses sufficient organic reserves to support nutrient cycling and soil microbial activity.

Organic Matter (OM)

Organic matter represents the total quantity of decomposed plant and animal residues within the soil and serves as a reservoir for essential nutrients. It also improves soil structure by enhancing aggregation, increasing water retention and reducing susceptibility to erosion. Organic matter contents ranged from approximately 0.72% to 2.22% across the analyzed samples. The measured values indicate low to moderate organic matter status, consistent with the predominantly silty sand texture and well-drained nature of the soils. The relatively higher organic matter concentrations observed in Site 2 correspond with the extensive ornamental landscaping, tree cover and continuous deposition of leaf litter throughout the campus environment. Despite the moderate organic matter contents, the soils exhibit sufficient biological productivity to sustain

the diverse grasses, shrubs and ornamental tree species identified during the flora assessment. The observed organic matter levels also contribute positively to soil aggregation, infiltration and resistance to erosion, thereby enhancing the environmental stability of the project area.

Carbon-to-Nitrogen (C:N) Ratio

The Carbon-to-Nitrogen (C:N) ratio is a key indicator of organic matter decomposition and nutrient mineralization. It reflects the balance between carbon-rich organic materials and available nitrogen within the soil. Low C:N ratios generally indicate rapid decomposition and active nutrient cycling, whereas excessively high ratios may slow microbial decomposition and temporarily immobilize nitrogen. The calculated C:N ratios across the project area ranged from approximately 7:1 to 12:1. These values indicate active decomposition of organic residues and efficient nutrient mineralization, which are characteristic of tropical soils supporting vigorous microbial activity. The relatively balanced C:N ratios demonstrate that soil microorganisms are effectively decomposing organic matter without causing significant nitrogen immobilization. This observation agrees with the moderate nitrogen concentrations and active microbial populations recorded during the laboratory analysis, indicating a healthy and functional soil ecosystem. From an ecological standpoint, the favourable C:N ratios support continuous nutrient recycling and contribute to maintaining vegetation productivity across the study area.

Carbon Stock

Soil carbon stock represents the amount of carbon stored within the soil profile and constitutes an important component of ecosystem carbon sequestration. Carbon storage contributes to climate regulation by reducing atmospheric carbon dioxide while simultaneously improving soil fertility and resilience. The laboratory results indicate moderate soil carbon stocks across the investigated locations, reflecting the combined influence of vegetation cover, organic matter accumulation and soil texture. The slightly higher carbon stocks observed within the landscaped portions of Site 2 correspond to the greater abundance of ornamental trees, shrubs and maintained lawns, all of which contribute organic residues to the soil through continuous litter fall and root turnover. Although the project area is not a major carbon sink compared with forest ecosystems, the existing vegetation contributes positively to localized carbon sequestration and environmental quality. Construction activities associated with the proposed REA project are expected to disturb only relatively small areas of topsoil. Consequently, any temporary reduction in soil carbon storage will be minimal and can be effectively mitigated through topsoil conservation and post-construction site restoration.

4.4.2.1.5 Anions

Anions are important constituents of the soil solution and play significant roles in nutrient availability, soil chemical balance, plant metabolism and environmental quality. The major anions analyzed during this study include chloride (Cl^-), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}). These parameters provide valuable information on nutrient cycling, possible anthropogenic influences and the potential for soil and groundwater contamination. The concentrations of these anions also provide insight into the baseline geochemical conditions of the proposed project area prior to the commencement of construction activities.

Chloride (Cl^-)

Chloride is a naturally occurring anion present in soils through weathering of parent materials, atmospheric deposition and anthropogenic inputs such as fertilizers and domestic activities. Although chloride is an essential micronutrient for plants, excessive concentrations may contribute to soil salinity and adversely affect plant growth. The analyzed soils recorded chloride concentrations ranging from approximately 105.29 to 315.86 mg/kg, with most samples exhibiting values around 210.57 mg/kg. The relatively consistent chloride concentrations across the sampling locations indicate a stable geochemical environment with no evidence of localized chloride contamination. The slightly elevated value recorded at one Site 2 location most likely reflects natural variability or localized accumulation of soluble salts rather than anthropogenic pollution. Considering the low electrical conductivity measured throughout the study area, the chloride concentrations do not indicate saline soil conditions or environmental impairment. Consequently, chloride is not expected to present any limitation to vegetation growth or infrastructure development.

Nitrate (NO_3^-)

Nitrate is the most mobile and plant-available form of nitrogen in soils. It is produced primarily through microbial nitrification of organic nitrogen and ammonium. Because of its high mobility, nitrate is susceptible to leaching and often serves as an indicator of nutrient cycling and fertilizer inputs. The laboratory results indicate nitrate concentrations ranging from approximately 6.73 to 49.16 mg/kg. The observed variability reflects natural differences in vegetation cover, microbial activity, organic matter decomposition and localized nutrient cycling. Site 2 generally recorded higher nitrate concentrations than Site 1, which corresponds well with the denser vegetation cover and higher organic matter observed within the landscaped portions of the campus. The measured nitrate concentrations remain within the range commonly encountered in productive tropical soils and do not indicate excessive nitrogen enrichment. Furthermore, there is no evidence of nitrate accumulation associated with sewage discharge, fertilizer misuse or other anthropogenic contamination sources. The presence of moderate nitrate concentrations further supports the conclusion that active mineralization and nutrient cycling are occurring within the study area.

Nitrite (NO_2^-)

Nitrite is an intermediate product formed during the microbial transformation of ammonium to nitrate. Under well-aerated soil conditions, nitrite is usually present only in small quantities because it is rapidly oxidized to nitrate. Nitrite concentrations ranged from approximately 1.29 to 16.55 mg/kg across the investigated samples. Most samples exhibited relatively low nitrite concentrations, indicating efficient nitrification and good soil aeration. The comparatively elevated concentration recorded in one sample is likely attributable to localized microbial activity or temporary variations in nitrogen transformation processes rather than persistent environmental contamination. Overall, the measured nitrite concentrations indicate healthy microbial nitrogen cycling within the soil profile and do not suggest adverse environmental conditions.

Phosphate (PO_4^{3-})

Phosphate is an essential nutrient involved in energy transfer, root development and plant metabolism. In tropical soils, phosphate commonly exhibits limited mobility because it readily reacts with iron, aluminium and calcium compounds to form relatively insoluble minerals. Measured phosphate concentrations varied between 0.00 and 11.25 mg/kg. Several samples contained very low or undetectable phosphate concentrations, while others exhibited moderate levels. This pattern is typical of tropical soils where phosphorus fixation limits the amount of plant-available phosphate despite the presence of total phosphorus within the soil. The relatively higher phosphate concentrations observed in the control location may reflect localized accumulation of organic residues or natural spatial variability rather than anthropogenic enrichment. Importantly, the measured phosphate concentrations do not indicate excessive nutrient loading or contamination that could contribute to eutrophication of nearby water bodies.

Sulphate (SO_4^{2-})

Sulphate is the principal plant-available form of sulphur and is essential for protein synthesis, chlorophyll formation and enzyme activity. Sulphate concentrations also provide useful information regarding mineral weathering and potential anthropogenic influences. The analyzed soils exhibited sulphate concentrations ranging from approximately 64.62 to 481.54 mg/kg, representing the widest variation among the analyzed anions. The observed variation is considered consistent with natural differences in parent material composition, organic matter mineralization and localized soil conditions. The relatively elevated sulphate concentration recorded in one Site 2 sample may reflect localized mineral accumulation or enhanced decomposition of sulphur-containing organic materials. Despite this variability, there is no accompanying evidence of soil acidification, excessive salinity or sulphur-related contamination. Consequently, the measured sulphate concentrations are not considered environmentally significant.

4.4.2.1.6 Heavy Metals

Heavy metals occur naturally in soils as constituents of parent rocks and minerals; however, their concentrations may increase through anthropogenic activities such as industrial operations, mining, waste disposal, vehicular emissions and the application of agrochemicals. Although certain metals are essential micronutrients at low concentrations, excessive accumulation may adversely affect soil quality, plant health, groundwater resources and human health. The laboratory analyses evaluated the concentrations of iron (Fe), copper (Cu), lead (Pb), zinc (Zn), aluminium (Al), arsenic (As) and chromium (Cr) to establish the baseline geochemical conditions of the proposed project area and determine whether any evidence of metal contamination exists prior to project implementation.

Iron (Fe)

Iron is one of the most abundant elements in tropical soils and plays an important role in plant metabolism, chlorophyll synthesis and numerous enzymatic reactions. The reddish-brown coloration commonly observed in tropical soils is largely attributable to iron oxides produced during prolonged weathering. The analyzed soils recorded iron concentrations ranging from approximately 13.54 to 40.61 mg/kg. The measured concentrations are characteristic of highly weathered tropical soils derived from Basement Complex rocks and indicate natural geochemical

conditions rather than contamination. Slight variations among the sampling locations reflect differences in parent material composition and weathering intensity. The observed iron concentrations are beneficial for plant nutrition and do not present environmental or engineering concerns. Furthermore, the near-neutral soil pH limits excessive iron solubility, thereby preventing toxicity to vegetation.

Copper (Cu)
Copper is an essential micronutrient required for photosynthesis, respiration and enzyme activation. However, elevated copper concentrations may become toxic to plants and soil microorganisms. Copper concentrations ranged between approximately 0.02 and 0.18 mg/kg across the investigated samples. These concentrations are extremely low and represent natural background levels commonly encountered in uncontaminated tropical soils. No evidence of copper enrichment associated with industrial activities, waste disposal or chemical contamination was identified. The measured concentrations remain well within acceptable environmental limits and therefore pose no ecological or public health concern.

Lead (Pb)
Lead is a non-essential and potentially toxic heavy metal that is commonly monitored during environmental baseline investigations because of its persistence and potential adverse effects on human health and ecosystems. Laboratory analysis indicates that lead was not detected in most of the analyzed samples, while only trace concentrations were recorded in a few locations. The absence or extremely low concentrations of lead demonstrate that the study area has not experienced significant contamination from vehicular emissions, industrial activities, waste disposal or other anthropogenic sources typically associated with lead accumulation. These findings indicate excellent baseline environmental quality and confirm that lead contamination is not a concern within the proposed project area.

Zinc (Zn)
Zinc is an essential micronutrient involved in enzyme activity, protein synthesis and plant growth. Similar to copper, zinc becomes environmentally significant only when present at elevated concentrations. Measured zinc concentrations ranged from approximately 0.12 to 0.86 mg/kg. The observed concentrations are low and consistent with naturally occurring background levels in tropical soils. The relatively uniform distribution across the sampling locations indicates stable geochemical conditions and the absence of localized zinc contamination. The measured zinc concentrations are adequate to support plant nutritional requirements while remaining well below levels capable of causing ecological toxicity.

Aluminium (Al)
Aluminium is a major constituent of most tropical soils and is particularly abundant in highly weathered environments. Under strongly acidic conditions, aluminium becomes more soluble and may adversely affect plant root development. The analyzed soils exhibited aluminium concentrations ranging from approximately 8.43 to 24.66 mg/kg. These concentrations reflect the natural mineralogical composition of the underlying Basement Complex geology. Because the measured soil pH values are slightly acidic to near neutral, aluminium mobility is expected to

remain low, thereby minimizing any potential phytotoxic effects. The aluminium concentrations therefore represent normal background conditions and do not indicate environmental degradation.

Arsenic (As)

Arsenic is a potentially toxic metalloid that is routinely included in environmental baseline assessments because of its potential risks to ecosystems and human health. The laboratory results detected only trace concentrations of arsenic within the analyzed soils. The detected concentrations are extremely low and are most likely attributable to natural weathering of parent rocks rather than anthropogenic contamination. Importantly, the values remain well below internationally recognized soil quality guideline values for residential and ecological land use. The results therefore indicate that arsenic does not constitute an environmental concern within the proposed project area.

Chromium (Cr)

Chromium may occur naturally in soils or be introduced through industrial activities such as metal processing, tanning and waste disposal. Elevated chromium concentrations can present significant ecological and human health risks. The laboratory analysis indicated that chromium was not detected in the analyzed soil samples. The absence of detectable chromium provides strong evidence that the project area has not been affected by chromium-related contamination. This finding further supports the conclusion that the study area maintains excellent baseline environmental quality.

4.4.2.1.7 Microbiological Characteristics

The microbiological quality of soil is a key indicator of ecosystem health, biological productivity and nutrient cycling. Soil microorganisms play indispensable roles in the decomposition of organic matter, mineralization of nutrients, soil aggregation and maintenance of ecological balance. They are also highly responsive to environmental disturbances and therefore serve as reliable indicators of soil quality and contamination. The microbiological assessment of the project area evaluated Total Heterotrophic Bacteria (THB), Total Heterotrophic Fungi (THF) and Total Coliform Count (TCC) to establish the baseline biological status of the soils prior to project implementation.

Total Heterotrophic Bacteria (THB)

Heterotrophic bacteria constitute the largest and most active group of microorganisms in soil ecosystems. They obtain energy through the decomposition of organic materials and are primarily responsible for nutrient mineralization, organic matter degradation and maintenance of soil fertility. The laboratory analysis revealed appreciable populations of heterotrophic bacteria across all sampling locations. The presence of active bacterial communities indicates that the soils possess favourable physicochemical conditions capable of supporting normal microbial metabolism. The slightly acidic to near-neutral pH, moderate organic matter content and adequate soil aeration collectively provide an environment conducive to bacterial growth. The observed bacterial populations are consistent with the healthy vegetation cover documented during the ecological survey and further confirm that nutrient cycling processes are actively

occurring within the study area. Importantly, no abnormal reduction in bacterial populations was observed. Such reductions would typically be expected in soils affected by heavy metal contamination, petroleum pollution or prolonged chemical disturbances. The results therefore provide further evidence that the project area remains environmentally stable.

Total Heterotrophic Fungi (THF)

Fungi constitute another important component of the soil microbial community and perform essential ecological functions including decomposition of resistant plant materials such as cellulose and lignin, formation of soil organic matter and enhancement of nutrient availability. The analyzed soils recorded active fungal populations throughout the project area. The widespread occurrence of heterotrophic fungi reflects the continuous availability of decomposable organic materials derived from grasses, ornamental shrubs and mature trees observed during the flora survey. Leaf litter accumulation beneath landscaped vegetation likely provides favourable substrates for fungal colonization and decomposition. The coexistence of healthy fungal and bacterial populations indicates a biologically balanced soil ecosystem with efficient decomposition processes and continuous nutrient recycling. From an environmental standpoint, the fungal populations further demonstrate that the soils have not experienced significant ecological stress or biological degradation.

Total Coliform Count (TCC)

Total coliform bacteria are widely used as indicators of faecal contamination and general sanitary quality. Their presence in soils may suggest contamination from sewage, domestic wastewater, livestock waste or other anthropogenic sources. The laboratory analysis indicated that total coliform bacteria were absent in all analyzed soil samples. The absence of coliform organisms is particularly significant because it demonstrates that the project area has not been impacted by faecal contamination or improper wastewater disposal. This finding reflects good environmental sanitation within the proposed project site and indicates minimal risk of pathogen-related public health concerns. The microbiological results therefore support the conclusion that the project area currently maintains satisfactory environmental hygiene and good baseline ecological conditions.

✧ **Dry Season (Secondary data)**

Table 4.8: Physico-Chemical and Biological Characteristics of Soil Samples (Secondary data)

S/N	PARAMETER	UNIT	SS1 (Top Soil)	SS1 (Bottom Soil)	SS2 (Top Soil)	SS2 (Bottom Soil	SS3 (Top Soil)	SS3 (Bottom Soil	SS Control (Top Soil)	SS Control (Bottom Soil
PHYSIOCHEMICAL ANALYSIS										
1.	Color	-	Reddish black 10R2.5/1	Light red 10R6/5	Dark gray 7.5YR4/1	Weak red 10R4/4	Light red 10R6/5	Dusky red 10R3/3	Dark brown 7.5YR3/4	Dark reddish gray10R3/1
2.	Temperature	^0C	38.30	34.40	34.60	37.30	35.20	36.70	30.20	36.50
3.	pH	-	7.20	7.20	7.30	7.20	7.30	7.60	7.30	7.80
4.	Permeability	-	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium
5.	Texture Sandy	%	42.11	71.43	74.42	82.50	66.67	76.92	78.26	
	Texture Clay	%	15.78	4.76	4.65	5.00	11.11	7.69	8.70	
	Texture Silt	%	42.11	23.81	20.93	12.50	22.22	15.39	13.04	
6.	Porosity	%	33.33	59.41	53.33	68.57	58.57	58.57	52..33	58.57
7.	Bulk Density	g/cm^3	0.93	1.02	1.17	0.87	1.04	1.23	1.04	0.98
8.	Moisture Content	%	10.25	11.36	13.25	9.53	11.61	14.04	11.61	10.87
9.	Electrical conductivity	µS/cm	222.00	271.00	283.00	321.00	325.00	279.00	198.00	285.00
10.	Nitrate (NO_3)	mg/kg	15.90	11.10	3.50	18.70	6.20	81.70	6.20	62.40
11.	Sulphate (SO^{4-})	mg/kg	ND	9.00	2.00	31.00	36.00	ND	35.00	25.00
12	Phosphate	mg/kg	1.39	1.22	0.76	1.36	0.99	1.23	0.44	1.08
13	Ammonia (NH^{3+})	mg/kg	ND	0.01	0.04	0.03	ND	ND	ND	ND
14	Ammonium	mg/kg	0.01	0.01	0.04	0.03	ND	ND	ND	ND
15.	NH^{3+} Nitrogen	mg/kg	ND	0.01	0.03	0.02	ND	ND	ND	ND
16.	Potassium (K)	mg/kg	0.013	0.015	0.003	ND	0.004	0.010	0.005	0.012
17.	Magnesium (Mg)	mg/kg	4.03	4.03	4.04	4.23	4.00	3.97	3.94	3.96
18.	Lead (Pb^{2+})	mg/kg	ND	ND	0.30	0.08	0.05	0.01	2.02	0.07
19.	Iron (Fe^{2+}/ Fe^{3+})	mg/kg	321.00	202.00	211.10	177.00	122.70	120.77	180.00	108.70
20.	Zinc (Zn^{2+})	mg/kg	0.93	0.12	0.80	0.59	0.48	0.57	0.58	0.98
21.	Copper (Cu^{2+})	mg/kg	0.35	0.19	0.37	0.36	0.23	0.33	0.24	0.28
MICROBIAL ANALYSIS										
22.	THB	CFU/g	$1.21x10^5$	$1.34 x10^5$	$1.27 x10^5$	$2.11 x10^5$	$1.14 x10^5$	$1.05 x10^5$	$1.27 x10^5$	$1.31 x10^5$
23.	Total Fungi	CFU/g	$1.33 x10^5$	$9.2 x10^4$	$1.55 x10^5$	$1.52 x10^5$	$4.6 x10^4$	$2.48 x10^5$	$6.4 x10^4$	$1.25 x10^5$
24.	Fecal Coliform	CFU/g	NG	NG	$2.7x10^1$	TFC	NG	TFC	TFC	$4.2x10^1$

***Source**: Final Environmental & Social Management Plan for the Construction of ACETEL Centre Jabi Abuja 2022.*

➢ ***Comparison between the wet and dry season soil samples and Inference for the project***

The values for wet-season soils (6.41–6.93) is consistent with the dry-season results indicating that seasonal rainfall has not significantly altered soil acidity and is considered suitable for civil engineering works. Electrical conductivity (EC) during the wet season ranges between 100 and 620 µS/cm, indicating non-saline soils. In comparison with the dry season, these values suggest that rainfall has diluted soluble salts, although localized increases at some sampling points may reflect runoff, fertilizer residues or natural mineral variability rather than contamination. As expected, the wet-season samples recorded relatively higher moisture contents than the dry-

season baseline. Increased rainfall enhances soil water retention and slightly reduces soil resistivity while improving microbial activities. Both investigations indicate relatively low to moderate nutrient levels typical of Guinea Savannah soils. Compared with the dry-season baseline: total nitrogen is slightly higher during the wet season due to increased mineralization and organic matter decomposition; available phosphorus remains generally low, indicating that phosphorus continues to be the limiting nutrient irrespective of season; potassium concentrations remain moderate and relatively stable between both studies. Overall, rainfall appears to improve nutrient mobility but does not significantly alter the fertility status of the soils. The concentrations of heavy metals remain low in both investigations: Iron continues to be the dominant naturally occurring metal, while chromium, cadmium and several other toxic metals were either absent or detected only at trace concentrations. Lead was largely absent from most project samples, with only isolated low values reported. Wet-season soils recorded relatively greater heterotrophic bacterial and fungal populations, which is expected because higher soil moisture promotes microbial growth. Total coliforms remained Not Detected (ND), indicating the absence of significant faecal contamination.

Overall, comparison between the wet and dry seasons indicate that the baseline soil quality has remained stable over time, with observed variations attributable mainly to seasonal climatic conditions rather than changes in land use or pollution. This supports the conclusion that the proposed project is being developed on land with good baseline environmental quality and no evidence of progressive soil degradation.

4.4.2.2 Groundwater Sampling & Quality Assessment

Groundwater constitutes one of the most important natural resources within any project environment because it serves as a major source of domestic water supply, supports ecological systems and reflects the hydrogeochemical characteristics of the underlying geological formations. Evaluation of groundwater quality is therefore essential for establishing baseline environmental conditions prior to project implementation and for identifying any existing contamination that may influence future environmental monitoring. Groundwater samples collected within the proposed project area were analyzed for a comprehensive suite of physicochemical, major ion, heavy metal and microbiological parameters in accordance with the American Public Health Association (APHA) standard analytical procedures. The analytical results were compared with the requirements of the National Environmental (Surface and Ground Water Quality Control) Regulations, 2011, in order to evaluate groundwater suitability and establish baseline conditions for the proposed Rural Electrification Agency (REA) solar photovoltaic development. These results provide an important environmental baseline against which any future project-related impacts can be assessed.

Groundwater samples were collected from four (4) operational water supply points distributed across the University campus to establish baseline groundwater quality conditions and to provide a representative assessment of groundwater quality in the campus.

Groundwater Sample GW1 was collected from a borehole located adjacent to the Faculty of Social Sciences at Latitude 9°01'19.36812"N and Longitude 7°24'34.40412"E. Groundwater Sample GW2 was obtained from a municipal water supply point located in front of the Senate

Building. The water source, supplied by the Water Board, serves the University community and was sampled at Latitude 9°01'12.67212"N and Longitude 7°24'31.446"E. Groundwater Sample GW3 was collected from a borehole situated near the University's main entrance, adjacent to the Faculty of Health Sciences Building, at Latitude 9°01'16.97044"N and Longitude 7°24'29.4048"E. Groundwater Sample GW4 was collected from the water supply point serving the Directorate of Physical Planning (DPP)/Administrative Block II at Latitude 9°01'14.05344"N and Longitude 7°24'33.72408"E.

The samples were analyzed for physicochemical parameters, heavy metals, microbial load, and hydrocarbon content. Appropriate sampling containers and preservation techniques were adopted to ensure sample integrity: clean plastic bottles were used for physicochemical parameters, nitric acid–preserved containers were used for heavy metal analysis, and pre-sterilized amber glass bottles were used for microbial and hydrocarbon analyses. The boreholes serve as primary sources of water for various domestic purposes and are therefore regarded as sensitive environmental receptors. To properly assess potential project-related impacts, in-situ measurements of temperature, total dissolved solids (TDS), pH, and electrical conductivity were taken at the point of collection. These field measurements provided immediate indicators of groundwater conditions and helped establish the pre-project baseline water quality status against which future changes can be evaluated.

Form the results of the in-situ measurements presented on Table 4.10 below, groundwater temperatures ranged from 28.4°C to 30.4°C, reflecting relatively stable subsurface thermal conditions characteristic of shallow groundwater aquifers within the Federal Capital Territory. The observed temperatures are consistent with ambient climatic conditions and indicate that groundwater has not been influenced by thermal pollution or other anthropogenic heat sources. Groundwater pH values ranged from 7.04 to 7.32 within the study area. All measured values fall within the WHO and NSDWQ acceptable range of 6.5–8.5, suggesting that groundwater acidity or alkalinity is unlikely to present constraints for domestic or institutional use following appropriate treatment where necessary (SON, 2015; WHO, 2022). The groundwater exhibited oxidation-reduction potential (ORP) values ranging between 210 mV and 285 mV indicating well-oxidized groundwater conditions and suggest that oxidizing geochemical processes predominate within the aquifer. Groundwater electrical conductivity values remained very low at 78 µS/cm for GW1–GW3 and increased to 369 µS/cm at GW4. Total Dissolved Solids ranged between 39 and 40 mg/L for GW1–GW3 and 182 mg/L for GW4. All measured TDS concentrations are substantially below the WHO and NSDWQ guideline value of 500 mg/L, indicating that the groundwater is weakly mineralized and contains relatively low concentrations of dissolved salts. Groundwater salinity was recorded as 0.00% in three locations and 0.01% at GW4, confirming that the aquifer contains fresh groundwater with negligible saline influence. The measured specific gravity of 1.000 across all sampling locations is also indicative of fresh groundwater containing low dissolved solid concentrations. Fertility values ranged between 1 and 2 ppm, suggesting low nutrient concentrations and the absence of significant nutrient enrichment within the groundwater system. The relatively high resistivity values recorded at GW1–GW3 (61.10–158.63 MΩ·cm) further support the low ionic strength indicated by the EC and TDS measurements.

Table 4.9: Groundwater Sampling Locations

Sample ID	Water Source	Sampling Location	Latitude (N)	Longitude (E)	Description
GW1	Borehole	Adjacent to the Faculty of Social Sciences	9°01'19.36812"	7°24'34.40412"	Borehole serving the academic area.
GW2	Municipal Water Supply	In front of the Senate Building	9°01'12.67212"	7°24'31.446"	Government water board supply serving the University.
GW3	Borehole	Adjacent to the Faculty of Health Sciences, near the main entrance	9°01'16.97044"	7°24'29.4048"	Borehole serving the front section of the campus.
GW4	Borehole	Directorate of Physical Planning (DPP)/Administrative Block II	9°01'14.05344"	7°24'33.72408"	Borehole serving the administrative section of the campus.

Table 4.10: In-Situ Results of Ground Water measurements

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	28.4	7.04	279	157.56	78	40	0.00	1.000	1
GW2	28.8	7.12	210	158.63	78	39	0.00	1.000	1
GW3	29.4	7.32	224	61.10	78	39	0.00	1.000	1
GW4	30.4	7.27	285	36.89	369	182	0.01	1.000	2

.

4.4.2.2.1 Laboratory Analysis, Interpretation and Discussions for Groundwater

Table 4.11: Laboratory Results of Ground Water

S/N	PARAMETERS	UNIT	TEST METHOD	FMEnv LIMITS FOR GROUNDWATER	GW1	GW2	GW3	GW4
PHYSICO- CHEMICAL PARAMETERS								
1	pH		APHA 4500-H^+	6.5 -8.5	6.990	7.290	7.190	6.840
2	TEMPERATURE	^0C	APHA 2550B	AMBIENT	27.900	27.900	27.900	27.900
3	TURBIDITY	NTU	APHA 2130B	≤ 5	4.000	0.000	0.000	0.000
4	TOTAL DISSOLVED SOLIDS	mg/l	APHA 2540C	≤ 500	25.900	53.200	51.800	253.800
5	CONDUCTIVITY	µS/cm	APHA 2510B	≤ 1000	37.000	76.000	74.000	362.000
6	TOTAL HARDNESS	mg/l	APHA 2340C	≤ 150	414.633	365.853	292.682	487.804
7	MAGNESIUM HARDNESS	mg/l	APHA 2340C	NS	146.341	146.340	121.950	195.122
8	CALCIUM HARDNESS	mg/l	APHA 2340C	NS	268.292	219.512	170.731	292.682
9	ALKALINITY	mg/l	APHA 2320B	≤ 100	80.000	20.000	40.000	140.000
10	TOTAL SUSPENDED SOLID	mg/l	APHA 2540D	NS	0.020	0.012	0.014	0.019
11	TOTAL SOLID	mg/l	APHA 2540B	NS	6.990	7.290	7.190	253.819
12	SALINITY	ppt	APHA 2510B	NS	0.057	0.038	0.058	0.057
MAJOR IONS								
13	CARBONATE	mg/l	APHA 2320 B	NS	0.07	0.04	0.06	0.091
14	BICARBONATE	mg/l	APHA 2320 B	NS	79.92	19.95	39.93	139.906
15	CALCIUM	mg/l	APHA 3500-Ca B	≤ 75	107.532	87.98	68.429	117.307
16	MAGNESIUM	mg/l	APHA 3500-Mg B	≤50	35.576	35.575	29.646	47.434
17	CHLORIDE	mg/l	APHA 4500-Cl B	≤250	31.586	21.057	31.585	31.586
18	SULPHATE	mg/l	APHA 4500-SO_4^{2-} E	≤100	14.308	9.231	1.077	6.462
19	NITRATE	mg/l	APHA 4500-NO_3 B	≤50	1.345	1.092	1.05	1.513
22	AMMONIUM	mg/l	APHA 4500-NH_4+ B	NS	1.17	2.05	1.21	0.990
23	PHOSPHATE	mg/l	APHA 4500-P04	NS	0.00	0.00	0.00	0.000
24	NITRITE	mg/l	APHA 4500-NO_2 B	≤0.2	0.051	0.074	0.026	0.088
METALS								
25	IRON	mg/l	APHA 3500-Fe B	≤0.2	0.448	0.676	1.095	0.267
26	SODIUM	mg/l	APHA 3500-Na B	100	0.15	0.098	0.121	0.994
27	POTASSIUM	mg/l	APHA 3500-K B	20	10.781	10.664	9.844	10.781

S/N	PARAMETERS	UNIT	TEST METHOD	FMEnv LIMITS FOR GROUNDWATER	GW1	GW2	GW3	GW4
28	MANGANESE	mg/l	APHA 3500-Mn B	≤3.0	0.002	0.004	0.002	0.000
29	ZINC	mg/l	APHA 3111B	≤0.5	0.085	0.045	0.02	0.154
30	COPPER	mg/l	APHA 3111B	≤1.0	0.376	0.531	0.518	0.538
31	LEAD	mg/l	APHA 3111B	≤0.01	0.000	0.138	0.158	0.203
32	CADMIUM	mg/l	APHA 3111B	≤0.003	0.126	0.075	0.184	0.301
33	CHROMIUM	mg/l	APHA 3111B	≤0.05	0.000	0.000	0.000	0.000
34	ARSENIC	mg/l	APHA 3111B	≤0.01	0.004	0.004	0.004	0.005
MICROBIAL PARAMETERS								
35	TOTAL BACTERIAL COUNT	cfu/ml	APHA 9215B	≤100	2.8×10^4	1.0×10^3	5.0×10^2	5.0×10^2
36	TOTAL COLIFORM	cfu/ml	APHA 9222B	0.00	ND	1.0×10^1	ND	ND
37	TOTAL FUNGI	cfu/ml	APHA 9222D	0.00	ND	1.0×10^1	ND	5.0×10^0
38	FEACAL COLIFORM	cfu/ml	APHA 9222E	0.00	ND	ND	ND	ND
STANDARD : NATIONAL ENVIRONMENTAL (SURFACE AND GROUND WATER QUALITY CONTROL) REGULATIONS, 2011.								
NOTE:								
mg/l = miligram per litre								
µS/cm = micro Siemens per centimetre								
cfu/ml = colony forming unit per milliliter.								
NS = Not stated								
ND = Not Detected								
TNTC = Too numerous to count								

4.4.2.2.2 Physicochemical Characteristics

Physicochemical parameters provide the primary indication of groundwater quality because they describe the physical appearance, mineralization, chemical stability and general suitability of water for domestic, agricultural and engineering purposes. The parameters evaluated include pH, temperature, turbidity, total dissolved solids (TDS), electrical conductivity (EC), total hardness, calcium hardness, magnesium hardness, alkalinity, total suspended solids (TSS), total solids (TS) and salinity. Collectively, these parameters provide insight into groundwater chemistry, water-rock interactions and potential anthropogenic influences.

pH

Hydrogen ion concentration (pH) is one of the most important indicators of water quality because it influences chemical reactions, metal solubility, biological activity and the effectiveness of water treatment processes. The National Environmental (Surface and Ground Water Quality Control) Regulations, 2011 recommend a pH range of 6.5–8.5 for groundwater intended for domestic use. The analyzed groundwater samples recorded pH values ranging from 6.84 to 7.29, with all four sampling locations falling comfortably within the recommended regulatory limits. These values indicate that the groundwater is essentially neutral to very slightly acidic, reflecting a chemically stable groundwater system. The near-neutral pH is characteristic of groundwater developed within crystalline Basement Complex terrains where prolonged interaction between groundwater and silicate minerals produces relatively well-buffered hydro chemical conditions. Such pH conditions minimize the mobility of many potentially toxic heavy metals, thereby reducing their bioavailability and limiting the potential for groundwater-induced corrosion or scaling. The observed pH values also provide favourable conditions for aquatic microorganisms and indicate that significant acidification or alkaline contamination has not occurred within the study area. Overall, the pH results indicate excellent acid-base balance and demonstrate compliance with national groundwater quality standards.

Temperature

Water temperature significantly influences dissolved oxygen concentrations, chemical reaction rates, microbial activity and overall water quality. Groundwater temperatures commonly approximate the prevailing subsurface environmental temperature because groundwater remains largely insulated from daily atmospheric fluctuations. All analyzed groundwater samples recorded an identical temperature of 27.9°C, corresponding closely with the ambient environmental conditions prevailing during sampling. The uniformity of groundwater temperature across all sampling locations suggests that the aquifer possesses relatively homogeneous hydrogeological conditions with limited external thermal influences. Furthermore, the absence of elevated temperatures indicates that no industrial thermal discharges or geothermal anomalies are affecting groundwater quality within the project area. Consequently, groundwater temperature reflects normal tropical environmental conditions and presents no environmental concern.

Turbidity

Turbidity represents the degree of cloudiness produced by suspended particles within water and is an important aesthetic and operational water quality parameter. High

turbidity may interfere with disinfection processes and may indicate erosion, surface runoff or microbial contamination. The regulatory limit for turbidity is 5 NTU. Measured turbidity values ranged between 0 and 4 NTU, with GW1 recording the highest value (4 NTU) while the remaining groundwater samples exhibited no measurable turbidity. All groundwater samples therefore satisfy the national regulatory standard. The slightly elevated turbidity observed in GW1 most likely reflects minor suspended particulate matter introduced during groundwater abstraction or natural fine-grained sediments within the aquifer rather than significant environmental contamination. Overall, the groundwater exhibits excellent clarity and low suspended particulate content.

Total Dissolved Solids (TDS)

Total Dissolved Solids represent the total concentration of dissolved inorganic salts and small quantities of organic substances present in groundwater. TDS provides an overall measure of mineralization and strongly influences water taste, palatability and suitability for domestic use. The regulatory limit is 500 mg/L. Measured TDS concentrations ranged from 25.9 to 253.8 mg/L, considerably below the recommended standard. These relatively low concentrations indicate that groundwater mineralization is generally low despite prolonged groundwater-rock interaction. The slightly higher concentration recorded at GW4 likely reflects increased dissolution of naturally occurring minerals within the aquifer matrix rather than anthropogenic contamination. Low TDS values indicate fresh groundwater with minimal dissolved salts, excellent aesthetic quality and low scaling potential. From a hydrogeochemical perspective, the groundwater may therefore be classified as fresh groundwater.

Electrical Conductivity (EC)

Electrical conductivity measures the ability of water to conduct electricity and provides a rapid estimate of dissolved ionic constituents. Measured conductivity values ranged between 37 and 362 µS/cm, substantially below the regulatory limit of 1000 µS/cm. These values indicate low ionic strength and low mineralization throughout the groundwater system. The relatively higher conductivity observed in GW4 corresponds well with its comparatively higher TDS concentration, illustrating the close relationship between dissolved ions and electrical conductivity. Overall, the conductivity values indicate chemically dilute groundwater with minimal salinity and excellent suitability for most domestic and engineering applications.

Total Hardness

Total hardness represents the combined concentration of dissolved calcium and magnesium salts in water, commonly expressed as milligrams per litre of calcium carbonate. Hardness is mainly controlled by groundwater interaction with calcium- and magnesium-bearing minerals within the aquifer. Although hardness is generally not considered an acute toxicological concern, excessive concentrations may reduce the acceptability of water for domestic use and create operational problems such as scaling of pipes, pumps, heating elements and storage systems. The applicable groundwater limit presented in the laboratory report is 150 mg/L. Total hardness concentrations recorded in the groundwater samples were: GW1: 414.633 mg/L, GW2: 365.853 mg/L, GW3: 292.682 mg/L, and GW4: 487.804 mg/L All four groundwater samples exceeded the stated limit. GW4 recorded the highest total hardness, followed by GW1, GW2 and GW3.

Magnesium Hardness

Magnesium hardness represents the portion of total hardness attributable to dissolved magnesium compounds. Magnesium is a naturally occurring element that enters groundwater mainly through mineral weathering and dissolution. It is an essential nutrient but contributes to water hardness and may affect taste when present at elevated levels. Magnesium concentrations ranged from 121.950 to 195.122 mg/L, as follows: GW1: 146.341 mg/L, GW2: 146.340 mg/L, GW3: 121.950 mg/L, and GW4: 195.122 mg/L.

Calcium Hardness

Calcium hardness represents the proportion of total hardness associated with dissolved calcium ions. Calcium commonly enters groundwater through mineral weathering and ion-exchange reactions and is generally the dominant hardness-producing ion in many aquifers. Calcium hardness concentrations ranged from 170.731 to 292.682 mg/L: GW1: 268.292 mg/L, GW2: 219.512 mg/L, GW3: 170.731 mg/L, and GW4: 292.682 mg/L. No separate regulatory limit was provided for calcium. However, calcium hardness exceeded magnesium hardness in all samples, showing that calcium was the principal contributor to the overall groundwater hardness. GW4 recorded the highest calcium hardness, followed by GW1, GW2 and GW3. This distribution corresponds directly with the total hardness pattern and supports the conclusion that natural water–rock interaction is the dominant control on hardness.

Alkalinity

Alkalinity represents the acid-neutralizing capacity of water and is primarily controlled by bicarbonate, carbonate and hydroxide ions. It provides an indication of the groundwater's buffering capacity and resistance to sudden changes in pH. The stated regulatory limit is 100 mg/L. Recorded alkalinity values were: GW1: 80 mg/L, GW2: 20 mg/L, GW3: 40 mg/L, and GW4: 140 mg/L. GW1, GW2 and GW3 complied with the stated limit, while GW4 exceeded it. The comparatively high alkalinity recorded in GW4 corresponds with its elevated bicarbonate concentration, TDS, conductivity, calcium, magnesium and total hardness. This indicates stronger dissolution of aquifer minerals and a greater degree of groundwater buffering at that location. The low alkalinity recorded in GW2 suggests relatively limited buffering capacity. Although its pH remained within the acceptable range, groundwater with low alkalinity may be more susceptible to pH changes if exposed to acidic contaminants. The GW4 alkalinity exceedance is associated with natural bicarbonate enrichment resulting from the reaction of infiltrating water with carbon dioxide and mineral constituents within the weathered aquifer.

Total Suspended and Dissolved Solids

Total Suspended Solids represent particulate materials retained in water, including fine sediments, clay particles, organic debris and microbial material. Elevated TSS may indicate poor borehole development, erosion, surface-water intrusion or disturbance during sampling. Measured TSS concentrations were extremely low, ranging from 0.012 to 0.020 mg/L: GW1: 0.020 mg/L, GW2: 0.012 mg/L, GW3: 0.014 mg/L, and GW4: 0.019 mg/L. No regulatory limit was stated in the table. However, the values indicate that all groundwater samples contained negligible

suspended matter. The low TSS results correspond with the low turbidity values and demonstrate that the groundwater is visually clear and largely free from particulate contamination. GW1 recorded the highest turbidity and TSS, but both parameters remained very low and environmentally acceptable. Total solids represent the combined quantity of dissolved and suspended materials contained in water. Reported concentrations were: GW1: 6.990 mg/L, GW2: 7.290 mg/L, GW3: 7.190 mg/L, and GW4: 253.819 mg/L. GW4 recorded a substantially higher total-solids concentration than the other sampling locations. The low suspended-solid content is favourable for groundwater use because it minimizes sediment accumulation in storage tanks, pipes, pumps and treatment systems. It also suggests that the sampled boreholes are generally protected from substantial sediment intrusion.

Salinity

Salinity refers to the concentration of dissolved salts in water and is an important indicator of groundwater suitability for domestic, agricultural and industrial uses. Recorded salinity values ranged from 0.038 to 0.058 ppt: GW1: 0.057 ppt, GW2: 0.038 ppt, GW3: 0.058 ppt, and GW4: 0.057 ppt. All values are extremely low and indicate fresh groundwater with no evidence of saline intrusion or significant salt accumulation. The low salinity results agree with the low conductivity, TDS and chloride concentrations. They indicate that the groundwater has not been affected by saline wastewater, evaporative concentration or intrusion of saline water. From an engineering and environmental perspective, low salinity is favourable because it reduces the likelihood of salt-related corrosion.

4.4.2.2.3 Major-Ion Characteristics

Carbonate

Carbonate concentrations ranged from 0.040 to 0.091 mg/L: GW1: 0.070 mg/L, GW2: 0.040 mg/L, GW3: 0.060 mg/L, and GW4: 0.091 mg/L. No regulatory limit was stated. The concentrations were extremely low in all samples. The low carbonate values are consistent with the near-neutral pH of the groundwater. Under such conditions, dissolved inorganic carbon is expected to occur predominantly as bicarbonate rather than carbonate. Carbonate becomes more dominant only under comparatively alkaline conditions. The highest carbonate concentration occurred in GW4, which also recorded the highest alkalinity and bicarbonate concentration. Nevertheless, its carbonate level remained negligible and presents no environmental concern.

Bicarbonate

Bicarbonate concentrations ranged from 19.95 to 139.906 mg/L: GW1: 79.92 mg/L, GW2: 19.95 mg/L, GW3: 39.93 mg/L, GW4: 139.906 mg/L. No separate limit was stated. Bicarbonate was the dominant alkalinity-producing ion and followed the same spatial pattern as the measured alkalinity. The elevated bicarbonate concentration in GW4 indicates stronger water–rock interaction and greater dissolution of minerals within the aquifer. Bicarbonate commonly develops when infiltrating rainwater absorbs carbon dioxide from the atmosphere and soil zone, forms weak carbonic acid and reacts with calcium- and magnesium-bearing minerals. The comparatively low bicarbonate concentration in GW2 indicates lower mineralization and reduced buffering capacity.

Calcium
Calcium concentrations ranged from 68.429 to 117.307 mg/L: GW1: 107.532 mg/L, GW2: 87.980 mg/L, GW3: 68.429 mg/L, and GW4: 117.307 mg/L. The stated limit is 75 mg/L. GW3 complied with the limit, while GW1, GW2 and GW4 exceeded it. GW4 recorded the highest concentration, followed by GW1 and GW2.

Magnesium
Magnesium concentrations ranged from 29.646 to 47.434 mg/L: GW1: 35.576 mg/L, GW2: 35.575 mg/L, GW3: 29.646 mg/L, GW4: 47.434 mg/L. All groundwater samples complied with the stated limit of 50 mg/L. GW4 approached the limit but remained compliant.

Chloride
Chloride concentrations ranged from 21.057 to 31.586 mg/L: GW1: 31.586 mg/L, GW2: 21.057 mg/L, GW3: 31.585 mg/L, and GW4: 31.586 mg/L. All concentrations were substantially below the applicable limit of 250 mg/L. The low chloride levels demonstrate that the groundwater has not been affected by saline intrusion, substantial wastewater infiltration or excessive chloride-containing inputs. The near-identical concentrations in GW1, GW3 and GW4 indicate a relatively uniform natural chloride background.

Sulphate
Sulphate concentrations ranged from 1.077 to 14.308 mg/L: GW1: 14.308 mg/L, GW2: 9.231 mg/L, GW3: 1.077 mg/L, GW4: 6.462 mg/L. All samples complied comfortably with the stated limit of 100 mg/L. The low sulphate concentrations indicate limited dissolution of sulphate-bearing minerals and no evidence of contamination from industrial discharges, sewage or sulphur-rich wastes. The results are favourable for infrastructure because elevated sulphate can contribute to concrete deterioration and corrosion under certain conditions. At the measured concentrations, sulphate-related engineering impacts are unlikely.

Nitrate
Nitrate concentrations ranged from 1.050 to 1.513 mg/L: GW1: 1.345 mg/L, GW2: 1.092 mg/L, GW3: 1.050 mg/L, and GW4: 1.513 mg/L All concentrations were substantially below the regulatory limit of 50 mg/L. The consistently low nitrate values indicate that the groundwater has not been impacted either by fertilizer leaching, sewage infiltration, septic systems or decomposing organic wastes.

Ammonium
Ammonium concentrations ranged from 0.990 to 2.050 mg/L: GW1: 1.170 mg/L, GW2: 2.050 mg/L, GW3: 1.210 mg/L, and GW4: 0.990 mg/L. Ammonium may originate from natural decomposition of organic matter, mineralization of nitrogen-containing materials, sewage infiltration or reducing conditions within groundwater. GW2 recorded the highest concentration. GW2 was the only sample containing detectable total coliform and also recorded the highest ammonium concentration. This combination may indicate localized influence from organic matter, poor sanitary protection or shallow contamination around the water source. However, faecal coliform was not detected, nitrate remained low and the ammonium concentrations were not accompanied by elevated phosphate.

Phosphate
Phosphate was not detected in any groundwater sample: GW1: 0.000 mg/L, GW2: 0.000 mg/L, GW3: 0.000 mg/L, GW4: 0.000 mg/L. This indicates no evidence of groundwater enrichment from detergents, fertilizers, wastewater or decomposing organic wastes. Phosphate is generally less mobile than nitrate because it is readily adsorbed by iron and aluminium oxides and fixed by soil minerals. This result supports the conclusion that the groundwater has not experienced significant nutrient contamination.

Nitrite
Nitrite concentrations ranged from 0.026 to 0.088 mg/L: GW1: 0.051 mg/L, GW2: 0.074 mg/L, GW3: 0.026 mg/L, and GW4: 0.088 mg/L. All samples complied with the stated limit of 0.2 mg/L. Nitrite is an intermediate product of nitrogen transformation and is normally present at low concentrations in well-oxygenated groundwater. The measured values indicate limited accumulation and generally effective conversion of reduced nitrogen forms. The highest concentration occurred in GW4, but it remained below the limit. The nitrite results do not indicate significant sewage or fertilizer contamination.

4.4.2.2.4 Metals and Trace Elements

Iron
Iron is a common constituent of groundwater, particularly in tropical Basement Complex terrains where weathering of iron-bearing minerals releases iron into the groundwater system. It may also originate from corrosion of steel borehole casings, pumps, pipes and storage facilities. The groundwater samples recorded iron concentrations of: GW1: 0.448 mg/L, GW2: 0.676 mg/L, GW3: 1.095 mg/L, and GW4: 0.267 mg/L. All four samples exceeded the stated groundwater limit of 0.2 mg/L. GW3 recorded the highest concentration, more than five times the stated limit, while GW4 recorded the lowest concentration but remained above the standard. The elevated iron concentrations may reflect natural dissolution of iron-bearing minerals within the weathered and fractured Basement Complex aquifer. Localized reducing conditions may also promote the conversion of relatively insoluble ferric iron to more soluble ferrous iron. Alternatively, corrosion of borehole casings, pumps or distribution pipes may contribute to the observed concentrations.

Sodium
Sodium is a naturally occurring major cation derived from mineral weathering, ion exchange, atmospheric deposition and, in some settings, domestic or industrial activities. Elevated sodium may affect taste and can be important where water is intended for people requiring sodium-restricted diets. Recorded sodium concentrations were: GW1: 0.150 mg/L, GW2: 0.098 mg/L, GW3: 0.121 mg/L, and GW4: 0.994 mg/L All samples were substantially below the stated limit of 100 mg/L. The concentrations are extremely low and confirm that the groundwater is not sodium-dominated. GW4 recorded the highest value, but this remained negligible relative to the applicable limit. The low sodium concentrations agree with the low salinity, conductivity and chloride results and indicate no evidence of saline intrusion, substantial wastewater influence or sodium-related contamination. Sodium is therefore not considered a groundwater-quality concern within the project area.

Potassium

Potassium is an essential nutrient that occurs naturally in groundwater through weathering of potassium-bearing minerals such as feldspars and micas. It may also enter groundwater through fertilizers, organic wastes and domestic wastewater, although it is generally less mobile than sodium because it is readily retained by soils and clay minerals. Potassium concentrations were: GW1: 10.781 mg/L, GW2: 10.664 mg/L, GW3: 9.844 mg/L, GW4: 10.781 mg/L. All samples complied with the stated limit of 20 mg/L. The relatively uniform concentrations indicate a stable natural geochemical background. There is no evidence of localized potassium enrichment from fertilizer use, wastewater discharge or waste disposal. The values are not considered environmentally significant and do not present a constraint to domestic, construction or project-related groundwater use.

Manganese

Manganese commonly occurs in association with iron-bearing minerals and becomes more soluble under reducing groundwater conditions. Measured manganese concentrations were: GW1: 0.002 mg/L, GW2: 0.004 mg/L, GW3: 0.002 mg/L, GW4: Not detected/0.000 mg/L. All values were far below the stated limit of 3.0 mg/L. The very low manganese concentrations indicate limited dissolution of manganese-bearing minerals and suggest that groundwater conditions do not strongly favour manganese mobilization. Manganese therefore presents no identified environmental, aesthetic or operational concern.

Zinc

Zinc is an essential trace element required for normal biological function but may affect taste and aquatic organisms at elevated concentrations. It may originate from natural mineral weathering, galvanized pipes, roofing materials, batteries and waste disposal. Measured zinc concentrations were: GW1: 0.085 mg/L, GW2: 0.045 mg/L, GW3: 0.020 mg/L, and GW4: 0.154 mg/L. All samples complied with the stated limit of 0.5 mg/L. The values represent low background concentrations. GW4 recorded the highest zinc concentration, but this remained well below the applicable limit. The spatial variation may reflect differences in aquifer mineralogy or contact with galvanized components within the borehole or distribution system. No evidence of significant zinc contamination was identified, and zinc is not considered a groundwater-quality constraint within the study area.

Copper

Copper is an essential micronutrient but may cause taste, staining and gastrointestinal effects when present at excessive concentrations. It may occur naturally or be introduced through corrosion of copper-containing plumbing, electrical installations, agrochemicals or wastes. Copper concentrations were: GW1: 0.376 mg/L, GW2: 0.531 mg/L, GW3: 0.518 mg/L, GW4: 0.538 mg/L. All samples remained below the stated limit of 1.0 mg/L. The relatively similar concentrations in GW2, GW3 and GW4 indicate a consistent background source or comparable contact with groundwater infrastructure. GW1 recorded a lower concentration. Although the values comply with the stated standard, the concentrations are higher than those of zinc and manganese. They may reflect natural geochemical conditions or contact with metallic borehole and plumbing components.

Lead

Lead is a toxic, non-essential metal with no beneficial biological role. It may enter groundwater through corrosion of pipes, solder, batteries, paints, waste disposal, vehicular residues, contaminated fill materials or industrial activities. Because of its persistence and toxicity, even relatively low concentrations are environmentally significant. Lead concentrations were: GW1: 0.000 mg/L, GW2: 0.138 mg/L, GW3: 0.158 mg/L, and GW4: 0.203 mg/L. The stated limit is 0.01 mg/L. Lead was not detected in GW1. However, GW2, GW3 and GW4 exceeded the limit. GW2 was approximately 13.8 times the limit, GW3 approximately 15.8 times the limit and GW4 approximately 20.3 times the limit. These exceedances are critical because lead exposure may affect neurological development, cognitive function, blood formation, kidney function and cardiovascular health. Children and pregnant individuals are particularly vulnerable. The absence of laboratory evidence for lead in GW1 and its occurrence at elevated concentrations in the other three samples suggest localized contamination or differences in water-supply infrastructure rather than a uniform aquifer-wide geochemical condition. Potential sources include corrosion of borehole components, pumps, plumbing fittings, solder, storage tanks or nearby waste materials.

Cadmium

Cadmium is a highly toxic, non-essential metal associated with batteries, pigments, metal plating, electronic wastes, fertilizers, industrial residues and corrosion of certain metallic components. It may also occur naturally in trace quantities in some geological materials. Measured cadmium concentrations were: GW1: 0.126 mg/L, GW2: 0.075 mg/L, GW3: 0.184 mg/L, and GW4: 0.301 mg/L. The stated limit is 0.003 mg/L. All four samples exceeded the limit by very large margins: GW1: approximately 42 times the limit, GW2: approximately 25 times the limit, GW3: approximately 61 times the limit, and GW4: approximately 100 times the limit. These results represent the most severe exceedances in the groundwater dataset. Cadmium is associated with kidney damage, bone demineralization and other chronic health effects following prolonged exposure. The groundwater must not be considered potable on the basis of the existing results.

Chromium

Chromium may occur naturally in ultramafic minerals or may be introduced through metal finishing, pigments, tanning, treated wood, industrial wastes and combustion residues. Its environmental significance depends strongly on its chemical form, with hexavalent chromium being more mobile and toxic than trivalent chromium. Chromium was not detected in any groundwater sample: GW1: 0.000 mg/L, GW2: 0.000 mg/L, GW3: 0.000 mg/L, and GW4: 0.000 mg/L. All samples therefore complied with the stated limit of 0.05 mg/L. The absence of detectable chromium indicates no evidence of chromium-related contamination within the sampled groundwater. This finding suggests that activities associated with chromium-containing industrial wastes have not significantly affected the water sources.

Arsenic

Arsenic is a toxic metalloid that may occur naturally through dissolution of arsenic-bearing minerals or may be introduced through pesticides, treated timber, mining, industrial wastes and combustion residues. Arsenic concentrations were: GW1: 0.004

mg/L, GW2: 0.004 mg/L, GW3: 0.004 mg/L, GW4: 0.005 mg/L. All samples complied with the stated limit of 0.01 mg/L. The low and relatively uniform concentrations indicate natural background occurrence rather than localized contamination. GW4 recorded the highest value, but this remained at half of the applicable limit. Although arsenic does not presently constitute a regulatory exceedance, its toxicological importance means it should remain part of future groundwater monitoring, particularly where hydro chemical conditions change.

➢ ***Implications for the Proposed Project***

The proposed REA development is not expected to generate significant quantities of lead or cadmium during normal operation. However, solar-energy installations involve electrical equipment, cables, batteries where energy storage is included, metallic components, lubricants and electronic materials. Poor handling or disposal could introduce metals into soil and groundwater over time. The project should therefore implement strict controls for:

- storage and handling of batteries and electronic components;
- management of damaged photovoltaic panels and electrical equipment;
- collection and disposal of metal-containing wastes;
- prevention of fuel and lubricant spills;
- use of lined and covered waste-storage areas; and
- engagement of licensed waste handlers.

Baseline metal exceedances should be investigated before construction so that the project is not incorrectly associated with pre-existing groundwater conditions during future monitoring.

4.4.2.2.5 Microbiological Characteristics

Total Bacterial Count

Total Bacterial Count provides a general measure of culturable heterotrophic bacteria present in water. It does not necessarily indicate faecal contamination or the presence of specific pathogens, but elevated counts may reflect poor sanitary protection, biofilm development, stagnant storage, inadequate maintenance or ingress of organic material. The reported counts were: GW1: 2.8×10^4 cfu/mL, GW2: 1.0×10^3 cfu/mL, GW3: 5.0×10^2 cfu/mL, GW4: 5.0×10^2 cfu/mL. The stated limit is 100 cfu/mL. All samples exceeded the limit. GW1 recorded the highest count at approximately 28,000 cfu/mL, followed by GW2 at 1,000 cfu/mL. GW3 and GW4 each recorded 500 cfu/mL. The results indicate substantial general bacterial activity, particularly at GW1. Potential causes include inadequate borehole-head protection, contamination of taps or storage tanks, biofilm formation within distribution pipes, poor disinfection, stagnant water or contamination introduced during sampling. The lack of faecal coliform in all samples indicates that the elevated total bacterial counts do not necessarily represent recent faecal pollution. Nevertheless, they demonstrate that the water does not meet the stated microbiological requirement and should not be consumed without treatment. GW1 requires particular investigation because it recorded the highest bacterial count despite having no detectable total or faecal coliform. This pattern may reflect non-faecal environmental bacteria, biofilm contamination or poor maintenance of the water-supply system.

Total Coliform

Total coliform bacteria are used as indicators of the sanitary integrity of water sources and distribution systems. They may originate from soil, vegetation, surface water, sewage or biofilms. Their presence suggests that pathways exist through which contamination can enter the water supply. The results were: GW1: Not detected, GW2: 1.0×10^1 cfu/mL, GW3: Not detected, GW4: Not detected. The stated standard is 0.00 cfu/mL. GW1, GW3 and GW4 complied with the stated requirement. GW2 recorded total coliform at approximately 10 cfu/mL and therefore failed the microbiological standard. The detection of total coliform in GW2 indicates compromised sanitary protection or contamination within the source, storage system or distribution line. This result is notable because GW2 also recorded the highest ammonium concentration and detectable fungi. Together, these findings suggest localized organic or sanitary influence. However, because faecal coliform was absent, the result does not establish recent faecal contamination. Potential non-faecal sources include soil-derived bacteria, biofilms, poorly maintained storage tanks or contaminated sampling outlets. A sanitary survey and repeat sampling are required. The borehole apron, drainage, wellhead seal, storage tank, tap condition and proximity to septic systems should be assessed.

Total Fungi

Fungal organisms may enter groundwater from soil, organic debris, airborne spores, storage tanks and distribution systems. Their presence is not always directly associated with faecal pollution, but it may indicate poor maintenance, stagnant water, biofilm formation or organic contamination. The results were: GW1: Not detected, GW2: 1.0×10^1 cfu/mL, GW3: Not detected, GW4: 5.0×10^0 cfu/mL. The stated standard is 0.00 cfu/mL. Fungi were absent in GW1 and GW3 but detected in GW2 and GW4. GW2 recorded the higher fungal count. The detection of fungi indicates some degree of biological ingress or growth within the groundwater-supply system. The occurrence in GW2 alongside total coliform and elevated ammonium strengthens the case for inspection of the borehole and distribution infrastructure. In GW4, the low fungal count may reflect localized biofilm development or contamination of the outlet or storage facility. Although the counts are relatively low compared with the total bacterial concentrations, they exceed the stated zero-tolerance criterion and require corrective action where the water is intended for potable use.

Faecal Coliform

Faecal coliform bacteria are more specific indicators of contamination from human or animal faecal matter. Their presence would indicate a heightened risk of enteric pathogens and would make the water unsuitable for drinking without treatment. Faecal coliform was not detected in any sample: GW1: Not detected, GW2: Not detected, GW3: Not detected, and GW4: Not detected. All samples complied with the stated requirement of zero detectable faecal coliform. This is a favourable result and indicates no laboratory evidence of faecal contamination at the time of sampling. It reduces concern regarding direct sewage intrusion but does not override the elevated total bacterial count or total-coliform detection in GW2. The water therefore still requires treatment and confirmatory monitoring before potable use.

➢ ***Implications for the Proposed Project***

Construction activities may temporarily increase the risk of microbiological contamination through disturbed drainage, surface runoff, excavation and poor sanitation. The project should maintain adequate separation between groundwater sources and toilets, septic systems, waste-storage areas and fuel-handling zones. Borehole heads should be protected using raised concrete aprons, proper seals and drainage channels. Storage tanks should be covered, cleaned and disinfected periodically. Water-distribution pipes and taps should be maintained to prevent biofilm growth and external ingress. Project workers should not consume untreated groundwater. Potable water should be sourced from a verified supply or treated and tested before distribution.

✧ **Dry Season (Secondary data)**

Table 4.12: Physico-Chemical and Biological Characteristics of the Groundwater (Secondary data)

S/N	PARAMETER	UNIT	RESULT		FMEnv LIMIT
			GW1 Borehole (Kuchingoro)	GW2 Borehole (Chika)	
	Physico-Chemical Analysis				
1.	Colour	Hazen unit	Colourless	Colourless	Colourless
2.	Odour	-	Odourless	Odourless	Odourless
3.	Temperature	^0C	32.90	31.50	-
4.	PH	-	7.50	7.43	6.50-8.50
5.	Turbidity	NTU	0.93	0.77	1.0
6.	Total Dissolved Solids	mg/L	52.90	42.40	500
7.	Electrical Conductivity	µS/cm	75.70	62.10	-
8.	Dissolved Oxygen	mg/L	0.90	0.50	7.50
9.	Total Suspended Solids	mg/L	3.00	3.00	>10
10.	Total Hardness	mg/L	45.10	37.60	200
11.	Calcium hardness	mg/L	14.70	17.00	-
12.	Magnesium hardness	mg/L	30.40	20.60	-
13.	Biochemical Oxygen Demand	mg/L	0.20	0.40	0
14.	Nitrate ($NO3^-$)	mg/L	2.70	0.70	10.0
15.	Nitrite	mg/L	0.021	0.016	1.0
16.	Ammonia	mg/L	0.09	0.12	<1.0
17.	Ammonium	mg/L	0.09	0.13	-
18.	Ammonia Nitrogen	mg/L	0.07	0.10	-
19.	Phosphate ($PO4^{2-}$)	mg/L	1.81	2.04	>5

20.	Sulphate (SO_4^{2-})	mg/L	1.00	1.00	500
21.	Potassium (K^+)	mg/L	0.015	0.018	-
22.	Magnesium	mg/L	0.025	0.047	-
23.	Iron (Fe^{2+}/ Fe^{3+})	mg/L	0.005	0.003	1.0
24.	Lead (Pb^{2+})	mg/L	0.02	0.02	0.05
25.	Zinc	mg/L	0.05	0.06	5.0
26.	Copper (Cu^{2+})	mg/L	0.04	0.06	0.1
	Microbial Analysis				
27.	Total Coliform Count	MPN/100ml	<1.1	<1.1	0
28.	Total Bacteria Count	CFU/ml	TFC	TFC	0
29.	Faecal Coliform	CFU/ml	NG	NG	0
30.	*Salmonella* spp.	CFU/ml	NG	NG	0
31.	*Shigella* spp	CFU/ml	NG	NG	0

***Source**: Final Environmental & Social Management Plan for the Construction of ACETEL Centre Jabi Abuja 2022*

- ***Comparison between the wet and dry season groundwater samples***

The dry-season groundwater temperatures (31.5–32.9°C) are noticeably higher than the wet-season temperature (27.9°C). This seasonal reduction is expected because groundwater recharge during the rainy season lowers shallow aquifer temperatures, while cooler ambient conditions reduce subsurface heat transfer. The dry-season pH (7.43–7.50) and wet-season pH (6.84–7.29) are within the acceptable range for potable groundwater. The dry-season EC values are uniformly low, while the 2026 wet-season results show a broader range. This may be attributable to localized recharge, differing residence times, and the fact that different boreholes were sampled. The dry-season groundwater exhibited very low turbidity (<1 NTU), whereas one wet-season borehole recorded a higher value (4 NTU), although still within regulatory limits. The 2022 dry-season study reported relatively soft groundwater (37.6–45.1 mg/L as $CaCO_3$), whereas the 2026 investigation classified all samples as hard. This may be due to varying groundwater abstraction depths and/or longer groundwater–rock interaction within some boreholes. Microbiologically, the 2022 dry season report recorded no significant faecal contamination, with E. coli, Salmonella and Shigella absent and total coliform levels remaining within acceptable limits while the 2026 wet season laboratory results similarly did not indicate widespread microbial contamination.

4.4.2.3 Hydrology, Topography, Drainage and Water Supply

The hydrology of the project area is characteristic of the crystalline Basement Complex terrain that underlies much of the FCT. Surface water occurrence is controlled primarily by seasonal rainfall, topography and the drainage network, while groundwater is largely stored within weathered and fractured basement aquifers. Consequently, groundwater availability in the FCT depends on the thickness of the weathered overburden and the degree of bedrock fracturing rather than primary rock porosity (Dan-Hassan, 2015; Nigeria Hydrological Services Agency (NIHSA), 2025). Local runoff generated during rainfall events is conveyed through ephemeral drainage channels into nearby tributaries before ultimately discharging into the Usuma River system. The topography of Abuja is undulating with hills and inselbergs that rise north-westwards to a maximum of 1,060 metres above sea level. There are extensive

plains found between hills in the study area. The Zuma rock stands out on its own as the most conspicuous inselberg at the boundary of Abuja and Niger State.

The drainage pattern within the project area is controlled by the gently undulating topography typical of the Abuja Basement Complex terrain. The main campus flood-control drainage channel conveys stormwater from the eastern side of the campus and adjoining Kado-Galadimawa Expressway corridor toward the western river system. This channel lies between the two project sites, approximately 54 m from Site 1 and 155 m from Site 2. An active open waste-disposal and burning area is located close to the main drainage channel. The Examination Scripts Warehouse is approximately 15 m south of this waste area. This relationship is relevant to drainage protection, waste-control measures and construction-phase housekeeping. The surface-water baseline included one sample from the flowing Jabi River (flowing from north to south direction) behind the rear perimeter fence and one sample from the flood-control drainage canal in front of the Examination Scripts and Warehouse Building.

From a project perspective, the proposed solar hybrid power plant project will have minimal interaction with local hydrological systems because photovoltaic electricity generation does not require abstraction of large quantities of water, nor does it generate process wastewater during normal operation. Also, given the relatively small development footprint of the proposed project, significant alteration of existing drainage characteristics is not anticipated. Nevertheless, construction activities involving excavation, earthworks and temporary stockpiling of materials could increase sediment transport into nearby drains during rainfall events if left uncontrolled. These risks will be minimized through implementation of good construction practices, including temporary sediment barriers, controlled stockpile management, stabilization of exposed soils and routine inspection of drainage channels throughout the construction period. The impacts of the project on hydrology are not anticipated to be significant.

4.4.2.4 Surface Water Sampling/Quality

Surface water samples measurements (SW1 and SW2) were undertaken to establish the baseline physico-chemical characteristics of surface water resources within the Area of Influence (AoI). The parameters measured included temperature, pH, oxidation-reduction potential (ORP), resistivity, electrical conductivity (EC), total dissolved solids (TDS), salinity, specific gravity and fertility. These parameters provide an indication of the existing water quality and serve as baseline conditions for future environmental monitoring.

Two surface water samples were collected from accessible water bodies located within the vicinity of the proposed project area. The first surface water sample (SW1) was collected from a flowing stream located behind the University, outside the rear perimeter fence behind the Faculty of Management Sciences. The stream was selected because it represents the nearest natural surface water body that could potentially receive runoff from the project area. The second surface water sample (SW2) was obtained from a concrete drainage canal situated at the front of the University, in front of the Examination Scripts and Warehouse Building. The drainage channel functions as a flood-control canal conveying stormwater away from the campus. At the time of

the field survey, water was observed flowing through the channel, making it suitable for sampling.

Surface water temperatures at both sampling locations were identical at 30.4°C, indicating relatively uniform thermal conditions within the study area at the time of sampling. Such temperatures are typical of shallow tropical surface waters and reflect prevailing ambient climatic conditions rather than thermal pollution. Since the proposed solar hybrid power project does not involve thermal processes or cooling water discharges, significant changes to surface water temperature during project operation are not anticipated. The measured pH values of 7.54 (SW1) and 7.41 (SW2) indicate that the surface water is essentially neutral to slightly alkaline. These values fall comfortably within the World Health Organization (WHO) guideline range of 6.5–8.5. Oxidation-Reduction Potential (ORP) values ranged from 58 mV to 75 mV, indicating mildly oxidizing conditions. The positive values generally suggest the presence of dissolved oxygen. Electrical conductivity is 343 µS/cm at SW1 and 795 µS/cm at SW2. This indicates variation indicates that SW2 contains a higher concentration of dissolved ionic constituents than SW1. The higher conductivity observed at SW2 may be attributable to localized surface runoff, weathering of surrounding geological materials, or dissolved minerals transported into the water body during rainfall events rather than anthropogenic contamination. Similar trends were observed in the Total Dissolved Solids (TDS), where concentrations ranged from 172 mg/L (SW1) to 396 mg/L (SW2), both of which remain below the 500 mg/L guideline recommended by WHO and the Nigerian Standard for Drinking Water Quality, indicating relatively low mineralization of the surface water. Measured salinity values of 0.01% and 0.04% indicate that the water bodies are freshwater systems with negligible salt content. Similarly, the measured specific gravity of 1.000 at both locations corresponds closely to that of pure water, indicating the absence of significant dissolved solids capable of altering water density. Fertility values of 2 ppm suggest relatively low nutrient concentrations and do not indicate excessive nutrient enrichment or eutrophication at the time of sampling. These baseline conditions are characteristic of freshwater systems within the Guinea Savannah ecological zone and provide favourable environmental conditions for the proposed project.

Table 4.13: Surface Water Sampling Locations

Sample ID	Water Body	Sampling Location	Latitude (N)	Longitude (E)	Description
SW1	Flowing Stream	Behind the University, outside the rear fence behind the Faculty of Management Sciences	9°01'23.448"	7°24'37.86012"	Natural flowing stream representing the nearest surface water receptor.
SW2	Drainage Canal	In front of the Examination Scripts and	9°01'18.34608"	7°24'38.01168"	Flood-control drainage canal with flowing water during the survey.

Sample ID	Water Body	Sampling Location	Latitude (N)	Longitude (E)	Description
		Warehouse Building			

Table 4.14: Surface Water 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)
SW1	30.4	7.54	58	39.01	343	172	0.01	1.000	2
SW2	30.4	7.41	75	19.014	795	396	0.04	1.000	2

4.4.2.4.1 Laboratory Analysis, Interpretation and Discussions for Surface Water:

Table 4.15: Surface Water Laboratory Results

S/N	PARAMETERS	UNIT	TEST METHODS	LIMIT FOR SURFACE WATER	SW1	SW2
PHYSICO- CHEMICAL PARAMETERS						
1	pH		APHA 4500 -H+	6.0-9.0	6.83	6.85
2	TEMPERATURE	^{O}C	APHA 2550 B	AMBIENT	27.900	27.900
3	TURBIDITY	NTU	APHA 2130 B	≤30	22.000	16.000
4	CONDUCTIVITY	µS/cm	APHA 2510B	1000	328.000	734.000
5	TOTAL SUSPENDED SOLIDS	mg/l	APHA 2540 D	≤30	1.430	1.760
6	DISSOLVED OXYGEN	mg/l	APHA 450-O G	≥5	7.040	7.100
7	BIOCHEMICAL OXYGEN DEMAND	mg/l	APHA 5210 C	≤10	21.384	28.512
8	CHEMICAL OXYGEN DEMAND	mg/l	APHA 5220 D	≤40	35.64	47.52
9	TOTAL DISSOLVED SOLIDS	mg/l	APHA 2540 D	NS	229.600	513.800
10	TOTAL SOLIDS	mg/l	APHA 2540 D	NS	231.030	515.560
11	TOTAL HARDNESS	mg/l	APHA 2340 C	500.00	365.85	439.02
12	MAGNESIUM HARDNESS	mg/l	APHA 3500-Ca B	NS	170.731	195.122

S/N	PARAMETERS	UNIT	TEST METHODS	LIMIT FOR SURFACE WATER	SW1	SW2
13	CALCIUM HARDNESS	mg/l	APHA 3500-Ca B	NS	195.122	243.902
14	TOTAL ALKALINITY	mg/l	APHA 2320 B	NS	100.00	220.00
15	SALINITY	ppt	APHA 2320 B	NS	0.076	0.209
IONS						
16	CARBONATE	mg/l	APHA 2320 B	NS	0.06	0.15
17	BICARBONATE	mg/l	APHA 2320 B	NS	99.93	219.85
18	CHLORIDE	mg/l	APHA 4500-Cl^- B	250.00	42.115	115.815
19	NITRITE	mg/l	APHA 4500-NO_2^- B	0.20	0.96	0.26
20	NITRATE	mg/l	APHA 4500-NO_3^- B	50	7.563	1
21	PHOSPHATE	mg/l	APHA 4500-P E	≤ 5	0.9	3.987
22	AMMONIUM	mg/l	APHA 4500-NH4+ B	≤ 0.5	0.974	2.015
23	SULPHATE	mg/l	APHA 4500-SO_4^{2-} E	250.00	7.08	0.46
METALS						
24	CALCIUM	mg/l	APHA 3500-Ca B	75.00	78.21	97.76
25	MAGNESIUM	mg/l	APHA 3500-Mg B	NS	41.51	47.43
26	SODIUM	mg/l	APHA 3500-Na B	120.00	0.43	1.44
27	POTASSIUM	mg/l	APHA 3500-K B	NS	9.22	21.29
28	LEAD	mg/l	APHA 3113 B	0.010	0.008	0.046
29	IRON	mg/l	APHA 3113 B	0.300	1.667	0.305
30	CHROMIUM	mg/l	APHA 3113 B	0.500	0.000	0.000
31	COPPER	mg/l	APHA 3113 B	1.000	0.034	0.015
32	MANGANESE	mg/l	APHA 3113 B	0.200	0.002	0.000
33	ZINC	mg/l	APHA 3113 B	3.000	0.042	0.052
34	ARSENIC	mg/l	APHA 3113 B	0.010	0.005	0.005
MICROBIAL PARAMETERS						
35	TOTAL BACTERIAL COUNT	cfu/ml	APHA 9215B	0	6.0 X 10^3	1.07 X 10^5
36	TOTAL FUNGI	cfu/ml	APHA 9222D	0	7.0 X 10^2	1.5 X 10^1
37	TOTAL COLIFORM	cfu/ml	APHA 9222B	100	3.0 X 10^1	7.0 X 10^2
38	FEACAL COLIFORM	cfu/ml	APHA 9222E	0	ND	3.5 X 10^2
STANDARD: NATIONAL ENVIRONMENTAL (SURFACE AND GROUND WATER QUALITY CONTROL) REGULATIONS, 2011. NOTE:						
µS/cm= microsimensper millitilitre						
mg/L = miligram per litre						
cfu/ml = colony forming unit per milliliter.						

S/N	PARAMETERS	UNIT	TEST METHODS	LIMIT FOR SURFACE WATER	SW1	SW2
NS = Not stated						
ND = Not Detected						
TNTC = Too numerous to count						

***Source**: BOLBEN LTD Fieldwork,2026.*

4.4.2.4.2 Physicochemical Characteristics

Physicochemical characteristics provide the first indication of the overall quality, ecological condition and suitability of surface water for domestic, recreational, agricultural, engineering and environmental purposes. Unlike groundwater, surface water responds rapidly to rainfall, runoff, evaporation, biological activity and anthropogenic influences. Consequently, its quality often reflects both the natural characteristics of the watershed and the cumulative effects of surrounding land-use activities. The physicochemical parameters analyzed include pH, temperature, turbidity, electrical conductivity, total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), total solids (TS), total hardness, magnesium hardness, calcium hardness, total alkalinity and salinity. Collectively, these parameters provide insight into water chemistry, oxygen balance, organic pollution, mineralization, buffering capacity and the general ecological health of the aquatic environment. The analytical results were compared with the National Environmental (Surface and Ground Water Quality Control) Regulations, 2011 to evaluate compliance and determine the suitability of the water for its intended environmental functions.

pH

Hydrogen ion concentration (pH) is one of the most important indicators of surface-water quality because it controls chemical equilibrium, nutrient availability, metal solubility, biological activity and the toxicity of numerous contaminants. Most aquatic organisms thrive within a relatively narrow pH range, while deviations from neutrality may increase the mobility of toxic metals, alter nutrient cycling and reduce ecosystem productivity. The National Environmental (Surface and Ground Water Quality Control) Regulations, 2011 prescribe an acceptable pH range of 6.0–9.0 for surface water. The analyzed surface-water samples recorded pH values of 6.83 (SW1) and 6.85 (SW2). Both values fall comfortably within the prescribed regulatory range and indicate that the water is essentially neutral to very slightly acidic. The similarity between the two sampling locations suggests relatively uniform acid-base conditions throughout the water body. Such stability is characteristic of natural surface waters receiving adequate buffering from dissolved bicarbonate and other alkalinity-producing ions. The observed pH conditions are favourable for most aquatic organisms because they support normal physiological processes, microbial activity and nutrient cycling. Furthermore, the near-neutral pH reduces the solubility and mobility of many toxic metals compared with strongly acidic waters. Although elevated concentrations of certain metals such as iron and lead were detected elsewhere in the analysis, their occurrence cannot be attributed solely to abnormal pH

conditions. Instead, their distribution is more likely controlled by natural geology, sediment interaction, localized contamination or hydrological processes. Overall, the pH results demonstrate excellent compliance with national standards and indicate chemically stable surface water capable of supporting normal ecological functions.

Temperature

Water temperature exerts a strong influence on virtually every physical, chemical and biological process occurring within aquatic ecosystems. It controls dissolved oxygen solubility, metabolic activity of aquatic organisms, microbial decomposition rates, nutrient cycling and the toxicity of several pollutants. Elevated temperatures may indicate thermal pollution from industrial discharges, while unusually low temperatures may reflect groundwater inflow or seasonal climatic variation. Both surface-water samples recorded identical temperatures of 27.9°C, corresponding closely with prevailing ambient tropical environmental conditions. The uniformity of temperature indicates that both sampling locations experience similar hydrological and climatic influences, with no evidence of localized thermal inputs or anthropogenic heating. Such temperatures are typical of tropical freshwater systems within Nigeria and are not considered environmentally abnormal. Although warmer tropical waters naturally contain lower dissolved oxygen concentrations than cooler temperate waters, the corresponding dissolved oxygen values recorded in this study remained above the regulatory minimum, indicating that oxygen availability has not been adversely affected by temperature. The temperature results therefore indicate a stable thermal regime suitable for sustaining aquatic biological processes and demonstrate the absence of thermal pollution within the project area.

Turbidity

Turbidity represents the optical property of water caused by suspended particles such as clay, silt, organic matter, plankton and other microscopic materials. It serves as an important indicator of sediment transport, watershed erosion, runoff intensity and potential microbial contamination. Excessive turbidity reduces light penetration, limits photosynthesis, interferes with aquatic habitats and may reduce the effectiveness of disinfection where water is intended for potable use. The regulatory limit for turbidity is 30 NTU. Measured turbidity values were: SW1: 22 NTU, and SW2: 16 NTU. Both sampling locations complied with the regulatory standard. Although compliant, SW1 exhibited noticeably higher turbidity than SW2, indicating greater suspended particulate content at that location. The observed difference may reflect localized erosion, sediment resuspension, storm-water runoff, shallow water conditions or increased organic matter inputs. Since total suspended solids remained extremely low in both samples, much of the measured turbidity may be associated with very fine colloidal particles or naturally occurring organic materials rather than heavy sediment loading. The relatively moderate turbidity values suggest that sufficient light penetration remains available for aquatic primary productivity while minimizing adverse impacts on aquatic organisms. For the proposed solar photovoltaic development, the measured turbidity presents no significant environmental concern. Nevertheless, effective erosion-control measures should be implemented during construction to prevent unnecessary increases in suspended sediment entering nearby surface waters. Overall, turbidity remains within acceptable environmental limits and reflects relatively good visual water quality.

Electrical Conductivity (EC)

Electrical conductivity provides a rapid estimate of the total concentration of dissolved ionic substances within water. It reflects the combined presence of dissolved salts, minerals and inorganic ions, making it one of the most useful indicators of overall mineralization. The National Environmental (Surface and Ground Water Quality Control) Regulations prescribe a maximum conductivity of 1000 µS/cm. Measured conductivity values were: SW1: 328 µS/cm, and SW2: 734 µS/cm. Both values complied with the applicable standard. However, SW2 recorded more than twice the conductivity observed at SW1, indicating substantially greater dissolved ionic content. This pattern corresponds closely with the higher concentrations of total dissolved solids, bicarbonate, hardness, calcium, magnesium and salinity observed in SW2, demonstrating strong internal consistency among the analytical results. The elevated conductivity in SW2 most likely reflects stronger mineral dissolution, longer water residence time, greater groundwater contribution or localized accumulation of dissolved ions through evaporation and natural weathering processes. Despite the higher conductivity, neither sampling location approaches the regulatory limit, indicating that the surface water remains only moderately mineralized. From an ecological perspective, the measured conductivity values remain suitable for freshwater aquatic ecosystems and do not indicate salinity stress or significant pollution from industrial effluents.

Total Suspended Solids (TSS)

Total Suspended Solids represent insoluble particulate materials retained within the water column, including clay particles, silt, algae, organic debris and microorganisms. Elevated TSS reduces water clarity, limits photosynthesis, clogs fish gills and promotes sediment deposition. The regulatory limit is 30 mg/L. Measured concentrations were: SW1: 1.43 mg/L, and SW2: 1.76 mg/L. Both values are substantially below the prescribed limit. These extremely low concentrations indicate minimal suspended sediment within the sampled water body. The results suggest that erosion, bank instability and sediment transport were relatively limited during sampling. Low TSS also supports the turbidity measurements and indicates that the surrounding catchment currently contributes only small quantities of suspended material. The low suspended-solid concentrations are environmentally favourable because they enhance light penetration, improve habitat quality for aquatic organisms and reduce sediment accumulation. For the proposed project, maintaining these low TSS levels should remain an important environmental objective through implementation of erosion-control measures, sediment traps and appropriate storm-water management throughout construction.

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) is one of the most important indicators of surface-water quality because it reflects the ability of a water body to sustain aquatic life and maintain ecological balance. Oxygen dissolved in water originates primarily from atmospheric diffusion and photosynthesis by aquatic plants and algae, while it is continuously consumed through respiration, decomposition of organic matter and various chemical oxidation processes. Adequate dissolved oxygen is essential for fish, aquatic invertebrates and aerobic microorganisms, whereas depleted oxygen concentrations may result in fish kills, reduced biodiversity and deterioration of ecosystem health. The National Environmental (Surface and Ground Water Quality

Control) Regulations, 2011 prescribe a minimum dissolved oxygen concentration of 5 mg/L for surface water. The measured dissolved oxygen concentrations were: SW1: 7.04 mg/L, and SW2: 7.10 mg/L. Both sampling locations exceeded the regulatory minimum requirement and therefore complied with the applicable standard. The recorded concentrations indicate that both water bodies remain well oxygenated and are capable of supporting aerobic aquatic organisms. The slightly higher DO concentration in SW2 may reflect increased atmospheric reaeration, lower biological oxygen consumption at the time of sampling or enhanced mixing within the water body. Despite SW2 exhibiting higher organic pollution indicators (BOD and COD), the dissolved oxygen concentration remained satisfactory, suggesting that oxygen replenishment presently exceeds oxygen consumption. The favourable dissolved oxygen concentrations indicate that the water body has not yet experienced severe oxygen depletion commonly associated with advanced organic pollution or eutrophication. Nevertheless, the elevated biochemical oxygen demand observed in subsequent analyses suggests that continued organic loading could eventually reduce dissolved oxygen if left unmanaged. Overall, the dissolved oxygen results indicate good ecological conditions and demonstrate that the surface water presently maintains sufficient oxygen to sustain aquatic life.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) measures the quantity of dissolved oxygen required by aerobic microorganisms to biologically decompose biodegradable organic matter present in water over a specified incubation period. It is one of the most widely used indicators of organic pollution and provides valuable information regarding the level of biodegradable waste entering a water body. Elevated BOD values generally indicate increased concentrations of organic materials originating from domestic wastewater, agricultural runoff, decaying vegetation, livestock activities or other organic discharges. The regulatory limit for BOD is 10 mg/L. The measured BOD concentrations were: SW1: 21.384 mg/L, and SW2: 28.512 mg/L. Both sampling locations exceeded the regulatory limit substantially. SW2 recorded the highest BOD concentration, approximately 2.9 times the permissible limit, while SW1 exceeded the limit by approximately 2.1 times. These results indicate considerable biodegradable organic loading within both surface-water samples. The elevated BOD suggests that significant microbial decomposition of organic matter is occurring, thereby increasing oxygen demand within the aquatic environment. Possible sources of biodegradable organic matter include: decaying vegetation; runoff carrying organic debris; agricultural activities; livestock access; domestic wastewater; localized sewage inputs; and organic-rich sediments. Although dissolved oxygen remained above the regulatory minimum, persistently elevated BOD increases the risk of future oxygen depletion, particularly during periods of reduced stream flow, elevated temperatures or additional pollutant loading. The higher BOD observed in SW2 corresponds closely with its elevated ammonium concentration, higher conductivity, greater bicarbonate concentration, increased hardness and poorer microbiological quality, suggesting that SW2 experiences greater organic enrichment than SW1. From an ecological perspective, the elevated BOD constitutes one of the principal water-quality concerns identified in this assessment and indicates moderate organic pollution requiring further investigation.

Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) represents the total quantity of oxygen required to chemically oxidize both biodegradable and non-biodegradable organic compounds present in water. Unlike BOD, which measures only biologically degradable organic matter, COD quantifies the overall oxidizable pollutant load and therefore provides a broader assessment of organic contamination. The applicable regulatory limit is 40 mg/L. Measured COD values were: SW1: 35.64 mg/L, and SW2: 47.52 mg/L SW1 complied with the regulatory limit, whereas SW2 exceeded the prescribed standard. The higher COD concentration in SW2 confirms that this location contains a greater overall organic pollutant load than SW1. The relationship between COD and BOD is particularly informative. Both sampling locations recorded elevated BOD concentrations, while only SW2 exceeded the COD limit. This pattern suggests that much of the organic pollution present is biodegradable, although SW2 also contains additional chemically oxidizable substances. Potential sources include: organic runoff; decaying plant materials; domestic wastewater; diffuse urban runoff; and agricultural inputs. No evidence presently suggests significant industrial chemical contamination, as most metal concentrations remained relatively low and conductivity remained within acceptable limits. The elevated COD in SW2 reinforces the conclusion that this location experiences greater anthropogenic or natural organic loading than SW1 and warrants continued environmental monitoring.

Total Dissolved Solids (TDS)

Total Dissolved Solids represent the combined concentration of dissolved inorganic salts, minerals and small quantities of organic matter present in water. TDS provides an overall indication of mineralization and is closely related to conductivity, salinity and groundwater contributions. No regulatory limit is specified within the laboratory report. Measured TDS concentrations were: SW1: 229.60 mg/L, and SW2: 513.80 mg/L Both values indicate relatively fresh surface water with low to moderate mineralization. SW2 recorded more than double the dissolved solids observed in SW1, confirming the conductivity results and indicating greater dissolved mineral content. The elevated TDS in SW2 likely reflects stronger interaction with surrounding geological materials, greater groundwater inflow, evaporation effects or localized accumulation of dissolved ions. Despite the higher concentration, the measured TDS remains well below internationally recognized freshwater thresholds and therefore does not indicate saline or highly mineralized conditions. The relatively low dissolved-solid concentrations are favourable for aquatic ecosystems and generally support a wide range of environmental and engineering applications.

Total Solids (TS)

Total Solids represent the combined concentration of dissolved and suspended materials within water and provide a comprehensive indication of the total material load transported by the water body. Measured concentrations were: SW1: 231.03 mg/L, and SW2: 515.56 mg/L. These values closely correspond with the measured TDS because suspended solids were extremely low in both samples. This relationship demonstrates excellent analytical consistency and confirms that dissolved materials account for almost all of the total solid content within the sampled surface waters. The low suspended-solid contribution indicates relatively stable watershed conditions with limited erosion or sediment transport during the sampling period. Although SW2 contains substantially greater total solids than SW1, the difference arises primarily from dissolved minerals rather than suspended sediments. Consequently, the higher

total solids in SW2 are unlikely to significantly impair light penetration or aquatic habitat quality but may contribute to increased mineral scaling where water is used operationally.

Total Hardness

Total hardness is primarily controlled by dissolved calcium and magnesium ions and influences numerous domestic, industrial and ecological water-quality characteristics. Hard water promotes scaling of pipes, boilers, pumps, heat exchangers and other hydraulic infrastructure, although it is generally not considered a direct public health concern. The applicable regulatory limit is 500 mg/L. Measured total hardness values were: SW1: 365.85 mg/L, and SW2: 439.02 mg/L. Both sampling locations complied with the regulatory standard. Nevertheless, the measured concentrations classify the surface water as very hard according to conventional water-quality classifications. SW2 exhibited greater hardness than SW1, consistent with its higher calcium, magnesium, bicarbonate and alkalinity concentrations. The elevated hardness most likely reflects natural weathering of calcium- and magnesium-bearing rocks within the watershed rather than anthropogenic contamination. Although acceptable environmentally, very hard water may: promote scaling of pumps and pipelines; reduce efficiency of water-distribution systems; leave mineral deposits on photovoltaic panels; increase detergent consumption; require softening for certain industrial applications. Therefore, hardness represents an important operational consideration for the proposed solar photovoltaic project where surface water may be considered for equipment cleaning or construction purposes.

Magnesium Hardness

Magnesium hardness represents the fraction of total hardness attributable to dissolved magnesium ions. Together with calcium hardness, it controls the overall hardness of water and influences scaling potential, soap consumption and operational efficiency of water-distribution systems. Magnesium is naturally released into surface water through the weathering of magnesium-bearing silicate and carbonate minerals and is commonly associated with groundwater inflows into rivers and streams. No regulatory limit was specified for magnesium hardness in the laboratory report.

The measured magnesium hardness values were: SW1: 170.731 mg/L, and SW2: 195.122 mg/L. Both sampling locations exhibited relatively high magnesium hardness, with SW2 recording the higher concentration. The results indicate that magnesium contributes substantially to the overall hardness of the surface water. However, comparison with the corresponding calcium hardness values shows that calcium remains the dominant hardness-producing constituent. The higher magnesium hardness in SW2 agrees closely with the observed increases in total hardness, electrical conductivity, bicarbonate concentration, alkalinity and total dissolved solids. This consistent pattern indicates greater mineralization at SW2, most likely resulting from enhanced water-rock interaction or longer residence time rather than anthropogenic contamination. From an environmental perspective, the measured magnesium hardness does not constitute a direct ecological concern. Magnesium is an essential nutrient for aquatic plants and animals and normally occurs naturally in freshwater systems. From an engineering perspective, however, magnesium contributes to scaling and mineral deposition within pumps, storage tanks, pipelines and other hydraulic infrastructure. Where surface water is intended for repeated operational use, particularly for cleaning photovoltaic panels or supplying

construction activities, treatment to reduce hardness may improve long-term equipment performance. Overall, magnesium hardness reflects natural hydrogeochemical processes and contributes significantly to the elevated hardness observed in the study area.

Calcium Hardness

Calcium hardness represents the proportion of total hardness contributed by dissolved calcium ions. Calcium is typically the dominant hardness-producing cation in natural freshwater systems because it is readily released through weathering of limestone, dolomite, feldspars and other calcium-bearing minerals. Calcium also plays an important ecological role in aquatic biological processes and contributes to the buffering capacity of freshwater ecosystems. No separate regulatory limit was specified for calcium hardness. Measured calcium hardness values were: SW1: 195.122 mg/L, and SW2: 243.902 mg/L. Both sampling locations exhibited relatively elevated calcium hardness, with SW2 recording approximately 25% higher concentrations than SW1. Comparison with magnesium hardness demonstrates that calcium is the principal contributor to total hardness within both sampling locations. The observed distribution is consistent with the measured dissolved calcium concentrations reported later in the metals analysis, confirming excellent agreement between the independent laboratory determinations. The elevated calcium hardness explains much of the high total hardness observed in both surface-water samples. Although calcium hardness is not generally considered a public-health concern, excessive concentrations may produce: scaling of pipelines; mineral deposits in pumps; clogging of irrigation equipment; reduced efficiency of hydraulic systems; and white mineral films following evaporation. These operational considerations are particularly relevant for the proposed REA Solar Photovoltaic Project if untreated surface water is used for equipment washing or construction purposes. Ecologically, calcium hardness is generally beneficial because it stabilizes aquatic ecosystems and reduces the toxicity of certain dissolved metals. Overall, calcium hardness reflects predominantly natural watershed geology and constitutes the principal contributor to surface-water hardness within the project area.

Total Alkalinity

Total alkalinity measures the acid-neutralizing capacity of water and reflects the combined concentrations of bicarbonate, carbonate and hydroxide ions. Alkalinity plays a fundamental role in stabilizing pH and protecting aquatic ecosystems from rapid acidification. Surface waters with adequate alkalinity are generally more resistant to sudden chemical disturbances caused by rainfall, runoff or pollutant inputs. No regulatory limit was specified within the laboratory report. Measured alkalinity values were: SW1: 100 mg/L, and SW2: 220 mg/L. SW2 exhibited more than twice the alkalinity measured in SW1. The observed pattern corresponds closely with the bicarbonate concentrations measured for both sampling locations, confirming that bicarbonate is the dominant contributor to alkalinity within the study area. The elevated alkalinity in SW2 indicates stronger buffering capacity and greater resistance to pH fluctuations. This finding also supports the higher conductivity, dissolved solids, hardness and bicarbonate concentrations observed at SW2, demonstrating that the location experiences greater mineralization than SW1. The alkalinity values suggest that both surface-water bodies possess sufficient buffering capacity to maintain the stable near-neutral pH observed during sampling. From an ecological perspective,

adequate alkalinity is beneficial because it protects aquatic organisms from rapid pH changes that may accompany rainfall events or localized pollutant discharges. Operationally, however, elevated alkalinity combined with high calcium hardness increases the likelihood of carbonate scale formation within water-distribution systems and on photovoltaic panel surfaces following evaporation. Overall, alkalinity contributes positively to chemical stability while simultaneously increasing scaling potential.

Salinity

Salinity represents the total concentration of dissolved salts present in water and provides an overall indication of freshwater or saline conditions. It is influenced by geological weathering, evaporation, groundwater inflow, surface runoff and anthropogenic inputs such as wastewater discharge and agricultural return flows. No regulatory limit was specified within the laboratory report. Measured salinity values were: SW1: 0.076 ppt, and SW2: 0.209 ppt. Both sampling locations exhibit extremely low salinity and clearly represent freshwater environments. Although SW2 recorded nearly three times the salinity of SW1, the absolute concentrations remain extremely low and are far below levels associated with saline or brackish waters. The salinity pattern closely mirrors the conductivity, TDS and bicarbonate results, indicating that the higher dissolved-ion concentrations in SW2 originate primarily from natural mineralization rather than saline intrusion or anthropogenic salt contamination. The measured salinity poses no ecological limitation to freshwater aquatic organisms and presents no concern for construction or project operations. The results further confirm the absence of significant seawater intrusion, evaporative salinization or excessive anthropogenic salt inputs within the study area. Overall, the salinity results indicate excellent freshwater quality.

4.4.2.4.3 Major-Ion Characteristics

Carbonate (CO_3^{2-})

Carbonate ions contribute to the alkalinity of natural waters and exist in equilibrium with bicarbonate, dissolved carbon dioxide and pH. Under near-neutral conditions, carbonate concentrations are typically very low because dissolved inorganic carbon occurs predominantly as bicarbonate. Appreciable carbonate concentrations generally occur only in alkaline waters with pH values exceeding approximately 8.3. No regulatory limit was specified for carbonate. Measured carbonate concentrations were: SW1: 0.06 mg/L, and SW2: 0.15 mg/L. Both sampling locations exhibited extremely low carbonate concentrations. The low carbonate values are entirely consistent with the measured pH values of 6.83–6.85. Under these conditions, dissolved inorganic carbon naturally occurs almost exclusively as bicarbonate rather than carbonate. SW2 recorded a slightly higher carbonate concentration than SW1. However, the difference is negligible and simply reflects the higher alkalinity and bicarbonate concentrations observed at that location. The measured carbonate concentrations do not indicate contamination and present no environmental concern. Instead, they represent the expected carbonate chemistry of tropical freshwater systems operating within a near-neutral pH range. Overall, carbonate contributes minimally to the total alkalinity of the surface water.

Bicarbonate (HCO_3^-)

Bicarbonate is the dominant alkalinity-producing ion in most natural freshwater systems. It forms when atmospheric and soil carbon dioxide dissolves in infiltrating rainwater to produce weak carbonic acid, which subsequently reacts with carbonate and silicate minerals. Consequently, bicarbonate serves as an important indicator of water-rock interaction, buffering capacity and hydro chemical evolution. No regulatory limit was specified. Measured bicarbonate concentrations were: SW1: 99.93 mg/L, and SW2: 219.85 mg/L. SW2 contained more than twice the bicarbonate concentration measured in SW1. The elevated bicarbonate concentration corresponds directly with the higher alkalinity, conductivity, total dissolved solids, hardness and calcium concentrations observed at SW2. This strong agreement demonstrates that groundwater inflow and natural mineral weathering exert a significant influence on the hydrochemistry of SW2. Bicarbonate performs an important ecological function by stabilizing pH and protecting aquatic organisms against rapid acidification. However, elevated bicarbonate combined with high calcium hardness also increases the tendency for carbonate scaling in engineering systems. The measured bicarbonate concentrations primarily reflect natural hydro chemical evolution rather than pollution. Overall, bicarbonate is the dominant dissolved anion controlling the acid-buffering capacity of the surface water.

Chloride (Cl^-)

Chloride is one of the most conservative major ions in natural waters because it undergoes relatively little biological or chemical transformation after entering the aquatic environment. Elevated chloride concentrations often indicate wastewater discharge, sewage contamination, saline intrusion, road salts or industrial effluents. The applicable regulatory limit is 250 mg/L. Measured chloride concentrations were: SW1: 42.115 mg/L, and SW2: 115.815 mg/L. Both samples complied comfortably with the prescribed limit. Although SW2 contained nearly three times the chloride concentration observed at SW1, the measured values remain relatively low. The elevated chloride concentration at SW2 may reflect greater groundwater influence, increased mineral dissolution or localized runoff containing naturally dissolved salts. However, the concentrations remain far below levels normally associated with saline contamination or wastewater pollution. Low chloride concentrations are environmentally favourable because they reduce the risk of salinity stress for freshwater organisms and minimize chloride-induced corrosion of metallic infrastructure. Overall, chloride does not constitute a water-quality concern within the study area.

Nitrite (NO_2^-)

Nitrite is an intermediate compound in the nitrogen cycle produced during the oxidation of ammonium to nitrate and the reduction of nitrate under oxygen-limited conditions. Because nitrite is generally unstable in well-oxygenated waters, elevated concentrations often indicate recent organic contamination, incomplete nitrification or active microbial decomposition. The regulatory limit is 0.20 mg/L. Measured nitrite concentrations were: SW1: 0.96 mg/L, and SW2: 0.26 mg/L. Both sampling locations exceeded the applicable standard. SW1 exceeded the regulatory limit by approximately 4.8 times, while SW2 exceeded the limit by approximately 1.3 times. The elevated nitrite concentrations indicate active nitrogen transformation within the surface water and suggest recent organic inputs or incomplete biological oxidation.

Interestingly, SW1 recorded the highest nitrite concentration despite having lower ammonium and lower microbiological contamination than SW2. This may indicate differences in microbial nitrification rates, oxygen availability within sediments or localized nutrient inputs. Although dissolved oxygen concentrations remain satisfactory, elevated nitrite represents an important water-quality concern because nitrite is considerably more toxic to aquatic organisms than nitrate. The elevated nitrite concentrations therefore indicate moderate nutrient enrichment requiring continued monitoring.

Nitrate (NO_3^-)

Nitrate is the most stable oxidized form of nitrogen in natural waters and is widely used as an indicator of agricultural runoff, fertilizer application, sewage contamination and organic waste decomposition. The applicable regulatory limit is 50 mg/L. Measured nitrate concentrations were: SW1: 7.563 mg/L, and SW2: 1.00 mg/L. Both sampling locations complied comfortably with the regulatory standard. SW1 recorded higher nitrate concentrations than SW2. Despite the elevated nitrite concentrations discussed previously, nitrate concentrations remain relatively low. This suggests that the nitrogen cycle within the surface water is dynamic, with active microbial transformation but limited long-term accumulation of nitrate. The low nitrate concentrations indicate that widespread fertilizer contamination or sewage pollution has not occurred. Ecologically, the measured nitrate concentrations present minimal risk of eutrophication. Overall, nitrate does not presently constitute a significant environmental concern.

Phosphate (PO_4^{3-})

Phosphate is an essential nutrient controlling aquatic productivity and is frequently the limiting nutrient for algal growth in freshwater ecosystems. Elevated phosphate concentrations often originate from fertilizers, detergents, sewage discharges, livestock activities and decomposing organic matter. The applicable regulatory limit is 5 mg/L. Measured phosphate concentrations were: SW1: 0.90 mg/L, and SW2: 3.987 mg/L. Both sampling locations complied with the regulatory limit. However, SW2 recorded substantially higher phosphate concentrations than SW1. Although compliant, the elevated phosphate concentration in SW2 indicates greater nutrient enrichment and may contribute to increased biological productivity if sustained over time. When considered together with the elevated BOD, COD, ammonium and microbiological contamination observed at SW2, the phosphate results suggest localized organic enrichment rather than severe nutrient pollution. Overall, phosphate concentrations remain acceptable but should continue to be monitored because phosphorus enrichment is often an early precursor to eutrophication.

Ammonium (NH_4^+)

Ammonium is a reduced form of nitrogen produced through the decomposition and mineralization of organic matter. It may enter surface water through natural decay of vegetation, animal waste, sewage, agricultural runoff, poorly managed waste, sediment release and other organic inputs. In well-oxygenated surface water, ammonium is generally converted biologically to nitrite and subsequently nitrate through nitrification. Elevated ammonium therefore often indicates recent organic enrichment, incomplete nitrification or continuous pollutant loading. The applicable regulatory limit is 0.5 mg/L. Measured ammonium concentrations were: SW1: 0.974

mg/L, and SW2: 2.015 mg/L. Both sampling locations exceeded the applicable limit. SW1 exceeded the standard by approximately 1.9 times, while SW2 exceeded it by approximately 4.0 times. SW2 therefore exhibited the more serious ammonium enrichment. The elevated ammonium concentrations indicate the presence of appreciable reduced nitrogen and suggest recent or continuing organic inputs into the surface-water system. Potential sources include decomposing plant material, animal waste, wastewater, surface runoff, nearby sanitation facilities or organic-rich sediments. The result for SW2 is particularly significant because it corresponds with: the higher BOD concentration; the COD exceedance; elevated phosphate; higher total bacterial count; elevated total coliform; detectable faecal coliform; and greater fungal presence. This combination provides strong evidence that SW2 is affected by more substantial organic and microbiological contamination than SW1. Ammonium itself is less toxic than un-ionized ammonia; however, the proportion present as ammonia increases with rising pH and temperature. Because the measured pH values were near neutral, the immediate risk of ammonia toxicity is reduced. Nevertheless, ammonium remains environmentally important because its oxidation consumes dissolved oxygen and may contribute to oxygen depletion where organic loading continues. The elevated ammonium concentrations therefore represent a significant surface-water quality concern and support the need for source investigation and pollution-control measures.

Sulphate (SO_4^{2-})

Sulphate is a naturally occurring major ion derived from the weathering of sulphur-bearing minerals, atmospheric deposition, decomposition of organic matter and groundwater inflow. Anthropogenic sources may include industrial wastewater, sewage, agricultural inputs, combustion residues and construction materials. The applicable regulatory limit is 250 mg/L. Measured sulphate concentrations were: SW1: 7.08 mg/L, and SW2: 0.46 mg/L. Both concentrations were substantially below the permissible limit. The low sulphate values indicate limited dissolution of sulphate-bearing minerals and no evidence of significant industrial discharge, sewage-related sulphate enrichment or sulphur-containing waste inputs. SW1 recorded a higher sulphate concentration than SW2, but the absolute concentration remained very low. The difference may reflect localized geological conditions, runoff characteristics or minor variation in groundwater contribution. From an ecological perspective, the measured sulphate concentrations do not present a concern. They are too low to cause taste problems, osmotic stress or adverse effects on freshwater organisms. From an engineering perspective, low sulphate is favourable because it minimizes the risk of sulphate-related corrosion and chemical deterioration of concrete infrastructure. Overall, sulphate does not constitute a surface-water quality constraint within the project area.

4.4.2.4.4 Metals and Trace Elements

Calcium

Calcium is a naturally occurring major cation released into surface water through the weathering and dissolution of calcium-bearing minerals. It contributes significantly to water hardness, alkalinity, buffering capacity and the overall ionic composition of

freshwater systems. Calcium is also biologically important because it supports skeletal development, osmoregulation and other physiological functions in aquatic organisms. The stated limit for calcium is 75 mg/L. The measured concentrations were: SW1: 78.21 mg/L, and SW2: 97.76 mg/L. Both samples exceeded the stated limit. SW1 exceeded the standard slightly, by approximately 4%, while SW2 exceeded it by approximately 30%. The higher calcium concentration at SW2 is consistent with its elevated calcium hardness, total hardness, bicarbonate, alkalinity, conductivity and TDS. These related parameters indicate that the calcium exceedance is predominantly associated with natural mineral dissolution and stronger water–rock interaction rather than a distinct toxic contamination source. The measured concentrations do not represent a major toxicological concern. Calcium is an essential nutrient and is generally more relevant as an aesthetic and operational parameter than as a direct health hazard. Nevertheless, elevated calcium contributes to the hard character of the surface water.

Magnesium

Magnesium is another major hardness-producing cation commonly derived from weathering of magnesium-bearing minerals, including silicates and carbonate materials. It occurs naturally in freshwater and is essential for chlorophyll formation, enzymatic activity and normal biological functioning. No specific regulatory limit was stated for magnesium in the laboratory results. Measured concentrations were: SW1: 41.51 mg/L, and SW2: 47.43 mg/L. SW2 recorded a moderately higher magnesium concentration than SW1. The results correspond with the magnesium-hardness measurements and confirm that magnesium contributes materially to total hardness at both sampling locations. However, calcium remains the dominant hardness-producing cation. The higher concentration at SW2 supports the broader pattern of stronger mineralization observed through its elevated conductivity, TDS, alkalinity, bicarbonate and total hardness. There is no indication that the magnesium concentrations result from pollution. The values are more reasonably attributed to natural weathering and groundwater or soil-water contributions to the surface-water system. Magnesium at the measured concentrations is unlikely to produce adverse ecological effects. Magnesium reflects natural hydrochemical conditions and does not independently constitute a significant surface-water quality concern.

Sodium

Sodium is a major dissolved cation that may originate from mineral weathering, atmospheric deposition, soil leaching, wastewater, detergents, saline intrusion and other salt-containing inputs. Elevated sodium commonly increases conductivity and salinity and may affect freshwater organisms where concentrations become excessive. The applicable regulatory limit is 120 mg/L. Measured sodium concentrations were: SW1: 0.43 mg/L, and SW2: 1.44 mg/L. Both concentrations were extremely low and substantially below the applicable standard. SW2 recorded a higher sodium concentration than SW1, but the absolute value remained negligible relative to the regulatory limit. The results confirm that the surface water is not sodium-dominated and has not experienced significant saline intrusion, wastewater-derived sodium loading or other salt-related contamination. The low sodium concentrations agree with the low salinity values and generally moderate conductivity. Although SW2 recorded higher conductivity and TDS than SW1, this increase is controlled mainly by calcium, magnesium, bicarbonate and chloride rather than sodium. The sodium concentrations

present no identified ecological, operational or human-health concern within the context of the surface-water assessment.

Potassium

Potassium is an essential nutrient released into water through weathering of feldspars, micas and other potassium-bearing minerals. Anthropogenic sources may include fertilizers, animal wastes, sewage, decomposing vegetation and agricultural runoff. Potassium is generally less mobile than sodium because it is readily retained by clay minerals and biological materials. No regulatory limit was stated for potassium. Measured concentrations were: SW1: 9.22 mg/L, and SW2: 21.29 mg/L. SW2 recorded more than twice the potassium concentration measured at SW1. The SW1 result is consistent with a relatively moderate natural background concentration. The higher value in SW2 may reflect stronger mineral dissolution, greater organic matter input, fertilizer-related runoff, wastewater influence or release from decomposing vegetation. The potassium result at SW2 should be interpreted together with the location's elevated ammonium, phosphate, BOD, COD and microbiological counts. This combination suggests that the increased potassium may partly reflect organic or anthropogenic inputs rather than natural mineralization alone. However, because no applicable regulatory limit was provided, the concentration cannot be classified formally as compliant or non-compliant. Potassium at the measured levels is not expected to represent a major direct toxicological concern. Its environmental significance lies mainly in its possible role as a supporting indicator of nutrient enrichment at SW2.

Lead

Lead is a toxic, non-essential metal with no known beneficial biological function. It may enter surface water through batteries, electronic waste, paints, vehicle residues, roofing materials, contaminated soil, industrial activities, plumbing components and uncontrolled waste disposal. Lead may be transported in dissolved form or attached to suspended sediments and organic matter. The applicable regulatory limit is 0.010 mg/L. Measured concentrations were: SW1: 0.008 mg/L, and SW2: 0.046 mg/L. SW1 complied with the standard, although its concentration was relatively close to the limit. SW2 exceeded the limit by approximately 4.6 times. The elevated lead concentration at SW2 is environmentally significant because lead is persistent, can accumulate in sediments and aquatic organisms and may adversely affect neurological, reproductive, renal and developmental processes. Aquatic organisms may be exposed through direct contact with water, ingestion of contaminated food or interaction with contaminated sediments. The difference between SW1 and SW2 indicates that lead enrichment is localized rather than uniform across the surface-water system. Potential sources may include: discarded or damaged batteries; electronic waste; vehicular and workshop residues; corroding metal materials; paints and roofing materials; contaminated runoff; waste-disposal areas; or historical accumulation within sediments. The relatively low TSS suggests that the recorded lead was not simply associated with a major suspended-sediment event at the time of sampling.

Iron

Iron is naturally abundant in tropical soils and Basement Complex geological environments. It may enter surface water through weathering of iron-bearing minerals, erosion, sediment resuspension, groundwater discharge, corrosion of metallic

structures and runoff from disturbed land. The applicable regulatory limit is 0.300 mg/L. Measured iron concentrations were: SW1: 1.667 mg/L, and SW2: 0.305 mg/L. Both samples exceeded the stated standard. SW1 exceeded the limit by approximately 5.6 times, while SW2 exceeded it only marginally, by about 2%. SW1 therefore represents the principal location of iron enrichment. The substantial difference between the two samples suggests localized geological, sedimentary or infrastructural influences. The high concentration at SW1 may result from: runoff over iron-rich tropical soils; natural weathering of iron-bearing minerals; localized bank erosion; groundwater inflow; disturbance of iron-rich sediments; or corrosion of metallic infrastructure. The near-neutral pH does not prevent iron occurrence, particularly where reducing groundwater enters an oxygenated surface-water body. Dissolved ferrous iron may oxidize after exposure to air and form reddish-brown ferric precipitates.

Chromium

Chromium may occur naturally through weathering of chromium-bearing minerals or enter surface water from metal finishing, pigments, leather tanning, treated wood, industrial wastes and combustion residues. Its environmental behaviour depends strongly on its oxidation state. Hexavalent chromium is generally more mobile and toxic than trivalent chromium. The applicable regulatory limit is 0.500 mg/L. Chromium was not detected in either sample: SW1: 0.000 mg/L, and SW2: 0.000 mg/L. Both samples complied with the standard. The absence of detectable chromium indicates that the sampled surface water has not been significantly affected by chromium-bearing industrial effluent, metal-processing waste or similar contamination sources.

Copper

Copper is an essential trace element that may enter surface water through natural mineral weathering, corrosion of electrical components and pipes, agrochemicals, industrial materials and urban runoff. At elevated concentrations, copper can be toxic to fish, aquatic invertebrates and microorganisms. The applicable regulatory limit is 1.000 mg/L. Measured concentrations were: SW1: 0.034 mg/L, and SW2: 0.015 mg/L. Both samples complied comfortably with the standard. SW1 recorded the higher copper concentration, but the measured value remained very low relative to the applicable limit. The results indicate no evidence of significant copper contamination from electrical equipment, plumbing, agrochemicals or waste materials. Water hardness can reduce the bioavailability and toxicity of certain dissolved metals, including copper. The very hard character of the surface water may therefore provide some natural buffering against copper toxicity, although compliance itself remains the primary finding. Copper does not constitute a significant environmental or operational concern within the sampled surface water.

Manganese

Manganese commonly occurs with iron in geological materials and may be mobilized under reducing conditions. It can enter surface water through groundwater inflow, soil erosion, sediment release and natural weathering. At elevated concentrations, manganese may cause staining, sediment formation and ecological effects. The applicable regulatory limit is **0.200 mg/L**. Measured concentrations were: SW1: 0.002 mg/L, and SW2: 0.000 mg/L. Both samples complied with the standard. The very low

manganese concentrations indicate limited mobilization of manganese-bearing minerals and no evidence of manganese contamination. The difference between elevated iron and negligible manganese is hydro chemically notable. Although both metals may become mobile under reducing conditions, their behaviour is controlled by different oxidation potentials, mineral associations and rates of precipitation. Iron can therefore become elevated while manganese remains low. Manganese presents no identified ecological, aesthetic or operational concern within the project area.

Zinc

Zinc is an essential trace element found naturally in rocks and soils. Anthropogenic sources include galvanized materials, roofing sheets, tires, batteries, paints, fertilizers, waste disposal and urban runoff. Elevated zinc can affect aquatic organisms, particularly in soft or acidic water. The applicable regulatory limit is 3.000 mg/L. Measured concentrations were: SW1: 0.042 mg/L, and SW2: 0.052 mg/L. Both values were substantially below the regulatory limit. SW2 recorded a slightly higher zinc concentration than SW1, but the difference is minor and does not indicate significant contamination. The concentrations represent low background levels and are unlikely to produce adverse ecological or operational effects. The near-neutral pH and high hardness also reduce the bioavailability of zinc relative to acidic, soft-water conditions. Zinc is therefore not considered a surface-water quality constraint.

Arsenic

Arsenic is a toxic metalloid that may occur naturally through dissolution of arsenic-bearing minerals or enter surface water through mining, pesticides, treated wood, industrial wastes, combustion residues and contaminated groundwater discharge. It is environmentally significant because chronic exposure may produce severe human-health effects and because it can accumulate in sediments and biological materials. The applicable regulatory limit is 0.010 mg/L. Measured concentrations were: SW1: 0.005 mg/L, and SW2: 0.005 mg/L. Both samples complied with the stated limit. The identical concentrations indicate a uniform low-level background occurrence rather than localized arsenic contamination. Each result represents approximately half of the applicable limit. Although compliant, arsenic should remain within future monitoring programmes because its toxicity is high and its mobility may change with pH, redox conditions and sediment disturbance. Based on the current results, arsenic does not prevent the surface water from meeting the stated metal-quality requirement.

4.4.2.4.5 Microbiological Characteristics of Surface Water

Total Bacterial Count

Total bacterial count provides a general measure of the viable bacterial population present in water. It does not exclusively represent pathogenic organisms; rather, it includes naturally occurring environmental bacteria as well as organisms introduced through soil runoff, decomposing organic matter, animal waste, wastewater and other sources. Surface water naturally supports larger bacterial populations than properly protected groundwater because it is openly exposed to the surrounding environment. Nevertheless, elevated bacterial counts may indicate organic enrichment, inadequate sanitary protection or pollution from nearby human and animal activities. Bacterial growth was recorded in both SW1 and SW2, demonstrating active microbial populations within the sampled surface-water system. SW2 exhibited the greater bacterial loading and therefore represents the more microbiologically impacted

location. The elevated bacterial population at SW2 corresponds with its: higher BOD; elevated COD; higher ammonium; higher phosphate; greater potassium concentration; presence of total coliform; presence of faecal coliform; and comparatively greater fungal population.

This consistent relationship indicates that the bacterial enrichment is associated with increased availability of organic matter and nutrients. Organic materials provide carbon and energy sources for heterotrophic microorganisms, while ammonium and phosphate support microbial and biological productivity. Possible sources of elevated bacterial populations include: runoff carrying soil and organic debris; animal access to the water body; livestock or bird droppings; wastewater or sewage inputs; poorly managed sanitation facilities; decomposing vegetation; refuse disposal; organic-rich bottom sediments; and stormwater drainage from developed areas. The bacterial counts do not independently confirm the presence of disease-causing organisms because total bacterial analysis is non-specific. However, elevated counts indicate that conditions support microbial growth and that the water may be vulnerable to pathogen contamination. From an ecological perspective, naturally occurring bacteria play an essential role in nutrient cycling and organic-matter decomposition. Excessive bacterial activity, however, may increase oxygen consumption and contribute to the elevated BOD measured at both locations. The surface water should therefore not be used directly for drinking, food preparation or other sensitive domestic purposes without appropriate treatment and microbiological confirmation.

Total Fungal Count

Fungi occur naturally in surface water and surrounding soils, where they contribute to the decomposition of leaves, wood, plant residues and other organic materials. Fungal spores and fragments may enter water through atmospheric deposition, runoff, soil erosion, decaying vegetation and wastewater. Fungal growth was detected in the surface-water samples, with the greater fungal occurrence associated with SW2. The presence of fungi is consistent with the availability of organic matter in the water body. SW2 recorded several related indicators of organic enrichment, including elevated BOD, COD, ammonium and phosphate. These conditions favour the survival and growth of fungi and other heterotrophic microorganisms. Potential sources include: decomposing vegetation; organic-rich soil runoff; accumulated plant litter; animal waste; wastewater; drainage from landscaped or vegetated areas; and resuspension of organically enriched sediments. The detection of fungi does not necessarily indicate severe pollution because fungal organisms are natural components of aquatic ecosystems. However, increased fungal counts may indicate elevated biodegradable organic matter or deterioration in sanitary quality. Fungi may also contribute to: objectionable taste and odour; biofilm development; discoloration; blockage of small pipes or filters; microbial growth in storage systems; and deterioration of water quality during prolonged storage. Where untreated surface water is stored for construction or operational purposes, fungal and bacterial growth may increase further, particularly under warm conditions and where storage tanks are exposed to sunlight. The fungal results therefore support the conclusion that the surface water, particularly SW2, contains appreciable organic material and should not be considered microbiologically suitable for direct human use.

Total Coliform

Total coliform organisms comprise a broad group of bacteria associated with soil, vegetation, surface runoff, animal waste and sewage. Their presence is widely used as an indicator of the sanitary integrity of water and its vulnerability to contamination. Total coliform was detected at SW2, indicating that this location is affected by sanitary or environmental contamination. Its detection demonstrates that the water has been exposed to runoff, organic waste, animal activity, wastewater or related contamination pathways. The absence or substantially lower occurrence of total coliform at SW1 suggests that SW1 was microbiologically less impacted at the time of sampling. The difference between the two locations further confirms that contamination is spatially variable and more pronounced at SW2. Potential sources of total coliform at SW2 include: human wastewater; poorly contained sewage; leaking septic systems; open defecation; animal droppings; livestock access; refuse disposal; stormwater runoff; contaminated drainage channels; and resuspension of contaminated sediment. The total-coliform result is consistent with the elevated bacterial count, faecal-coliform detection, ammonium enrichment, increased BOD and COD exceedance at SW2. Collectively, these parameters provide stronger evidence of organic and sanitary contamination than any individual parameter alone. The detection of total coliform means that SW2 should not be used for drinking or food-related activities without treatment. It also warrants further sanitary investigation to identify upstream or nearby contamination sources. Where the water is used for recreational contact, equipment washing or construction, workers should minimize direct ingestion and observe appropriate hygiene measures.

Faecal Coliform

Faecal coliform bacteria represent a more specific indicator of contamination by the intestinal wastes of humans and warm-blooded animals. Their presence demonstrates relatively recent faecal input and raises concern regarding the possible occurrence of enteric pathogens. Faecal coliform was detected at SW2, while SW1 did not exhibit the same level of faecal indication. The detection at SW2 is environmentally and hygienically significant because it confirms that at least part of the microbial contamination is associated with faecal material rather than only soil, vegetation or natural aquatic microorganisms. Possible contamination pathways include: sewage or wastewater discharge; leakage from septic systems; open defecation; livestock access; dog, cattle, bird or other animal droppings; runoff from contaminated land; drainage from sanitation facilities; and contaminated sediments. The faecal-coliform finding corresponds with the elevated ammonium and organic-pollution indicators at SW2. Faecal and other organic wastes contain nitrogenous compounds that decompose to release ammonium, while their microbial degradation increases BOD and COD. The presence of faecal coliform means that the water may contain pathogenic bacteria, viruses, protozoa or parasites, although these organisms were not individually analysed. Consequently, untreated water from SW2 is unsuitable for: drinking; food preparation; washing food-contact materials; bathing or recreational contact; handwashing; or any activity involving likely ingestion. Where surface water from SW2 is required for essential project activities, its use should be restricted to controlled non-potable applications and should not expose workers or surrounding communities to aerosols, splashes or accidental ingestion. Faecal-coliform detection represents the most direct evidence of sanitary contamination in the surface-water assessment and requires corrective attention.

✧ **Dry Season (Secondary data)**

Table 4.16: Surface Water Result for Physico-Chemical & Microbial Characteristics (Secondary data)

S/N	PARAMETER	UNIT	SW1 Chika Stream	SW2 Kuchingoro Stream)	FMEnv LIMIT	
					For aquatic life	*For Recreational Purpose*
Physico-Chemical Analysis						
1.	Appearance	-	Clear	Clear	-	-
2.	Odour	-	Odourless	Odourless	-	-
3.	Temperature	0C	26.30	29.90	20-33°C	20-33
4.	PH	-	7.18	7.22	6.0-90	5.0-9.0
5.	Turbidity	NTU	3.35	5.41	-	<55
6.	Total Dissolved Solids	mg/L	48.40	76.12	-	-
7.	Electrical Conductivity	µS/cm	126.30	123.71	-	-
8.	Dissolved Oxygen	mg/L	4.09	4.45	6.8	>5
9.	Total Suspended Solids	mg/L	11.00	12.00	NS	-
10.	Total Hardness	mgCaCO3/l	1.56	2.32	-	-
11.	Chemical Oxygen Demand	mg/L	12.01	25.00	-	-
12.	Biochemical Oxygen Demand	mg/L	3.94	3.55	4.0	2.0
14.	Phosphate (PO_4^{2-})	mg/L	25.60	22.50	NS	-
15.	Sulphate (SO_4^{2-})	mg/L	1.00	2.04	-	-
16.	Potassium (K^+)	mg/L	0.20	0.24	NS	-
17.	Magnesium (Mg)	mg/L	1.20	1.25	-	-
18.	Calcium (Ca^{2+})	mg/L	1.29	1.40	-	-
19.	Iron (Fe^{2+}/ Fe^{3+})	mg/L	0.074	0.066	1.0	-
20.	Lead (Pb^{2+})	mg/L	ND	ND	0.0017	-
21.	Copper (Cu^{2+})	mg/L	0.01	ND	0.002	-
22.	Zinc (Zn)	mg/L	<0.01	<0.01	0.03	-
23.	Nickel	mg/L	<0.01	<0.01	0.025	
24.	Cadmium	mg/L	<0.01	<0.01	-	
25.	Chromium	mg/L	<0.01	<0.01	0.002	
26.	Arsenic	mg/L	<0.001	<0.001	-	

The surface water temperatures ranged from 26.3°C in the Chika Stream to 29.9°C in the Kuchingoro Stream. Disparity between the dry and wet season results may be attributed to differences in sampling time, solar radiation, rainfall intensity and stream depth. The slight disparity in pH values between both studies may be attributed to rainfall distribution. It also indicates stable hydrochemical conditions and minimal influence from industrial or chemical contamination. Electrical Conductivity and Total Dissolved Solids had values of 123.71–126.30 µS/cm and 48.40–76.12 mg/L respectively in the dry season with wet season also indicating low EC and TDS values, confirming that the streams remain freshwater systems with low mineralization and remain free from significant saline or industrial contamination. Dry season turbidity values ranged between 3.35 and 5.41 NTU, while total suspended solids ranged from 11 to 12 mg/L. The wet season data also indicates relatively low turbidity values, although slight increases were observed at some

sampling locations, likely reflecting rainfall-induced runoff. Results from both seasons indicate low nutrient concentrations, moderate dissolved oxygen levels and relatively low BOD and COD concentrations. The low values for heavy metals suggest that there is no evidence of significant heavy-metal pollution within the surface-water environment surrounding the NOUN campus. The laboratory results also suggest that microbiological quality has remained generally satisfactory, although untreated surface water should continue to be considered unsuitable for direct potable use.

4.5 Land Use, Land Cover and Land Utilization.

Land cover refers to the biophysical features present on the land surface, such as vegetation, bare ground, water bodies and built-up areas, whereas land use relates to the socioeconomic functions assigned to the land, including residential, commercial, institutional, agricultural and recreational purposes. The project site is situated within an already developed university environment characterized predominantly by academic buildings, administrative facilities, internal road networks, parking areas, landscaped open spaces and utility infrastructure. Consequently, the proposed development represents an institutional infrastructure upgrade rather than a conversion of agricultural, forest or ecologically sensitive land to another land use. The project area consists mainly of previously disturbed open land with sparse grasses, ornamental vegetation and scattered shrubs that have developed within the university premises. No primary forest, wetlands, protected habitats or areas of high ecological sensitivity were observed within the proposed development footprint during the site reconnaissance.

As a result, the ecological value of the proposed project site is relatively low compared with undisturbed natural habitats, and the project is unlikely to result in significant loss of natural vegetation or biodiversity. Construction activities will involve only localized site clearing, minor earthworks, installation of photovoltaic module support structures, battery energy storage facilities, inverter stations and associated electrical infrastructure, hence, no changes to the approved land use designation are anticipated.

Land utilization within the project area is predominantly institutional and locating the proposed solar hybrid power project within this existing institutional landholding minimizes the need for additional land acquisition, avoids involuntary resettlement and eliminates potential conflicts with residential, commercial or agricultural land uses. This site selection is consistent with the principles of the Abuja Master Plan, which promotes orderly land development and the efficient utilization of designated institutional land within the Federal Capital Territory.

4.6 Ecological Description of the Project Site

4.6.1 Ecological Setting

The project area falls within the Northern Guinea Savannah ecological zone, which occupies much of north-central Nigeria and is characterized by open woodland, tall grasses, scattered deciduous trees and seasonally variable vegetation influenced by alternating wet and dry seasons (National Biodiversity Strategy and Action Plan

(NBSAP), 2016), however, the original natural vegetation of this ecological zone has, however, been extensively modified due to rapid urbanization, institutional development and associated infrastructure expansion, resulting in fragmented habitats dominated by ornamental vegetation, managed landscapes and secondary plant communities.

The ecological characteristics of the NOUN campus reflect this urbanized setting comprising landscaped lawns, ornamental trees, shrubs, herbaceous vegetation and disturbed open spaces maintained primarily for institutional, recreational and aesthetic purposes rather than natural ecological functions. Consequently, the ecological sensitivity of the project footprint is considered relatively low compared with undisturbed Guinea Savannah ecosystems. No environmentally sensitive ecosystems, critical habitats, wetlands, protected forests or legally designated conservation areas were encountered within or immediately adjacent to the proposed project site during the ecological survey.

4.6.2 Methodology for Flora and Fauna Assessment at the Study Area

Considering that the project is located within previously disturbed environments, a Rapid Ecological Assessment (REA) was adopted for the baseline ecological survey. The ecological survey comprised systematic walk-over reconnaissance of the proposed project sites; direct observation and identification of plant and animal species; photographic documentation of representative habitats and species; identification of habitat characteristics; recording of indirect evidence of wildlife activities such as termite mounds, grazing signs, nests and burrows; consultation of standard Nigerian floras and faunal identification guides; and verification of the conservation status of recorded species using the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (2024). Field investigations were carried out between 07:00 and 17:00 hours.

4.6.3 Flora Sampling

Vegetation is one of the most vital natural resources, providing food, fuelwood, and maintaining soil fertility. It underpins life for all organisms, as every living being depends on it directly or indirectly. Plants supply essentials such as food, timber, fuel, and shade, which highlights the importance of protecting and managing vegetation to ensure environmental sustainability and continued human progress. Vegetation contributes to soil stabilization, carbon sequestration, microclimate regulation, dust interception and provision of a habitat.

Field observations indicate that vegetation within the proposed project area is dominated by common herbaceous species and ornamental plants established mainly for landscaping, erosion control and beautification of the University environment. No primary forest vegetation, wetlands or ecologically sensitive plant communities were encountered during the survey. The vegetation therefore represents a typical disturbed

urban Guinea Savannah ecosystem rather than a natural woodland community. Site 1 consists predominantly of grasses and ruderal (disturbance-tolerant) plant species colonizing reclaimed sandy soils. Dominant species include Cymbopogon spp. (Wild Lemon Grass), Bidens pilosa (Blackjack), Digitaria spp./Paspalum spp. (Crabgrass/Paspalum Grass) and Mimosa pudica (Sensitive Plant). These pioneer species provide ground cover, reduce erosion and support pollinating insects and other invertebrates, thereby contributing to ecosystem stability despite their low conservation significance while Site 2 exhibits relatively greater floristic diversity owing to extensive landscaping around academic and administrative buildings. Dominant species include Delonix regia, Platycladus orientalis, Veitchia merrillii, Rhapis excelsa, Psidium guajava, Leucaena leucocephala, Duranta erecta, Euphorbia spp., together with managed lawn grasses. Most of these species are planted ornamentals that provide shade, improve microclimatic conditions, stabilize soils and enhance the visual quality of the campus environment rather than serving as components of a natural ecosystem. No nationally protected plant species or plant species classified as threatened by the IUCN Red List were recorded during the survey.

Table 4.17: Name, Description and Economic Importance of Dominant Flora Species Recorded within the Study Area

S/N	Probable Scientific Name	Common Name	Family	Occurrence	Ecological Importance	IUCN Status
1	*Cymbopogon* spp.	Wild Lemon Grass	Poaceae	Site 1	Ground cover, erosion control and habitat for insects.	Least Concern (LC)
2	*Bidens pilosa*	Blackjack	Asteraceae	Site 1	Pioneer species supporting pollinating insects.	Least Concern (LC)
3	*Digitaria* spp. / *Paspalum* spp.	Crabgrass/Paspalum Grass	Poaceae	Site 1	Surface stabilization and soil protection.	Not Evaluated (NE)
4	*Mimosa pudica* (probable)	Sensitive Plant	Fabaceae	Site 1	Nitrogen fixation and ground cover.	Least Concern (LC)
5	*Delonix regia*	Flamboyant (Royal Poinciana)	Fabaceae	Site 2	Shade, habitat and landscape enhancement.	Least Concern (LC)

S/N	Probable Scientific Name	Common Name	Family	Occurrence	Ecological Importance	IUCN Status
6	*Platycladus orientalis*	Oriental Arborvitae	Cupressaceae	Site 2	Ornamental landscaping and erosion control.	Least Concern (LC)
7	*Veitchia merrillii* (probable)	Christmas Palm	Arecaceae	Site 2	Ornamental palm providing habitat and aesthetic value.	Least Concern (LC)
8	*Rhapis excelsa* (probable)	Lady Palm	Arecaceae	Site 2	Ornamental landscaping species.	Least Concern (LC)
9	*Psidium guajava*	Guava	Myrtaceae	Site 2	Fruit-bearing tree providing food resources for birds and small mammals.	Least Concern (LC)
10	*Leucaena leucocephala* (probable)	Lead Tree	Fabaceae	Site 2	Nitrogen fixation and soil improvement.	Least Concern (LC)
11	*Duranta erecta*	Golden Dewdrop	Verbenaceae	Site 2	Ornamental hedge and boundary landscaping.	Least Concern (LC)
12	*Euphorbia* spp.	Candelabra Tree	Euphorbiaceae	Site 2	Drought-tolerant ornamental species.	Least Concern (LC)
13	*Cynodon* spp., *Axonopus* spp. and related grasses	Lawn Grasses	Poaceae	Site 2	Ground cover, erosion control and landscape aesthetics.	Least Concern (LC)



Plate 4.11a: Madagascar Umbrella Tree (*Terminalia mantaly*)



Plate 4.11b: Oriental Arborvitae (*Platycladus orientalis*)



Plate 4.11c: Tropical Almond (*Terminalia catappa*).



Plate 4.11d: Mango (*Mangifera indica*)



Plate 4.11e: Orange Jasmine / Mock Orange (*Murraya paniculata*)



Plate 4.11f: Mango (*Mangifera indica*)



Plate 4.11g: Coat Buttons (*Tridax procumbens*)



Plate 4.11h: Banana/Plantain (*Musa* spp.)



Plate 4.11i: Lead Tree (*Leucaena leucocephala*).



Plate 4.11j: Signal grass (Brachiaria decumbens)

4.6.4 Fauna Assessment

The faunal assessment indicates that wildlife diversity within the proposed project footprint is limited owing to continuous human activities associated with the University's academic environment. No wild terrestrial mammals, reptiles or amphibians were observed within either project site during the field survey.

The only vertebrate species observed consisted of Bos indicus (Zebu cattle) grazing outside the University's perimeter fence. These animals are domesticated livestock belonging to local pastoralists and do not constitute resident wildlife populations. Evidence of Macrotermes spp. (termites) was also recorded through active termite mounds situated along the perimeter wall. These termites perform important ecological functions including decomposition of organic matter, nutrient recycling, improvement of soil fertility and enhancement of soil aeration.

No breeding sites, nesting areas, burrows or migration corridors were identified within the proposed development footprint. Likewise, no threatened or protected wildlife species were encountered during the survey, indicating that the project area possesses low faunal conservation value and low ecological sensitivity,

Table 4.18: Dominant Fauna and Evidence of Faunal Activities within the Study Area

S/N	Scientific Name	Common Name	Observation	Occurrence	Ecological Significance	IUCN Status
1	*Bos indicus*	Zebu Cattle	Grazing herd observed outside the University perimeter fence	Immediate surroundings	Livestock production; meat and milk supply; socio-economic importance to pastoral communities.	Domesticated (Not assessed under IUCN wildlife criteria)
2	*Macrotermes* spp.	Termites	Active termite mound observed along the perimeter wall	Immediate surroundings	Decomposition of organic matter; nutrient recycling; improves soil aeration and fertility; ecosystem engineer.	Not Evaluated (NE)

Evidence of Faunal Activities

Indirect evidence of faunal activities recorded during the survey included:

- Grazing activities of domesticated cattle on herbaceous vegetation adjacent to the project area.
- Active termite mounds indicating established termite colonies and ongoing biological activity within the surrounding environment.

The observed fauna and associated activities were confined to areas outside the proposed project sites, while no significant faunal activities were recorded within the project footprints. Therefore, construction and operation of the proposed project are expected to have negligible impacts on fauna, provided that unnecessary disturbance beyond the project boundaries is avoided.

Overall, the ecological assessment indicates that the proposed project sites possess low ecological sensitivity, with vegetation dominated by common ornamental and herbaceous species and fauna largely restricted to domesticated animals and common soil invertebrates. No critical habitats, protected ecosystems or species of conservation concern were identified within the project area, and with the implementation of appropriate environmental management measures, significant ecological impacts are not anticipated.



Plate 4.12: Cows grazing on the field.



Plate 4.13: Termite Mound.

4.7 Socio-economic and Health Conditions of the Study Area

This sub-section presents the baseline socio-economic characteristics of the National Open University of Nigeria (NOUN) Main Campus, located in Abuja Municipal Area Council (AMAC) of the FCT based on the results of the field survey conducted witin the campus. Understanding the socio-economic profile of the area provides critical insight into existing livelihood activities, which can inform employment opportunities and social interventions during both the construction and operational phases of development projects. This assessment also identifies social and economic activities that may be affected by project implementation, specifically the proposed project initiated by the Federal Government of Nigeria (FGN) through the Rural Electrification Agency (REA), with financial support from the African Development Bank (AfDB).

The baseline socio-economic information serves as a reference point for evaluating the project's impacts on the University community throughout its life cycle. Key themes addressed in the study include population characteristics, socio-cultural organization, university structure, existing campus facilities, employment patterns, income distribution and stakeholder perspectives regarding the project. Additionally, the study incorporates an analysis of gender-related issues, encompassing gender-specific activities and gender-based violence within the university community.

4.7.1 Study Approach and Methodology

Considering that all the project components for the 1-Megawatt (MW) Solar Hybrid (PV) Power Plant are located entirely within the Main Campus of the National Open University of Nigeria (NOUN) and the impacts of the project are expected to be minimal, stakeholder consultations and questionnaire administration were restricted to the University community. Consequently, the selected study area captures the principal receptors that may experience project-related benefits or impacts during the construction, operation and decommissioning phases.

The socio-economic survey adopted a purposive sampling technique complemented by convenience (availability) sampling. The purposive sampling technique was employed to ensure that respondents comprised members of the university community who possess adequate knowledge of the campus environment and are the primary beneficiaries and users of the proposed Project. The survey was conducted during a period when the University was not in academic session; consequently, students were absent from the campus. However, to ensure that reliable baseline information was obtained, questionnaires were administered to members of staff (academic and non-academic) who routinely occupy and utilize the campus facilities and are familiar with existing electricity supply challenges, infrastructure, environmental conditions and institutional operations. Their responses were complemented by field observations and key informant interviews with relevant university officials.

A combination of primary and secondary data collection techniques. Primary data were obtained through structured questionnaire administration, key informant interviews (KIIs), field observations and stakeholder consultations with members of the university community. A structured questionnaire was used as the principal survey instrument. The questionnaire comprised both closed-ended and open-ended questions to facilitate quantitative and qualitative analyses. Key Informant Interviews (KIIs) were conducted with representatives of the University Management to obtain additional information on community infrastructure, institutional arrangements, existing environmental concerns, public utilities, local development priorities and anticipated project benefits. Field observations were undertaken concurrently with the questionnaire survey to verify information given.

Following completion of the field survey, questionnaire responses were checked for completeness, coded and analysed using descriptive statistical techniques. The interpreted results provide the baseline against which potential positive and adverse socio-economic impacts associated with the proposed 1-MW Solar Hybrid Power Project are evaluated in subsequent chapters of this ESIA.



Figure 4.14: Aerial map highlighting the project sites, NOUN and Jabi Community.

4.7.1.1 Study Design

The study employed sequential mixed methods research design including quantitative and qualitative methods of data gathering, analysis and reporting. Information collected during the study was triangulated to separate perception from reality. The study was carried out on 6th July, 2026. The study made use of a questionnaire for quantitative data gathering and Key informant interviews, and stakeholders' consultation for the qualitative data.

4.7.1.2 Sample Size and Target Population for the Study

The proposed project occupies a relatively small footprint within an existing university campus and is not expected to result in land acquisition, involuntary resettlement or significant off-site socio-economic impacts. Consequently, the principal stakeholders are members of the university community who are directly affected by or expected to benefit from the project.

The number of questionnaires administered was determined based on the nature, scale and anticipated impacts of the proposed project, the defined Area of Influence, the institutional setting of the project, the availability of respondents during the survey period and the objectives of the Environmental and Social Impact Assessment. According to Bailey (1994) and Kothari (2004), descriptive surveys may rely on relatively small samples provided that respondents are knowledgeable about the subject under investigation and the findings are interpreted within the context of the study objectives rather than generalized to the entire population. A sample of 50 respondents was therefore considered adequate to capture a broad range of views from the relevant stakeholder groups while remaining proportionate to the scale and anticipated impacts of the project.

The study population comprised Staff and students of the National Open University of Nigeria (NOUN), Main Campus, Jabi. The target population were respondents that

were 18 years and above. However, participation in the survey was voluntary and only individuals who provided informed consent were included in the assessment.

4.7.1.3 Ethical Considerations

All interviews were conducted with the prior informed consent of participants. Confidentiality and anonymity were strictly maintained. Participation in the survey was entirely voluntary and respondents were informed of their right to withdraw from the study at any stage without any consequence or discomfort.

4.7.2 Background of the National Open University of Nigeria (NOUN)

The National Open University of Nigeria (NOUN) is Nigeria's premier Open and Distance Learning (ODL) institution, established in 1983, suspended shortly thereafter, and formally revived in 2002 by the Federal Government of Nigeria to expand equitable access to university education. The University's Main Campus (Headquarters) is located at Plot 91, Cadastral Zone, University Village, Nnamdi Azikiwe Expressway, Jabi, Abuja, and serves as the administrative, academic and policy coordination centre for the University's nationwide network of study centres. The Main Campus accommodates the offices of the Vice-Chancellor, principal officers, central directorates, academic support units, faculties, and the School of Postgraduate Studies.

The Main Campus currently houses eight (8) academic faculties together with the School of Postgraduate Studies (SPGS). The faculties comprise Agricultural Sciences, Arts, Education, Health Sciences, Law, Management Sciences, Sciences, and Social Sciences, while postgraduate programs are coordinated centrally through the School of Post Graduate Studies (SPGS). These academic units are responsible for curriculum development, teaching, research, quality assurance and examination administration across the University's national study-centre system.

As of 2026, NOUN has over 190,000 active students distributed across more than 128 study centres nationwide, making it the largest Open and Distance Learning institution in Nigeria. During the University's 30th Matriculation Ceremony in 2026, 25,517 newly admitted students were matriculated, comprising 19,149 undergraduate students, 2,194 Postgraduate Diploma students, 4,107 Master's students, 20 M.Phil. students and 47 Ph.D. students, demonstrating continued growth in both undergraduate and postgraduate enrolment.

The University presently offers more than 100 accredited undergraduate and postgraduate programs spanning bachelor's degrees, postgraduate diplomas, master's degrees, M.Phil. and doctoral programs across its faculties. The digital academic catalogue currently lists over 100 approved academic programs, reflecting the University's broad academic coverage and commitment to expanding access to higher education through flexible learning.

The University Community is administered through a conventional Nigerian university governance framework adapted to Open and Distance Learning. Overall leadership is vested in the Governing Council, while academic administration is headed by the Vice-Chancellor, supported by principal officers including the Deputy Vice-Chancellors, Registrar, Bursar and University Librarian. Academic matters are

regulated by the Senate, whereas each faculty is headed by a Dean and departmental academic activities are coordinated by Heads of Department. The Main Campus also houses numerous directorates, institutes, research centres and administrative units responsible for admissions, examinations, quality assurance, student support services, information technology, works and physical planning, and other institutional functions.

The National Open University of Nigeria has had visionary leaders with international reputation from inception. Professor Gabriel J. Afolabi-Ojo, whose tenure lasted between September, 1981 and April, 1984 was the first and only Vice-Chancellor of the National Open University (NOU) before it was suspended by the then military authorities on 25th April 1984. Professor Gabriel J. Afolabi-Ojo, whose tenure lasted between September, 1981 and April, 1984 was the first and only Vice-Chancellor of the National Open University (NOU) before it was suspended by the then military authorities on 25th April 1984. Prof Uduma Oji Uduma, who assumed office on the 11th of February, is the current Vice Chancellor of the University succeeding Prof. Olufemi Peters.

NOUN is at the forefront of internationalization of higher education in Nigeria. The University is a member of the Association of West African Universities (AWAU), Association of African Universities (AAU), African Council for Distance Education (ACDE), and International Council for Distance Education (ICDE), among others. Through these organizations, the University shares best practices with its global peers. Through conference participation and research collaboration, NOUN academics reach out to their international colleagues.

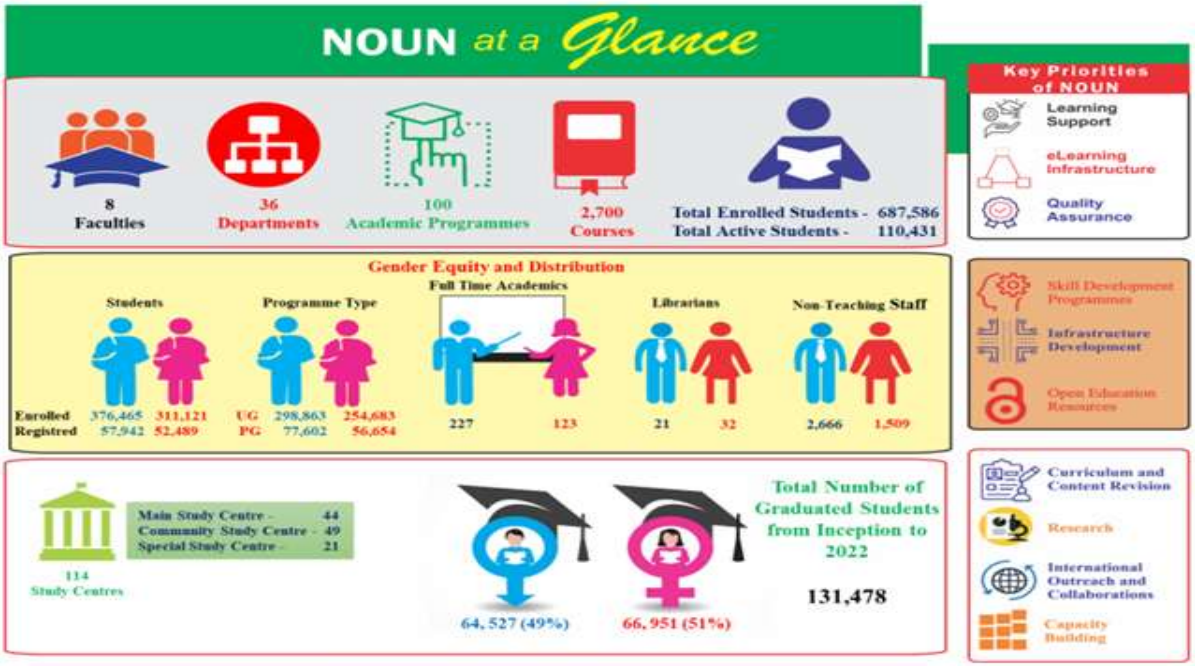


Figure 4.15: A Snapshot of the University's Growth
***Source**: NOUN Portal (https://nou.edu.ng/)*

4.7.3 University Community Administrative Structure & Governing Council

The President and Commander-in-Chief is the Visitor to the university, as is the case for all federal universities in Nigeria. NOUN also has a Chancellor appointed by the Visitor. There is a Governing Council, headed by the Pro-Chancellor, whose membership is constituted by the Visitor. The Vice-Chancellor is the CEO and Chief Accounting Officer of the university and is responsible for the day-to-day running of the University. The Governing Council is the highest decision-making body of the Federal University. The organizational structure of the University is depicted below in a flow diagram:

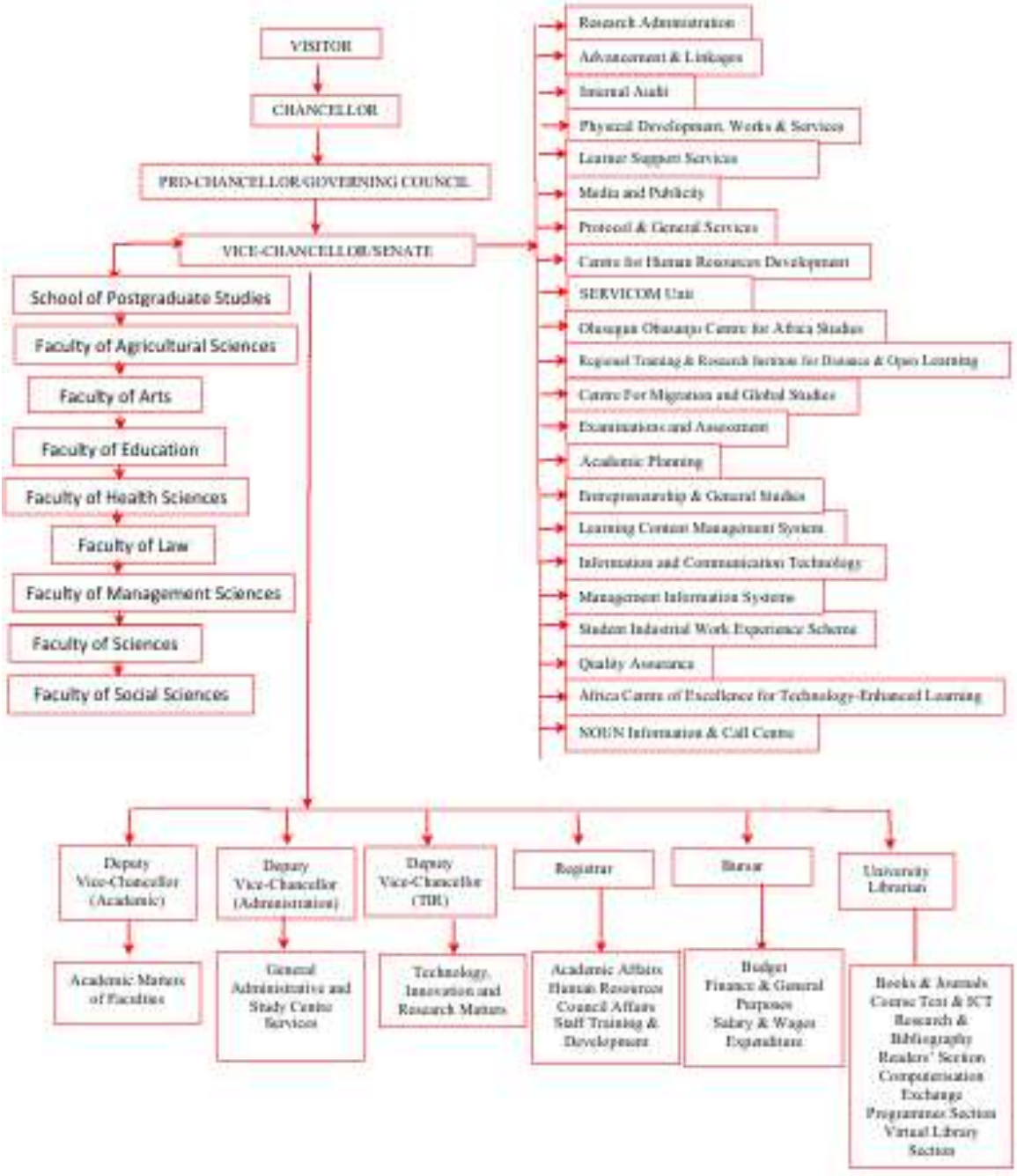


Figure 4.16: Organizational Structure of NOUN

***Source**: National Open University of Nigeria at a Glance (Third Edition Handbook)*

4.7.4 Land Tenure and Ownership

The NOUN Main Campus occupies Federal Government-owned land situated within the University Village, Jabi, Abuja. The land is under the custody of the National Open University of Nigeria as a Federal Government educational institution established by law for public purposes. Consequently, the campus land tenure is institutional in nature, with ownership vested in the Federal Government of Nigeria and managed by the University for educational, research and administrative activities. The Main Campus continues to accommodate new academic and infrastructural developments in line with its institutional expansion mandate.

Observations during the site visit indicate that the project area has adequate social amenities, infrastructure diverse economic activities. Commercial establishments located around the university complement institutional activities by providing goods and services to the university community.

Table 4.19: Some of the Observations

Socio Characteristics	
Social Activities	**Social Amenities and Infrastructure**
✧ Raked point sitting area for ceremonial activities i.e Matriculation, Convocation, etc. ✧ Sporting and recreational activities ✧ Research and academic collaborations ✧ Staff meetings and administrative activities ✧ Religious activities (church and mosque services) ✧ Training, seminars, and workshops ✧ Networking and professional meetings ✧ Garden and Bench Park	✧ University Clinic ✧ Central library ✧ Places of worship (mosque and church) ✧ Recreational Garden and sports facilities ✧ Good road network ✧ Car parks at strategic places on campus ✧ Street lighting ✧ Strategic water supply (boreholes and government water board) ✧ Electricity supply infrastructure (Transformers, Generators) ✧ Waste collection points. ✧ Telecommunication and internet infrastructure
Economic Characteristics	
✧ Formal employment provided by the university. ✧ Business centres providing printing, photocopying, typing and internet services ✧ Government and private sector employment within the surrounding area. (Cleaning and janitorial services) ✧ Small businesses (food shops, stationery shops, POS operators).	




Plate 4.13: Admin Block 1 & Admin Block 2



Plate 4.14: Mosque



Plate 4.15: Christian Fellowship Centre



Plate 4.16: Central Library



Plate 4.17: Sports Complex



Plate 4.18: ACETEL Building



Plate 4.19: Block of Shops

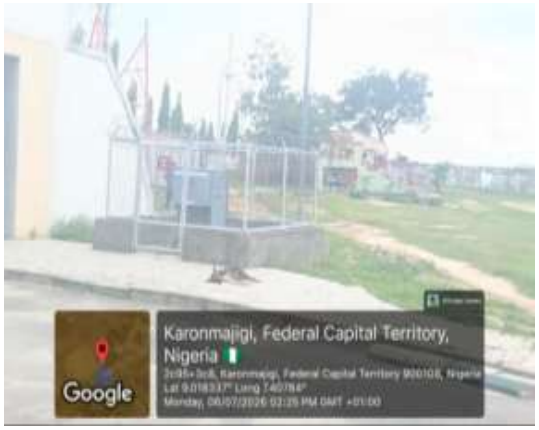


Plate 4.20: Transformer (Close to Main Gate)



Plate 4.21: View of Substation/PowerStation



Plate 4.22: View of the University Clinic



Plate 4.23: Inside the University Clinic



Plate 4.24: Convocation Arena



Plate 4.25: Open Dumping of Wastes within the Study Area



Plate 4.26: A Supermarket in the host Community



Plate 4.27: Trading activity within the host Community

4.7.5 Sampled Population/NOUN Socioeconomic Characteristics

This assessment examines the economic and human dimensions of the host institution, with particular emphasis on sources of power and other relevant socioeconomic variables. The parameters considered include gender and age distribution, ethnic affiliation, religion, literacy level, occupation, household size and duration of stay within the project area, income level and general health status.

These key socioeconomic characteristics provide valuable insight into the structure and dynamics of the university community and are essential for effective stakeholder engagement.

The information will support the project proponent and facility operators in designing appropriate communication, employment and participation strategies during both the construction and operational phases of the proposed project. In addition, the findings will assist the beneficiary school authority in informed decision-making, planning and management related to the proposed development.

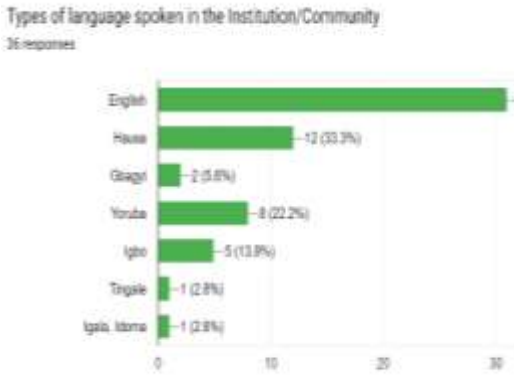
A total of 50 structured questionnaires were distributed to academic and non-academic staff across different administrative and academic units within the

University. Of these, 37 questionnaires were successfully retrieved, representing a 74% response rate, while 35 questionnaires were found to be properly completed and suitable for statistical analysis. Two retrieved questionnaires were excluded from the analysis because they contained incomplete or inconsistent responses that could compromise the reliability of the results

Table 4.20: Respondent's Socio-Economics Characteristics

			Findings
Gender			
Options	Frequency	Percent	The respondents were slightly predominantly female, with 52.8% (19 females) and 47.2% (17) males. The near-balanced gender distribution ensures that both male and female perspectives on the proposed solar project are adequately represented supporting gender-responsive planning in both the construction and operational phases.
Male	17	47.2	
Female	19	52.8	
Total Response	**36**	**100**	
Age of Respondents			The majority of respondents (63.9%; 23 persons) were aged 31–45 years, followed by 16.7% (6) each within the 18–30 years and 46–54 years age groups. Only 2.8% (1) were aged 55 years and above. This indicates that most respondents are within the economically active and productive age group, suggesting a workforce capable of supporting and benefiting from the proposed project.
Options	Frequency	Percent	
18-30 years	6	16.7	
31-45 years	23	63.9	
46-54 years	6	16.7	
55 years and above	1	2.8	
Total Response	**37**	**100**	
Marital Status			
Options	Frequency	Percent	Most respondents (65.7%; 23 persons) were married, while 34.3% (12) were single. No respondents reported being widowed. The predominance of married respondents suggests that many have family responsibilities and may place greater value on reliable electricity for household welfare and productivity.
Married	23	65.7	
Single	12	34.3	
Widowed	-	-	
Total Response	**35**	**100**	
House size			
Options	Frequency	Percent	Nearly half of the respondents 17 (48.6%) had small households (2–4 members), followed by 37.1% (13) with medium-sized households (5–8 members) and 14.3% (5) with large households (above 9 members).
Large (Above 9)	5	14.3	
Medium (5-8)	13	37.1	
Small (2-4)	17	48.6	

			Findings
Total Response	**35**	**100**	This indicates that small to medium-sized households are most common among respondents which highlights the potential for the solar project to positively impact multiple beneficiaries within each household.
Religion			
Options	Frequency	Percent	Majority of respondents - 65.7% (23 persons) identified as Christians, while 34.3% (12 persons) were Muslims. No respondents identified with traditional religion. This reflects awareness of religious diversity is important for culturally sensitive engagement and community mobilization during project implementation.
Christianity	23	65.7	
Isam	12	34.3	
Traditional	-	-	
Total Response	**35**	**100**	
Education			
Options	Frequency	Percent	Respondents were generally highly educated. Majority of the respondents - 77.1% - possessed HND/B.Sc. qualifications, while 11.4% (4) had M.Sc. degrees. A small proportion (2.9%; 1 each) had Primary School, NCE/ND, M.A., and Ph.D. qualifications. The high educational attainment is expected in a university environment and is shall facilitate effective communication about project objectives, benefits, and safety measures.
Primary School	1	2.9	
NCE/ND	1	2.9	
HND/B.Sc	27	77.1	
M.Sc	4	11.4	
M.A	1	2.9	
Ph.D in view	1	2.9	
Total Response	**35**	**100**	
Occupation			
Options	Frequency	Percent	The respondents were majorly non-teaching staffs 30 (85.7%), while 11.4% (4) were teaching staff and 2.9% (1) was a trader. No students participated in the survey, because the institution was not in academic session during data collection.
Teaching Staff	4	11.4	
Non-teaching Staff	30	85.7	
Trader	1	2.9	
Student	-	-	
Total Response	**35**	**100**	
Monthly Income			
Options	Frequency	Percent	Most respondents 27 (81.8%) earned ₦120,000 and above per month. Smaller proportions earned ₦70,000–₦90,000 3 - (9.1%) ₦31,000–₦70,000 (6.1%) 2, and ₦0–₦30,000 (3.0%) 1. This indicates that most respondents fall within the higher income category, reflecting the
₦0 to ₦30,000	1	3	
₦31,000 to ₦70,000	2	6.1	
₦70,000 to ₦90,000	3	9.1	
₦120,000 +	27	81.8	

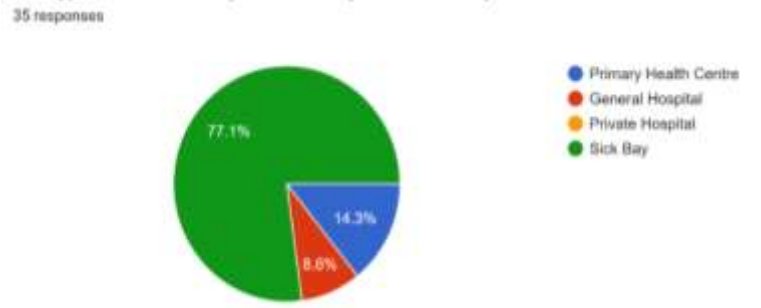
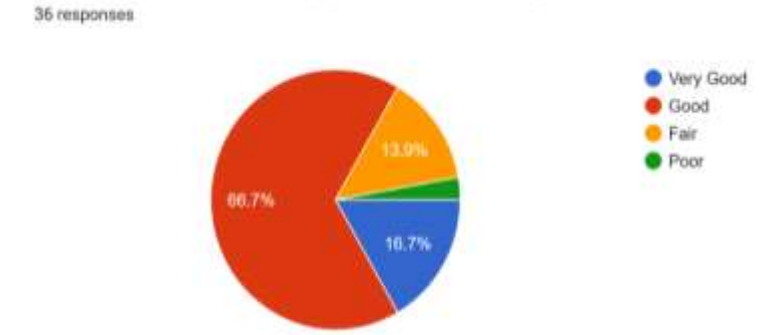
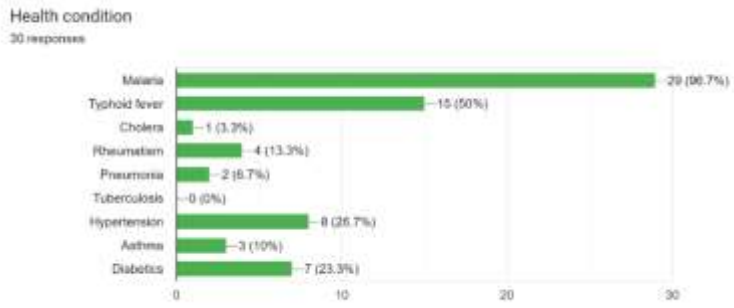
<table>
<tr><th colspan="3"></th><th>Findings</th></tr>
<tr><td>Total Response</td><td>33</td><td>100</td><td>predominance of university employees.</td></tr>
<tr><td colspan="3">Duration of stay in the institution/Community</td><td rowspan="7">Most respondents 40.0% (14) had stayed in the institution or community for 1–5 years, while 28.6% (10) who had stayed 6–10 years, 22.9% (8) for 11–19 years, and 8.6% (3) for 20 years and above. This suggests a mix of relatively new and long-term members of the university community.</td></tr>
<tr><td>Options</td><td>Frequency</td><td>Percent</td></tr>
<tr><td>1-5yrs</td><td>14</td><td>40</td></tr>
<tr><td>6-10yrs</td><td>10</td><td>28.6</td></tr>
<tr><td>11-19yrs</td><td>8</td><td>22.9</td></tr>
<tr><td>20 and above</td><td>3</td><td>8.6</td></tr>
<tr><td>Total Response</td><td>35</td><td>100</td></tr>
<tr><td colspan="3">Types of language spoken in the institution/community</td><td></td></tr>
<tr><td colspan="3"> 
</td><td>The respondents predominantly speak English 31 (86.1%), reflecting its role as the primary language of communication within the University. Other commonly spoken languages include Hausa (33.3%; 12 respondents), Yoruba (22.2%; 8), and Igbo (13.9%; 5 respondents), while Gbagyi (5.6%; 2 respondents), Tiv (2.8%; 1), and Igala/Idoma (2.8%; 1 respondent) are spoken by a smaller proportion.

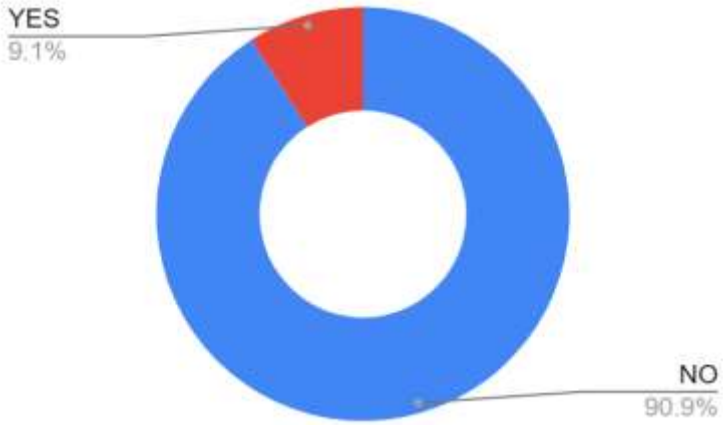
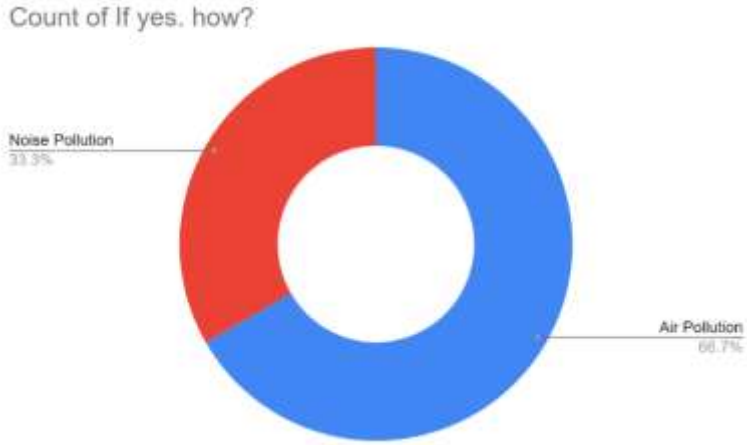
The multilingual nature of the institution indicates that although English is the dominant medium for official communication, stakeholder engagement and awareness activities should also consider the linguistic diversity of the university community where necessary.

Note: The percentages exceed 100% because respondents were allowed to select more than one language they speak.</td></tr>
</table>

Health Status

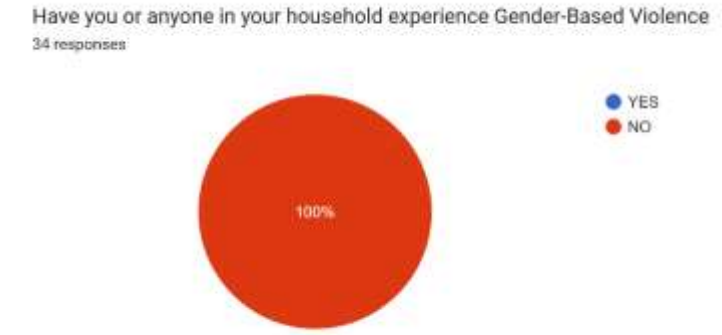
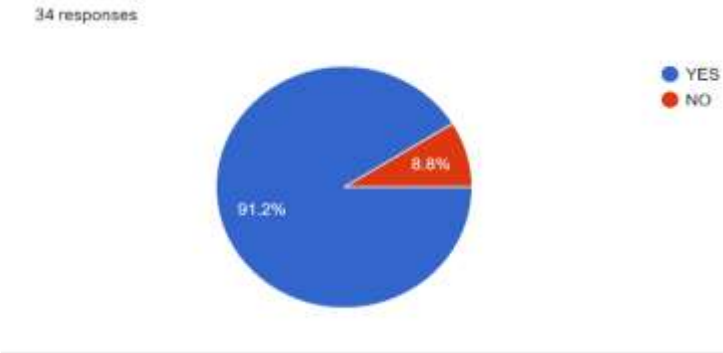
Category	Key Observations
Available Health Facility in the Institution/Community	

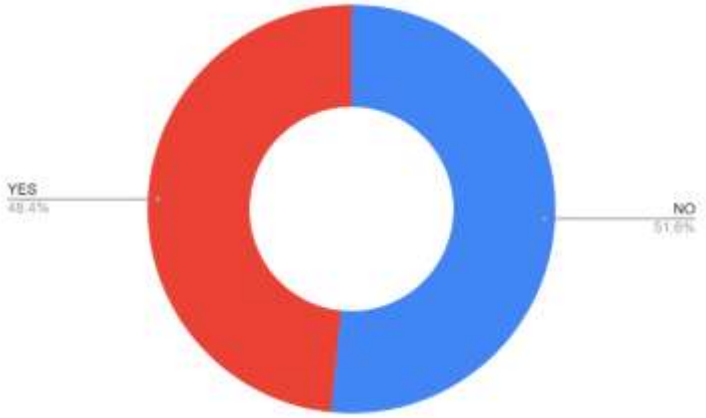
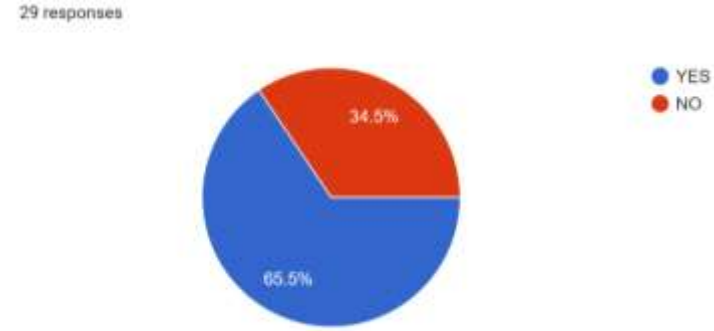
Category	Key Observations
	The University Sick Bay serves as the primary healthcare facility for the University Community including staff, students and visitors, providing basic healthcare services within the institution. Specialized medical care is sought outside the institution when required.
Condition of Health Facility Within the Institution/Community	
	The findings indicate that the institutional health facility is generally in good condition and is considered adequate for providing basic healthcare services.
Common Health Conditions Within the Institution/Community	
	Malaria remains the predominant health concern within the institution, reflecting the need for continuous mosquito control and environmental sanitation. The occurrence of non-communicable diseases such as hypertension and diabetes also highlights the importance of routine health awareness and screening programmes. *(Multiple responses were allowed; therefore, percentages exceed 100%.)*
Perceived Negative Impact of the Project	

Category	Key Observations
	The proposed solar project enjoys a high level of public acceptance, with very few respondents expressing concerns about potential adverse environmental impacts. Which will be controlled by following al necessary national and international environmental guideline.
Type of Potential Negative Impact	
	The perceived impacts are limited to temporary construction-related activities. Appropriate mitigation measures such as dust suppression, proper equipment maintenance, and noise control shall be available to effectively minimize these impacts.
How do you think these can be averted (1 response)	
- With clean energy and stop open burning	

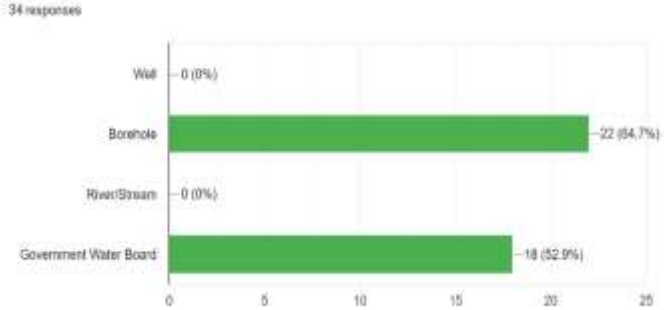
Gender-Based Violence and Gender Equality Indicators

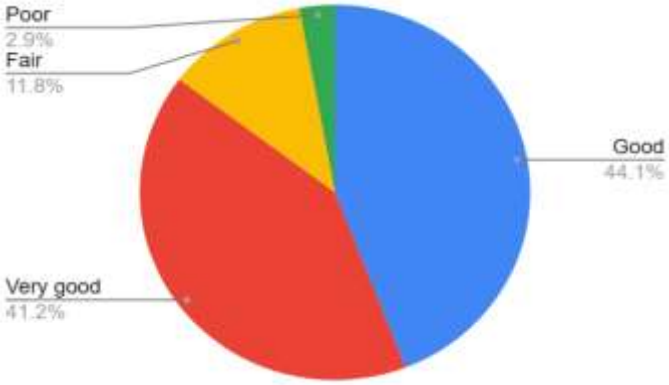
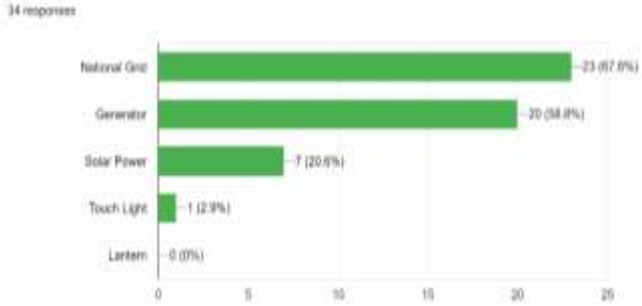
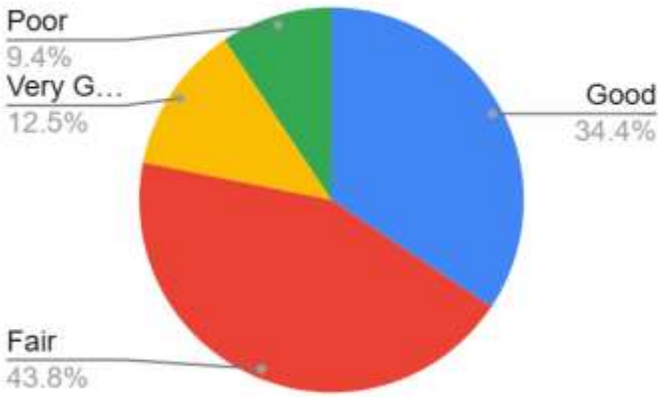
Category	Key Observations
Experience of Gender-Based Violence (GBV)	

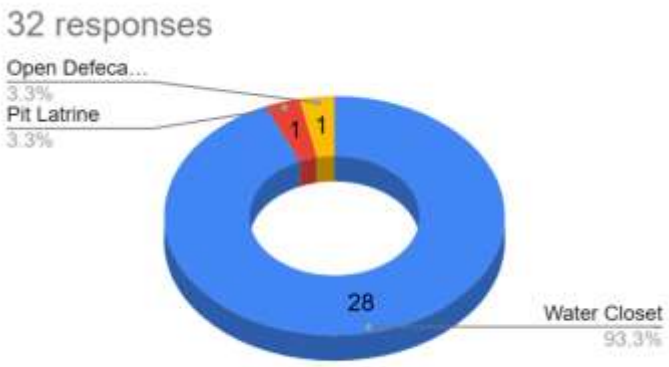
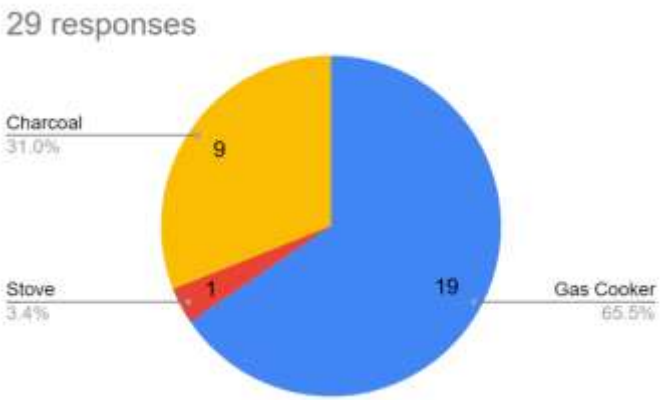
Category	Key Observations
	The findings indicate that no cases of GBV were reported among the surveyed respondents or their households during the study period. This suggests a low reported prevalence of GBV within the respondent group.
Do you think men and women have equal access to economic opportunities in your institution/community?	
	Majority believe men and women have equal access to economic opportunities, suggesting moderate gender inclusivity. A significant minority perceive inequality, indicating potential barriers for women in employment or income-generating activities. Which shall be addressed in all phases of the project activities for women inclusion in strategic tasks.
Do you believe that cultural norms in your community/institution influence the prevalence of GBV?	

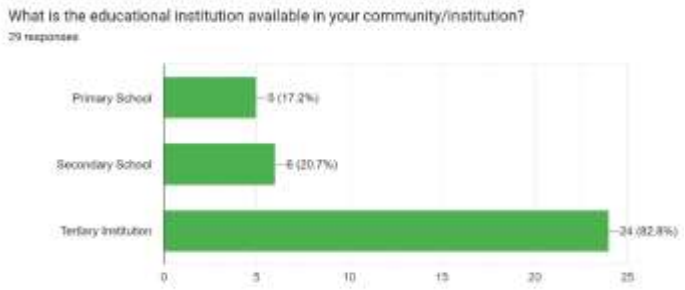
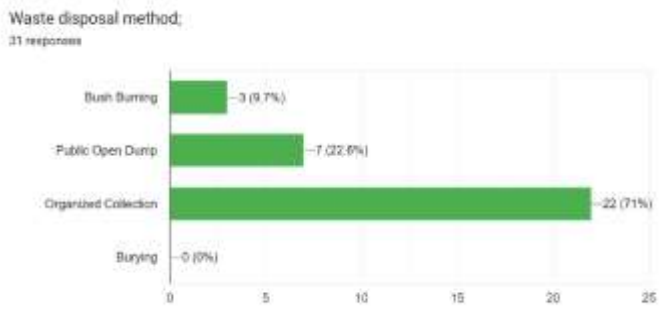
Category	Key Observations
	The mixed responses suggest differing perceptions regarding the influence of cultural norms on GBV within the institution and surrounding community. This highlights the need for continued awareness and sensitization programmes that address cultural and social factors associated with GBV.
Availability of Support Services for GBV Survivors	
	The majority of respondents perceive adequate support services is available for survivors of GBV support services in the institution.

Community/Institutional Utilities and Services Profile

Category	Key Observations
Source of Water Supply	
	Boreholes (64.7%) are the primary source of water supply for respondents, followed by the Government Water Board (52.9%). No respondents reported relying on wells or rivers/streams, indicating that the institution has access to relatively improved water sources. *(Multiple responses were allowed.)*

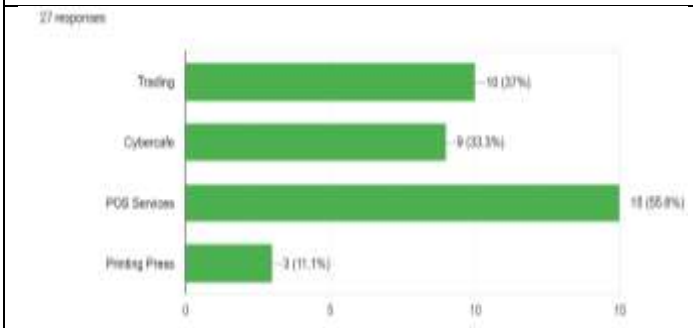
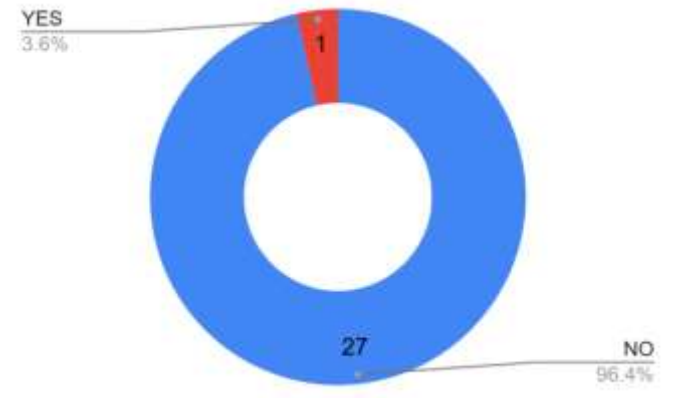
Category	Key Observations
Condition of Potable Water	
	The quality of potable water was generally rated positively, with 44.1% of respondents rating it as Good and 41.2% as Very Good. Only 11.8% rated it as Fair, while 2.9% considered it Poor, indicating that potable water is generally considered safe and satisfactory.
Available Source of Electricity	
	The National Grid (67.6%) remains the principal source of electricity, while 58.8% of respondents also rely on backup generators due to intermittent grid supply. Solar power (20.6%) has limited adoption, and only 2.9% reported using a touch light. No respondents relied on lanterns. *(Multiple responses were allowed.)*
Condition of Public Electricity	
	The condition of electricity supply was rated Fair (43.8%) by most respondents, followed by Good (34.4%), Very Good (12.5%), and Poor (9.4%). These findings suggest that although electricity is available, its reliability and quality remain inconsistent, resulting in continued dependence on alternative power sources such as generators.
Sanitation Facilities	

Category	Key Observations
	Water closets (93.3%) are the predominant sanitation facility used by respondents, indicating a high level of access to improved sanitation. Only 3.3% reported using pit latrines, while another 3.3% practiced open defecation. This reflects generally good sanitation conditions within the institution and surrounding community.
Cooking Fuel	
	The survey indicates that gas cookers are the dominant cooking fuel, used by 65.5% (19 of 29) of respondents, suggesting a relatively high adoption of cleaner cooking energy. Charcoal is the second most common fuel, used by 31.0% (9 respondents), indicating that a notable proportion of households still rely on solid fuels. Only 3.4% (1 respondent) reported using a stove, while no respondents reported using firewood or kerosene as their primary cooking fuel. Overall, the findings suggest a transition toward cleaner cooking options, although reliance on charcoal persists among a significant minority.
Educational Institutions	

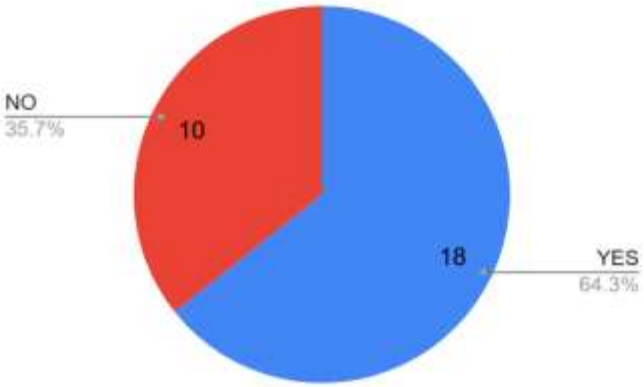
Category	Key Observations
	The assessment shows that tertiary institutions are the most widely available educational facilities (Baze and Nile University), with 82.8% (24 of 29) of respondents reporting their presence within the community or institution. Secondary schools were reported by 20.7% (6 respondents), while primary schools were identified by 17.2% (5 respondents). These findings suggest strong access to higher education facilities but comparatively limited availability of primary and secondary educational institutions within the surveyed area.
Waste Disposal Method	
	The results indicate that organized waste collection is the predominant waste disposal method, reported by 71.0% (22 of 31) of respondents, suggesting the availability of formal waste management services for the majority of households. However, 22.6% (7 respondents) still dispose of waste through public open dumps, while 9.7% (3 respondents) practice bush burning, reflecting the continued use of environmentally unsustainable disposal methods by a minority of households. Overall, while organized waste collection is well established, efforts are still needed to eliminate informal disposal practices

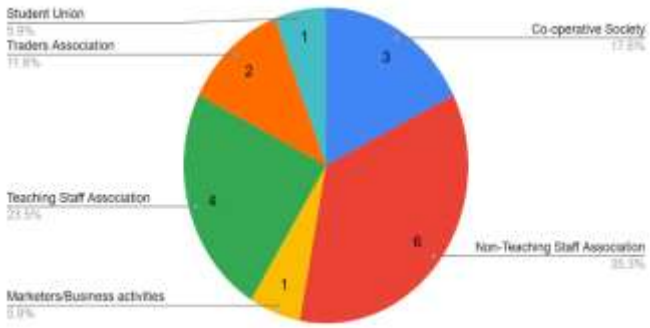
Category	Key Observations
	that may pose environmental and public health risks.

Traditional Practices and Cultural Heritage

Category	Key Observations
Traditional Economic Activities Practiced	
	Existing Businesses/Economic Activities in the Community POS Services: 15 (55.6%); Trading: 10 (37.0%); Cybercafés: 9 (33.3%) Printing Press: 3 (11.1%) The local economy is primarily driven by small-scale service and commercial enterprises. POS services are the most common business activity, indicating strong demand for financial transaction services. Trading is also widespread, while cybercafe provide digital and internet-related services. Printing press businesses are limited, suggesting relatively low demand for printing services within the community.
Will Proposed Project Affect any Valued Resources/Cultural Assets/Archeological Site Within the Institution/Community?	
	Majority of respondents indicated that the proposed project is not expected to affect valued cultural resources, sacred sites, or archaeological assets. Only one respondent expressed concern about potential impacts. This suggests that significant adverse effects on cultural heritage are unlikely; however, precautionary measures, including a chance-find procedure during construction, should be implemented to safeguard any previously undiscovered cultural or archaeological resources.

Community Awareness, Perceived Benefits, and Social Associations

Category	Key Observations
Awareness of Proposed Project	
	The survey results indicate a high level of awareness of the proposed project among respondents. 18 respondents (64.3%) indicated that they were aware of the project, while 10 respondents (35.7%) reported that they were not aware. This suggests that the majority of university community and institutional stakeholders have already been reached through previous consultations or information-sharing activities. However, the proportion of respondents who remain unaware is still considerable, highlighting the need for additional sensitization and public awareness campaigns to ensure broader stakeholder participation and support throughout the project implementation process.
What do you think is the socio-economic benefit of the project? (20 responses)	
- Increase in business activities - This will help to improve our learning system and will help government to send from the proposed budget - Improve public health, job creation, environmental protection and economic growth - To reduce dependence on generators - The project will be a very good social economic benefit - The benefit of the project will render a self services to the community - Uninterrupted power that will boost the economy of the community - It will reduce cost of diesel and power supply generally - Constant power supply and prompt service delivery - The project will be very effective for social economic growth	Respondents identified several anticipated socio-economic benefits of the proposed solar project. The most frequently mentioned benefit was the provision of reliable and uninterrupted electricity, which respondents believed would significantly improve living standards and institutional operations. Many respondents also expected the project to reduce dependence on diesel-powered generators, thereby lowering energy costs and minimizing environmental pollution. Overall, respondents perceive the project as a significant

Category	Key Observations
- Development and Growth - The benefit is that the community will no longer be in abject darkness and business will be moving well - It will improve infrastructural capacity, enhance learning and working environment for student and staff - Increase productivity because of power supply. It also increase health condition. - To make things easy for learner and visitor - Light Stability - Steady Light - It will reduce the cost of buying diesel - Boost to business activities - It will reduce the cost of buying diesel	change for economic growth, enhanced educational outcomes, and a better quality of life.
Count of Indicate the social association existing in your community/institution	
	The diversity of social associations represented in the survey indicates that the proposed project has the potential to engage multiple stakeholder groups across the institution and surrounding community. Staff associations provide important institutional communication channels, while cooperatives and traders can facilitate community participation and local economic engagement. Although student and business group representation is relatively low, these groups remain important stakeholders whose involvement could enhance project awareness, ownership, and long-term sustainability.

4.7.6 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 University, including - NOUN Main Entrance; NOUN–EFCC Road; NOUN–EFCC Junction; Abdulrasheed Na'Allah Way; FMC Junction (Kado–Galadima Expressway); Kado–Galadima Expressway; and Karonmajigi Junction.

The observed traffic reflect the urban setting of the NOUN Main Campus and is composed mainly of private cars; taxis; motorcycles; tricycles (Keke); commercial minibuses; delivery vans; and articulated trucks on adjoining arterial roads. Field observations clearly indicate that traffic volume varies considerably throughout the day. The presence of police checkpoints, traffic control points and security gates contributes to orderly vehicular movement in the area.

The roads surrounding the University appear capable of accommodating relatively high traffic volumes because they consist predominantly of dual carriageways with adequate lane widths and paved shoulders. It was also observed that FMC Junction, Kado–Galadima Expressway and the NOUN Main Gate experience localized congestion during peak hours due to traffic signal delays, security checks, pedestrian crossings and turning movements into adjoining facilities. 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 resumption, commuters and institutional activities
Mid-day (11:00 am–2:00 pm)	Moderate traffic volume with intermittent congestion around the university gate and adjoining intersections
Afternoon (2:00–5:00 pm)	High traffic volume due to closing hours, visitors and commercial activities
Evening	Moderate traffic with reduced institutional traffic but sustained public traffic along adjoining arterial 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 1-MW 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.



Plate 4.28a: Traffic situation along Abdulrasheed Na'allah way



Plate 4.28b: Traffic situation along the NOUN-EFCC road

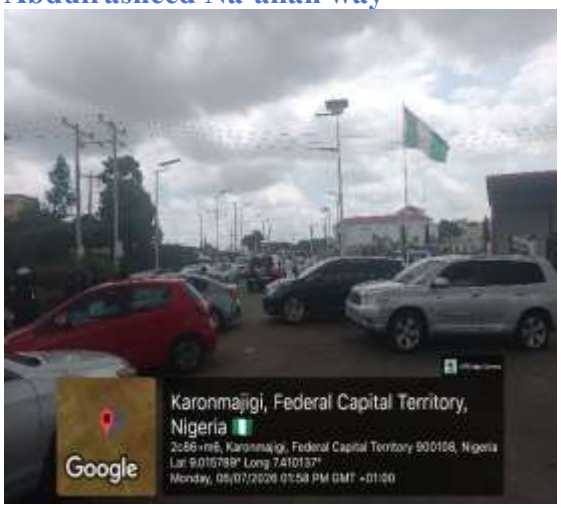


Plate 4.58c: Traffic situation at EFCC-NOUN Checkpoint Junction

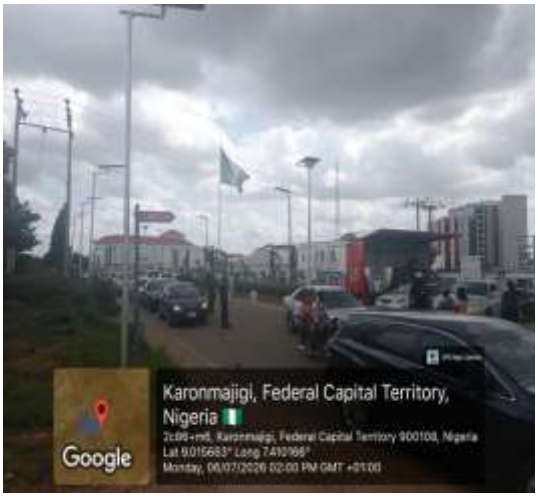


Plate 4.28d: Traffic situation at EFCC-NOUN Checkpoint Junction

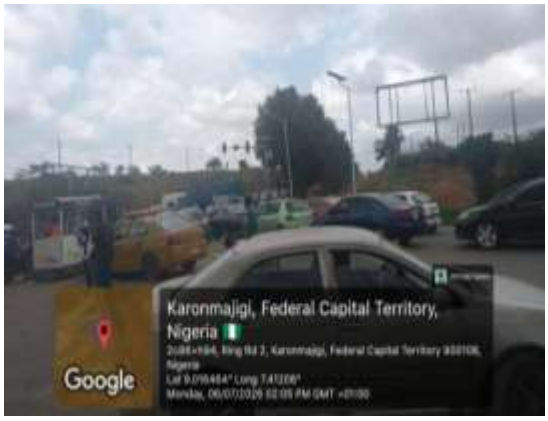




Plate 4.28e: Traffic at FMC Junction/Police Checkpoint along Kado - Galadima Expressway

4.8 Consultation Process

4.8.1 Institutional Consultation

The Federal Ministry of Environment serves as the primary regulatory authority for the proposed project, while the Abuja Environmental Protection Board functions as the secondary regulatory authority. Both institutions were duly notified of and appropriately engaged in, the Environmental Impact Assessment (EIA) studies in line with applicable regulatory requirements.

4.8.2 Public Involvement

The entire university community including all University Staff (both academic and non - academic) as well as campus vendors, visitors, project employees and contractors, were accorded the opportunity to participate actively in the consultation process. This was to obtain baseline information, identify potential concerns and incorporate local perspectives into the ESIA process. However, no students participated because the institution was not in academic session as at the time of the survey.

4.8.3 Stakeholder Consultation

4.8.3.1 Introduction

Stakeholder engagement is a two-way process of communication between the project proponent, his EIA Consultants and key stakeholders. It is a key aspect of the EIA process, allowing stakeholders to express their views about the project. It involves sharing information and knowledge, seeking to understand the apprehensions of others and building relationships based on collaboration, thereby allowing stakeholders to understand the risks, impacts and opportunities of a project in order to achieve positive outcomes. The underlying principles for stakeholder engagement are as follows:

- Inclusive of all the relevant groups within the community, including the vulnerable and marginalized;
- Culturally appropriate (i.e., using appropriate materials and local languages where possible, etc.);
- Held in venues that are accessible to all groups, e.g., women, people with disability and other vulnerable groups;
- Free of external manipulation, interference, coercion, or intimidation;
- In-depth exchange of views and information constituting ‘free, prior and informed consent’.

4.8.3.2 Stakeholder Engagement Requirements and Approach

The stakeholders' engagement process followed the requirements of the Nigerian Environmental Impact Assessment Act, CAP E12 LFN 2004. To fulfil the requirements for stakeholder engagement described above, the project developed a plan for engagement with stakeholders through the project life cycle. The plan included the following key steps:

- Identification of stakeholders and mechanisms for their engagement (meetings, letters, press releases, etc.);
- Development of project information for dissemination, including the community presentation; and

- Identification of where, in the ESIA cycle, certain stakeholders should be contacted and how.

The four stages of the stakeholder consultation plan for the study are as follows:

- Scoping
- ESIA Study.
- ESIA Disclosure; and
- Project Execution (Construction and Operations).

This section specifically relates to stakeholder engagement completed during scoping and the ESIA study.

4.8.3.3 Stakeholder Identification

The stakeholder identification process for the REA Desert to Power Project (Phase II) – 1MW Solar Hybrid Power at NOUN is designed to identify all individuals and groups within the university that could be potentially affected, positively or negatively, by the project. It is a continuous process, regularly reviewed and updated throughout the project lifecycle. Engagement activities include community consultation meetings, focus group discussions, key informant interviews and household surveys, guided by structured tools and questionnaires to capture a wide range of perspectives. This approach ensures that stakeholder concerns, risks, impacts and opportunities are systematically addressed, supporting informed decision-making and positive project outcomes.

The primary stakeholder for the project is the University community, that is, all University Staff (both academic and non - academic), students, campus vendors, visitors, and project employees/contractors; while the secondary stakeholders include the Federal Ministry of Environment, Rural Electrification Agency, African Development Bank, FCDA, and AMAC. Despite not being involved in the survey, students of the university were identified as part of the primary stakeholders.

Table 4.21: Stakeholders for the Project:

S/N	Stakeholders	Type	Relevance to the Project
A	***Primary Stakeholders***		
1	The entire National Open University of Nigeria (NOUN) community – Staff and students	Affected	Provides access to the university campus for project siting and construction., Coordinates operational integration with existing university infrastructure and facilitate project activities such as site security, utilities and field monitoring.
2	Project employees and contractors	Affected	Responsible for implementing construction, installation and maintenance activities. Ensure adherence to project timelines, technical standards and safety protocols and serve as key personnel for monitoring environmental and occupational health compliance.
3	Campus Vendors and Visitors	Affected	Highlight potential impacts on sales, access and pedestrian movement; Provide

S/N	Stakeholders	Type	Relevance to the Project
			information on business operating hours and suggest measures to minimize disruption; Identify preferred access routes and potential construction-related constraints; Provide information on power reliability needs and anticipated operational benefits; and provide information on peak business periods, recommend measures to maintain customer access.
B	***Secondary Stakeholders***		
4	Afircan Development Bank (AfDB)	Interested	Provides financing oversight, safeguards requirements, implementation support, monitoring and reporting requirements, and ensures compliance with AfDB Operational Safeguards and Environmental and Social Assessment Procedures.
5	The Federal Ministry of Environment and Abuja Environment Protection Board.	Interested	The Federal Ministry of Environment (FMEnv.) and Abuja Environment Protection Board (AEPB) are statutorily mandated to ensure the protection and conservation of FCT's terrestrial and maritime biodiversity. The FMEnv is responsible for ensuring that the project is in compliance with the Environmental Impact Assessment (EIA) process and implemented in accordance with the EIA Act (Cap E12 LFN 2004).
6	Rural Electrification Agency (REA)	Interested	Supervises project execution and ensures alignment with national electrification policies. Coordinates funding, reporting and project performance monitoring. Acts as a link between government policies and field-level implementation.
7	Federal Capital Development Authority (FCDA)	Interested	Confirmation of land use compatibility, development control, campus planning consistency.
8	Abuja Municipal Area Council (AMAC)	Interested	Provide local government perspectives on municipal infrastructure and services; advise on local environmental sanitation practices; coordinate public health and sanitation programs where necessary; facilitate communication with surrounding communities if off-site impacts arise; support emergency preparedness and public awareness where required..

4.9 Outcome of Focus Group Discussion and Key Informant Interview

Key Informant Interviews (KIIs) were conducted with some of the staff of the university while they were filling the questionnaires. These method was used to

collect important socio-cultural, economic and historical information with the aim of gathering in-depth community insights for informed project planning and decision-making. The highlights of the KII are presented below:

Table 4.22: Highlights of the KII

Representative Respondents	Outcome
Management and Staff of NOUN	**Project Awareness and Acceptance**: Regarding the proposed project at NOUN University, most respondents are aware of its existence and objectives. Their expectations focus on enhancing the university's overall standards, particularly in terms of research capacity and the learning environment. They also anticipate that the project will address current power supply challenges during grid downtime and improve security and visibility across the campus, thereby creating a safer and more conducive environment for academic staff and Students. **Socio-Economy**: The project will enhance academic productivity and operational efficiency. Employment opportunities may be created for university staff, local contractors, and service providers during both construction and operational phases. Additionally, improved infrastructure and security will attract more students and researchers, boosting ancillary economic activities such as catering and small-scale businesses within and around the campus. **Socio-cultural**: The proposed project at NOUN University is expected to have socio-cultural implications. According to respondents a community where farming predominates, the project may foster stronger interaction between university staff and the local population through labour exchange, collaborative initiatives, and mutual support, strengthening social cohesion. Employment and business opportunities created by the project can enhance income for both staff and local community members, while the improved infrastructure and research facilities at the university may encourage knowledge sharing and skill development. **Fears and Concerns**: concerns include potential disruptions to university activities during construction, such as noise, dust, and limited access to certain campus areas. There are also apprehensions about security, both for the campus and the neighbouring community directly opposite the university, particularly regarding equipment and infrastructure protection. Stakeholders emphasized the

Representative Respondents	Outcome
	need for fair inclusion of local community members in employment and service opportunities to prevent social tension. Additionally, concerns were raised about environmental impacts, including vegetation disturbance and proper waste management **University Needs and Expectation**: The university community expects the proposed 1-Megawatt (MW) Solar Hybrid Power under the REA Desert to Power Project (Phase II) to enhance the institution's energy reliability, particularly during periods of grid downtime, ensuring a stable and uninterrupted power supply for academic, research, and administrative activities. also anticipate improvements to campus infrastructure, including security enhancements and better lighting, to create a safer and more conducive learning environment. **Consultant's response:** The Consultant acknowledges the university's needs and expectations regarding the proposed 1-Megawatt (MW) Solar Hybrid Power power plant under the REA Desert to Power Project (Phase II). It is recommended that the project be designed and implemented to ensure a reliable and uninterrupted power supply to support academic, research, and administrative activities. The Consultant also encourages the integration of security enhancements, improved campus lighting, and sustainable energy solutions that align with the university's long-term development objectives.

CHAPTER FIVE
POTENTIAL AND ASSOCIATED IMPACTS

5.1 Introduction

This chapter undertakes an evaluation of the biophysical, health, and socioeconomic implications across all project phases, including pre-construction, construction, operation, and decommissioning. It presents the findings from a comprehensive assessment of the potential environmental impacts associated with the proposed 1 MW solar-hybrid power plant project to be situated and operated within the National Open University of Nigeria. The assessment considers both normal operational impacts and potential effects arising from abnormal occurrences.

The identified impacts are categorized as either threats or opportunities to human and environmental wellbeing. Project activities and their environmental interfaces encompass a wide array of concerns, such as air and water pollution, impacts on employment, and land use change, among others. These concerns have been thoroughly examined to determine the potential impacts of the proposed project on environmental receptors. This section outlines the overall approach to impact assessment and mitigation. The impact evaluation methodology is based on sectoral guidelines provided by FMEnv, African Development Bank (AfDB) operating system, and all other relevant regulatory frameworks. It involves:

- Screening of potential impacts associated with each project phase using a Risk Assessment Matrix.
- Detailed evaluation of impact-producing factors within each project phase, with the significance of potential impacts quantified using consistent criteria.

The assessment approach involves aligning the proposed project's activities with the existing environmental components, identifying, and evaluating potential changes in the environment resulting from these interactions, and proposing mitigation measures to address such changes. At this stage of the Environmental and Social Impact Assessment (ESIA), both negative and positive impacts of the proposed solar-hybrid power plant project on the existing environment have been identified. The ISO 14001 approach, and the Hazard and Effect Management Process (HEMP) were utilized in the identification process. The Risk Assessment Matrix (RAM) was employed to determine risks posed by identified potential impacts and to propose appropriate mitigation measures. In predicting impacts, a practical 'worst-case scenario' approach was utilized to assess extreme effects, while a 'consensus of opinions' method was employed to determine the importance of affected environmental components. Evaluation of impacts was conducted using specific criteria such as legal/regulatory requirements, magnitude of impact, risk posed, public perception, and importance of affected environmental components. This section of the report presents the outcomes of the identification and evaluation processes.

5.2 Impact Methodology Description

Figure 5.1 below depicts the steps taken in identifying, assessing, and evaluating the potential and associated impacts of the proposed project.

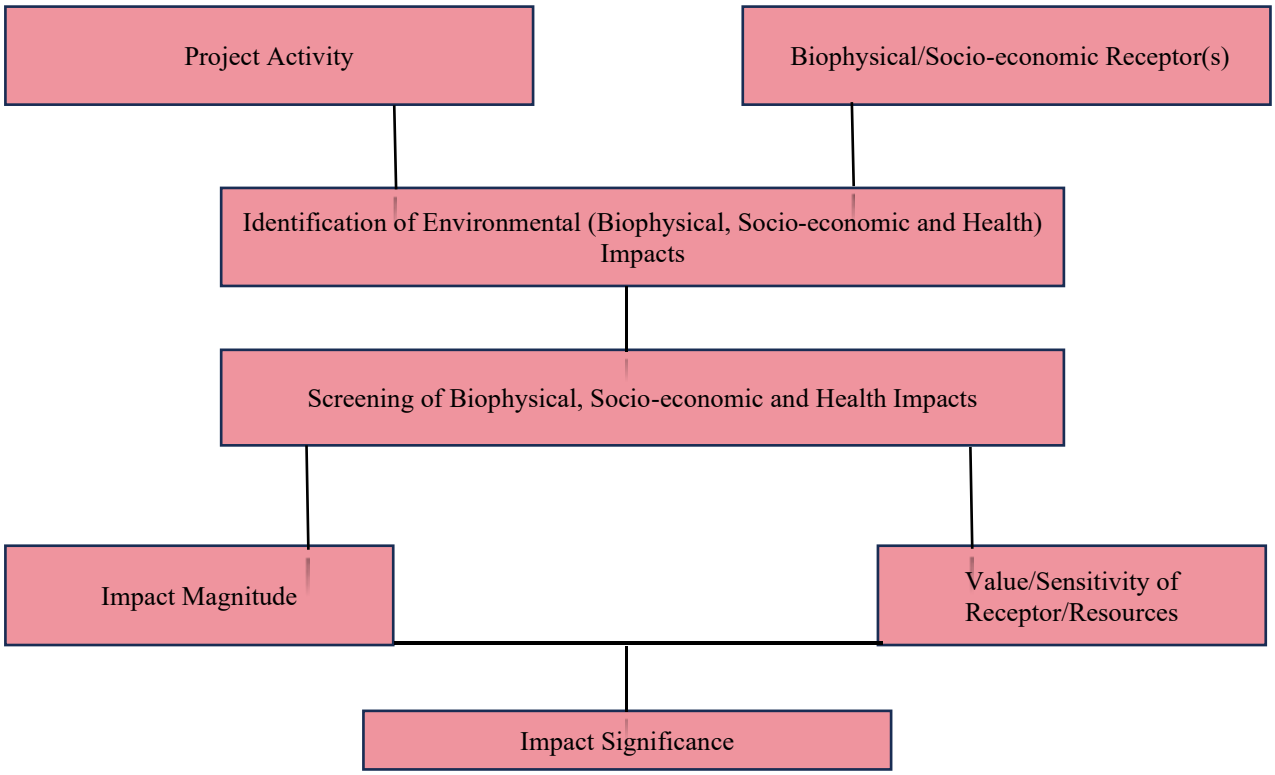


Figure 5.1: Impact Methodology Overview

5.2.1 Environmental and Social Indicators

The activities described in Section Three of this report are expected to interact with various components of the environment. These interactions may generate impacts that require systematic monitoring and evaluation. To effectively track and manage these impacts, specific environmental indicators will be applied and the receptors determined. These indicators include:

a. Noise and Vibrations

Measurement Unit: Decibels (dB)

Indicators:

- **Baseline Noise Levels:** Pre-construction measurements within the institution and its environment.
- **Construction Noise:** Monitoring of equipment and vehicle noise during installation works.
- **Operational Noise:** Assessment of inverter and transformer noise during operation (expected to be minimal).
- **Vibration Levels:** Monitoring during civil works, particularly near the Faculty of Management Sciences, Faculty of Science, Central Library, Senate Building, Convocation Arena, DPP Building and other nearby academic and administrative facilities and campus users

***Note**:* Given the 1MW scale, noise impacts are expected to be localized.

b. Ecological Impacts

Since NOUN is an institutional environment (not a natural forest ecosystem), ecological impacts are expected to be limited.

Floral Abundance and Diversity

- **Species Inventory:** Identification of vegetation within the project footprint.
- **Vegetation Cover:** Monitoring clearing activities and post-construction restoration.
- **Invasive Species Monitoring:** Observation of potential introduction of non-native species during landscaping.

Fauna Abundance and Diversity

- **Species Inventory:** Identification of fauna species within the site.
- **Population Monitoring:** Observation of any displacement during construction.
- **Habitat Quality:** Assessment of habitat alteration within the limited project area.

c. Hydrology and Water Quality

Groundwater:

- Dissolved and Suspended Solids: Measurement to assess water clarity and pollution levels.
- pH Levels: Monitoring to ensure water remains within safe limits for aquatic life and human use.
- Biochemical Oxygen Demand (BOD): Evaluation of organic pollution by measuring oxygen consumption.
- Chemical Oxygen Demand (COD): Measurement of total oxygen required to oxidize both organic and inorganic matter.
- Turbidity: Assessment of water clarity, indicating the presence of suspended particles.
- Toxicity: Testing for the presence of harmful substances.
- Heavy Metals: Analysis for metals like lead, mercury, and cadmium that can have severe health impacts.
- Microbial Loads: Checking for pathogens and indicator organisms such as coliform bacteria.

d. Soil

Type and Composition:

- **Soil Type Classification:** Identification of existing soil conditions within the site.
- **Physicochemical Properties:** pH, nutrient content, and organic matter.
- **Soil Compaction:** Especially due to construction equipment.
- **Erosion Monitoring:** Particularly during rainy seasons.

- **Contamination Monitoring:** From accidental oil or chemical spills.

e. Socio-Economic and Health Impacts

Since the project is within a university campus, impacts relate primarily to staff and students.

Community Needs and Concerns

- **Stakeholder Engagement:** Consultations with university management, staff, and student representatives.
- **Grievance Redress Mechanism:** Functional complaint handling system.

Livelihood and Employment

- **Local Employment Opportunities:** Monitoring short-term construction employment.
- **Fair Labor Practices:** Compliance with labor standards.

Health and Safety

- **Occupational Health & Safety (OHS):** PPE usage and contractor safety compliance.
- **Public Safety:** Ensuring safe movement around construction zones.
- **Emergency Preparedness:** Fire and electrical safety measures.

Waste and Sanitation

- **Construction Waste Management**
- **E-waste Handling**
- **Proper disposal of packaging materials**

Land Use

- **Land Use Compatibility:** Ensuring alignment with university master plan.
- **Zoning Compliance:** Compliance with institutional land use planning.

Table 5.1: Valued Environmental and Social Components (VECs)

Environmental Component	Sensitive Receptor
Air Quality	Staff, students, visitors
Climate	University environment
Soil	Project footprint
Surface Water / Drainage	Campus drainage channels and nearest downstream surface-water receptors
Groundwater	Boreholes
Vegetation	Campus green areas
Fauna	Birds and urban wildlife
Noise	Academic buildings
Traffic / Parking / Access	Central/main car park, internal campus roads, pedestrians, staff, visitors and other campus users
Land Use	Institutional land
Occupational Health	Workers
Community Health	University community
Waste	Campus environment

Visual Quality	Campus landscape

These indicators are essential for ensuring that the solar power project is conducted responsibly, with minimal adverse impacts on the environment and local communities. Monitoring these indicators will help in making informed decisions and implementing necessary mitigation measures.

5.2.2 Impact Identification and Characterization Technique

Impact identification is a crucial process that ensures the comprehensive identification and consideration of all potentially significant impacts during project design and implementation. These impacts are categorized into two types: positive and negative. Assessment of impacts should occur across the four lifecycle phases defined in Chapter 3: pre-construction, construction (including testing and commissioning), operation, and decommissioning. To assess the overall significance of the impacts, the adopted techniques consider factors such as the nature, type, and reversibility of the impact, the magnitude of the change, and the current status and sensitivity of the resource/receptor. This process is illustrated in Figure 5.2.

Table 5.2: Impact Descriptions

NATURE OF IMPACTS	
Positive Impacts	These are significant benefits that result from an improvement to the baseline or the inclusion of new, desirable factor.
Negative Impacts	These are impacts that arise directly from a project activity or source without an intervening pathway.
Direct Impacts	These are impacts that occur through a secondary pathway or are separated in space or time from the activity that causes them.
Indirect Impacts	These are the changes that are less obvious, or impacts are further away from the impact source.
Cumulative Impacts	Impacts resulting from the interaction of project components or activities with other activities in past, concurrently, or in the future.
Residual Impacts	These are the effects that persist even after mitigation measures have been implemented.
REVERSIBILITY / IRREVERSIBILITY	
Reversible Impacts	These are impacts that do not cause permanent change to the components of the environment.
Irreversible Impacts	These impacts cause permanent impairment to the environmental component of the area.
DURATION OF IMPACTS	
Long Term	Impacts expected to continue for more than five years and potentially through the anticipated 25-year operational life of the solar-hybrid power plant; they may cease or change following decommissioning and site restoration.
Short term	Impacts expected to persist for a limited period, generally up to two years, including temporary effects during pre-construction, construction, maintenance or decommissioning activities.

5.2.3 Determination of Impact Significance

Determination of impact significance is based on the following criteria;

Table 5.3: Impact Significance Criteria

Significance	Interpretation
Negligible	No mitigation required
Minor	Routine mitigation
Moderate	Specific mitigation required
Major	Significant mitigation required

Table 5.4: Sensitivity of Receptor and Extent

Sensitivity	Definition
Low	Highly resilient
Moderate	Moderately sensitive
High	Very sensitive
Extent	**Definition**
Site	Within project footprint
Local	Within NOUN Campus
Regional	Beyond campus but within FCT

Table 5.5: Impact Likelihood Criteria

LIKELIHOOD LEVEL	LIKELIHOOD CRITERIA
Almost Certain (3)	The impact or event can reasonably be expected to occur as a routine or very frequent consequence of the proposed activity.
Likely (2)	The impact or event has occurred in similar operations and project conditions make its occurrence likely.
Possible (1)	The impact or event has occurred occasionally in similar operations and could occur under the proposed project conditions.
Unlikely (0)	The impact or event is not expected under normal project conditions, although occurrence remains theoretically possible.

RISK MATRIX

1. Risk Assessment Matrix

Consequence ∠ / Likelihood →	Likelihood			
	1 – Improbable	2 – Occasional	3 – Probale	4 – Frequent
	Medium (2)	Medium (2)	High (3)	High (3)
4 – Major	Low (1)	Medium (2)	High (3)	High (3)
3 – Moderate	Low (1)	Medium (2)	Medium (2)	High (3)
2 – Minor	Low (1)	Low (1)	Low (1)	Low (1)
1 – Negligible	Low (1)	Low (1)	Low (1)	Low (1)

2. Risk Rating Interpretation

Risk Level	Score	Description
High	3	Requires alternative approach/design and mitigation measures to minimize impact.
Medium	2	Requires mitigation measures.
Low	1	Proceed with care; apply standard controls. No additional mitigation required.

Figure 5.2: Impact Evaluation Matrix

5.3 Impact Methodology Description

The Impact Methodology Description provides a structured framework for assessing and evaluating the potential environmental and social impacts of proposed projects. This document outlines the methodologies, criteria, and tools utilized in conducting the Environmental and Social Impact Assessment (ESIA). The primary goal is to identify, predict, and mitigate adverse impacts while maximizing positive outcomes. The methodology overview includes:

Baseline Data Collection:
The assessment begins with comprehensive data collection to establish baseline conditions of the project area. This includes gathering information on environmental, social, economic, and cultural aspects through field surveys, interviews, and literature reviews.

Impact Identification:
Utilizing the collected baseline data, potential impacts associated with the project are identified. These impacts are categorized into environmental (e.g., air quality, water quality, biodiversity), social (e.g., community displacement, cultural heritage), and economic (e.g., employment opportunities, income generation). For this NOUN project, physical displacement, economic displacement and involuntary resettlement are not anticipated because the project is located on University-owned institutional land. No known cultural heritage resource was identified within the project footprint.

Impact Prediction:

Various tools and models are employed to predict the magnitude, extent, and significance of identified impacts. Techniques such as Geographic Information Systems (GIS), environmental modeling, and stakeholder consultations are utilized to forecast potential impacts under different scenarios.

Impact Assessment:
Impacts are assessed based on predetermined criteria including severity, duration, reversibility, and spatial extent. Qualitative and quantitative methods are employed to evaluate both positive and negative impacts, considering their significance on the affected environment and communities.

Risk Assessment:
Risks associated with project activities are identified and analyzed, considering the likelihood and potential consequences of adverse events. This includes assessing risks related to natural hazards, project operations, and socio-economic factors.

Mitigation and Management Measures:
Based on the identified impacts and risks, appropriate mitigation and management measures will be developed to avoid, minimize, or compensate for adverse effects. These measures aim to enhance sustainability of the solar power project and promote environmental and social responsibility.

Monitoring and Evaluation:
A monitoring and evaluation plan will be established to track the implementation of mitigation measures and assess the effectiveness of impact management strategies. Regular monitoring ensures compliance with regulatory requirements and enables adaptive management based on real-time data and feedback.

5.4 Impact Severity and Profiling

Tables 5.6 - 5.9 illustrate the potential impacts and receptors throughout all stages/phases of project execution. It outlines the sources of impacts/risk, affected resources, intensity, scope, duration, consequence level and score, likelihood level and scope, as well as significance and residual impacts. These parameters facilitate the assessment of impact severity and the profiling of project activities.

Table 5.6: Summary of Key Impacts and Receptors for Pre-Construction Phase

Project Activity	Environmental Receptor	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Sensitivity	Significance
Site selection	Land resources	Long-term occupation of allocated institutional land at Sites 1 and 2 for renewable-energy infrastructure.	Negative	Low	Site	Long-term	Certain	Partially reversible	Moderate	Minor
	Land use	Reduction in existing parking capacity and redistribution of parking demand because Site 2 occupies part of the University central/main car park	Negative	Moderate	Site	Long-term	Certain	Reversible	Moderate	Moderate
Stakeholder engagement	University community	Improved awareness and acceptance	Positive	Moderate	Site	Long-term	Likely	-	Moderate	Moderate Positive

Engineering survey	Soil	Localized soil disturbance	Negative	Low	Site	Short-term	Likely	Reversible	Low	Minor
Mobilization and Site Demarcation/Marking Out	Traffic	Slight increase in campus vehicle movement	Negative	Low	Local	Short-term	Possible	Reversible	Moderate	Minor
	Local economy	Procurement opportunities	Positive	Low	Local	Short-term	Certain	Reversible	-	Minor Positive
	Campus users	Temporary access restrictions	Negative	Low	Site	Short-term	Likely	Reversible	-	Minor
Recruitment	Employment	Temporary employment	Positive	Moderate	Local	Short-term	Likely	Reversible	-	Moderate Positive
	Women	Increased employment opportunities	Positive	Moderate	Local	Short-term	Likely	Reversible	-	Moderate Positive
	Vulnerable persons	Potential exclusion	Negative	Low	-	Short-term	-	Reversible	-	Minor

Table 5.7: Summary of Key Impacts and Receptors for Construction Phase

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
Land Resources	Site clearing, grading and establishment of work areas	Permanent occupation of institutional land for renewable energy infrastructure	Negative	Low	Site	Long-term	Certain	Partially Reversible	Moderate	Minor
	Construction and installation of PV infrastructure across Sites 1 and 2	Change in land use from open institutional space to renewable energy infrastructure	Negative	Low	Site	Long-term	Certain	Reversible	Moderate	Minor
		Improved utilization of under-utilized institutional land for clean energy generation	Positive	High	Local	Long-term	Certain	-	Moderate	Major Positive
	Excavation and material storage	Temporary reduction in aesthetic quality and visual character of the project area	Negative	Low	Site	Short-term	Likely	Reversible	Low	Minor

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
Traffic / Parking / Access	Occupation of Site 2 and movement of construction vehicles	Reduction of existing parking capacity, redistribution of parking demand and increased potential for temporary congestion and pedestrian/vehicle conflict on internal campus routes	Negative	Moderate	Local	Short- to long-term	Likely	Reversible	Moderate	Moderate
Vegetation / Ecology	Vegetation clearance within the approved project footprint	Localized removal of grasses, pioneer vegetation and limited ornamental landscaping on previously disturbed institutional land	Negative	Low	Site	Short-term	Certain	Reversible	Low	Minor
Fauna / Ecology	Site clearing, excavation and equipment movement	Temporary disturbance or displacement of common urban-adapted fauna;	Negative	Low	Site	Short-term	Possible	Reversible	Low	Minor

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
		no critical habitat or threatened species is expected to be affected								
Soil Resources	Vegetation clearance and excavation	Removal of topsoil and disturbance of soil profile	Negative	Moderate	Site	Short-term	Certain	Reversible	Moderate	Moderate
	Equipment movement	Soil compaction and reduced infiltration	Negative	Moderate	Site	Short-term	Likely	Reversible	Moderate	Moderate
	Earthworks	Increased susceptibility to soil erosion during rainfall	Negative	Moderate	Site	Short-term	Possible	Reversible	Moderate	Moderate
	Fuel handling and equipment maintenance	Hydrocarbon contamination of soil from accidental spills	Negative	Moderate	Site	Short-term	Possible	Reversible	High	Moderate
Groundwater Resources	Water abstraction for construction and domestic use	Slight increase in demand on existing campus water supply	Negative	Low	Local	Short-term	Likely	Reversible	Moderate	Minor
	Fuel and	Potential	Negativ	Moderate	Site	Short-	Unlikely	Reversible	High	Moderate

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	lubricant storage	project-related deterioration of groundwater quality from seepage following accidental spills, relative to established baseline conditions	e			term				
	Concrete works	Potential localized project-related deterioration of groundwater quality from improper disposal of concrete wash water, relative to established baseline conditions	Negative	Low	Site	Short-term	Unlikely	Reversible	Moderate	Minor
Surface Water and Drainage	Site grading and excavation	Increased sediment-laden runoff into campus drains	Negative	Moderate	Local	Short-term	Possible	Reversible	Moderate	Moderate

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
		during rainfall								
	Construction activities	Temporary obstruction of natural drainage pathways	Negative	Moderate	Site	Short-term	Possible	Reversible	Moderate	Moderate
	Equipment maintenance	Pollution of runoff by fuels, oils and lubricants	Negative	Moderate	Local	Short-term	Unlikely	Reversible	High	Moderate
Air Quality	Earthworks and vehicle movement	Fugitive dust (PM_{10} and $PM_{2.5}$) emissions	Negative	Moderate	Local	Short-term	Certain	Reversible	High	Moderate
	Construction equipment	Exhaust emissions (NO_x, SO_2, CO, VOCs and particulate matter)	Negative	Moderate	Local	Short-term	Likely	Reversible	Moderate	Moderate
	Material handling	Localized deterioration in ambient air quality	Negative	Low	Site	Short-term	Likely	Reversible	Moderate	Minor
Noise and Vibration	Heavy equipment operation	Increased construction noise affecting academic activities	Negative	Moderate	Local	Short-term	Certain	Reversible	High	Moderate
	Excavation and vehicle	Localized vibration	Negative	Low	Site	Short-term	Possible	Reversible	Moderate	Minor

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	movement									
Socio-economic Environment	Contractor mobilisation	Temporary employment opportunities	Positive	Moderate	Local	Short-term	Certain	-	Moderate	Moderate Positive
	Procurement of goods and services	Increased patronage of local businesses and suppliers	Positive	Moderate	Local	Short-term	Certain	-	Moderate	Moderate Positive
	Construction activities	Temporary disruption of campus movement and routine activities	Negative	Moderate	Local	Short-term	Likely	Reversible	High	Moderate
	Construction traffic	Increased traffic congestion and road safety risks within the campus	Negative	Moderate	Local	Short-term	Likely	Reversible	High	Moderate
	Contractor presence	Potential conflict between workers and university community	Negative	Low	Local	Short-term	Possible	Reversible	Moderate	Minor
	Renewable energy infrastructure development	Improved energy reliability for teaching, research and administration (future benefit)	Positive	High	Local	Long-term	Certain	-	High	Major Positive

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
Socio-economic Environment	Contractor mobilisation	Temporary employment opportunities	Positive	Moderate	Local	Short-term	Certain	-	Moderate	Moderate Positive
	Procurement of goods and services	Increased patronage of local businesses and suppliers	Positive	Moderate	Local	Short-term	Certain	-	Moderate	Moderate Positive
Waste Generation and Handling	Construction works	Generation of excavated spoil, scrap metal, timber, plastics and packaging wastes	Negative	Moderate	Site	Short-term	Certain	Reversible	Moderate	Moderate
	Workforce activities	Generation of domestic solid waste	Negative	Low	Site	Short-term	Certain	Reversible	Moderate	Minor
	Equipment servicing	Generation of used oil and hazardous wastes	Negative	Moderate	Site	Short-term	Possible	Reversible	High	Moderate
Community Health and Safety	Construction activities	Increased exposure of staff and authorised visitors to dust, noise and moving equipment	Negative	Moderate	Local	Short-term	Likely	Reversible	High	Moderate
	Vehicle	Increased risk of	Negativ	Moderate	Local	Short-	Possible	Reversible	High	Moderate

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	movement	pedestrian accidents	e			term				
	Construction works	Increased risk of emergency incidents (fire, collapse or accidental injury)	Negative	Moderate	Site	Short-term	Possible	Reversible	High	Moderate
Occupational Health and Safety	Excavation and civil works	Slips, trips and falls	Negative	Moderate	Site	Short-term	Likely	Reversible	High	Major
	Structural and electrical installation	Falls from height	Negative	High	Site	Short-term	Possible	Reversible	High	Major
	Electrical installation	Electric shock and electrocution	Negative	High	Site	Short-term	Possible	Reversible	High	Major
	BESS and transformer installation	Fire, explosion and thermal hazards	Negative	High	Site	Short-term	Unlikely	Reversible	High	Major
	Manual handling	Musculoskeletal injuries	Negative	Moderate	Site	Short-term	Likely	Reversible	Moderate	Moderate
	Outdoor construction activities	Heat stress, dehydration and fatigue	Negative	Moderate	Site	Short-term	Likely	Reversible	Moderate	Moderate
Gender, GBV and Social Inclusion	Recruitment	Increased employment	Positive	Moderate	Local	Short-term	Likely	-	Moderate	Moderate Positive

Environmental/Social Component	Construction Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
		opportunities for women								
	Recruitment	Potential exclusion of women and vulnerable groups	Negative	Low	Local	Short-term	Possible	Reversible	Moderate	Minor
	Contractor presence	Risk of Gender-Based Violence (GBV), Sexual Exploitation and Abuse (SEA) and Sexual Harassment (SH)	Negative	Moderate	Local	Short-term	Unlikely	Reversible	High	Moderate
	Stakeholder engagement	Enhanced participation of women and vulnerable groups in project implementation	Positive	Moderate	Local	Long-term	Likely	-	Moderate	Moderate Positive

Table 5.8: Summary of Key Impacts and Receptors for Operation Phase

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
Land Resources	Continuous operation of	Continued occupation of	Negative	Low	Site	Long-term	Certain	Reversible	Moderate	Minor

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	the solar PV plant	institutional land by solar infrastructure								
	Operation of the solar hybrid system	Long-term productive utilization of previously underutilized institutional land	Positive	High	Local	Long-term	Certain	-	Moderate	Major Positive
	Routine maintenance	Preservation of landscaped areas through vegetation management	Positive	Low	Site	Long-term	Certain	-	Low	Minor Positive
Traffic / Parking / Access	Continued occupation of Site 2 by solar PV infrastructure	Long-term reduction in parking capacity and redistribution of parking demand and campus circulation	Negative	Moderate	Local	Long-term	Certain	Reversible	Moderate	Moderate
Visual Quality / Campus Landscape	Continuous presence of PV arrays and associated equipment	Long-term change in the visual character of Sites 1 and 2	Negative	Low	Site	Long-term	Certain	Reversible	Low	Minor
Groundwater Resources	Periodic cleaning of PV modules	Increased demand on campus water supply for panel cleaning	Negative	Low	Local	Long-term	Likely	Reversible	Moderate	Minor
	Routine maintenance of	Potential groundwater	Negative	Moderate	Site	Long-term	Unlikely	Reversible	High	Moderate

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	transformers and BESS	contamination from accidental leakage of transformer oil or battery electrolyte								
	Solar power generation	Reduced dependence on diesel generators, thereby lowering risks of hydrocarbon contamination of groundwater	Positive	Moderate	Local	Long-term	Certain	-	High	Moderate Positive
Surface Water and Drainage	Routine site operation	Minor increase in runoff from hardstand areas	Negative	Low	Site	Long-term	Possible	Reversible	Moderate	Minor
	Equipment maintenance	Contamination of runoff and downstream surface-water receptors from accidental oil or electrolyte spills, relative to established baseline conditions	Negative	Moderate	Local	Long-term	Unlikely	Reversible	High	Moderate
	Vegetation management	Improved stormwater infiltration due to controlled	Positive	Low	Site	Long-term	Likely	-	Moderate	Minor Positive

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
		vegetation cover								
Air Quality	Solar electricity generation	Elimination of routine emissions associated with diesel generator use	Positive	High	Local	Long-term	Certain	-	High	Major Positive
	Renewable energy generation	Reduction in greenhouse gas emissions and contribution to climate change mitigation	Positive	High	Regional	Long-term	Certain	-e	High	Major Positive
	Maintenance vehicles	Minor exhaust emissions from maintenance vehicles	Negative	Low	Site	Long-term	Possible	Reversible	Low	Negligible
Noise and Vibration	Operation of inverters and transformers	Low-level operational noise	Negative	Low	Site	Long-term	Likely	Reversible	Moderate	Minor
	Elimination of diesel generators	Significant reduction in campus noise levels	Positive	Moderate	Local	Long-term	Certain	-	High	Moderate Positive
Socio-economic Environment	Reliable electricity supply	Improved teaching, research, ICT services and administrative efficiency	Positive	High	Local	Long-term	Certain	-	High	Major Positive

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	Solar hybrid power generation	Improved energy security and reduced dependence on public grid and diesel generation	Positive	High	Local	Long-term	Certain	-	High	Major Positive
	Reduced diesel consumption	Long-term reduction in operational energy costs	Positive	High	Local	Long-term	Certain	-	High	Major Positive
	Routine operation	Creation of permanent technical and maintenance employment	Positive	Moderate	Local	Long-term	Certain	-	Moderate	Moderate Positive
	Restricted operational area	Continued restriction of public access to operational facilities	Negative	Low	Site	Long-term	Certain	Reversible	Low	Minor
Waste Generation and Handling	Routine maintenance	Generation of damaged PV modules	Negative	Moderate	Site	Long-term	Likely	Reversible	Moderate	Moderate
	BESS operation	Generation of spent lithium-ion batteries at end of service life	Negative	High	Local	Long-term	Certain	Reversible	High	Major
	Electrical	Generation of	Negative	Moderate	Site	Long-term	Likely	Reversible	Moderate	Moderate

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	maintenance	damaged electrical cables, fuses and electronic components								
	Transformer maintenance	Generation of used lubricants and transformer oil	Negative	Moderate	Site	Long-term	Possible	Reversible	High	Moderate
	Routine office activities	Generation of minor domestic solid waste	Negative	Low	Site	Long-term	Certain	Reversible	Low	Minor
Community Health and Safety	Routine operation	Risk of unauthorized public access to energized equipment	Negative	Moderate	Site	Long-term	Possible	Reversible	High	Moderate
	Electrical operation	Electrical hazards to unauthorised persons	Negative	Moderate	Site	Long-term	Unlikely	Reversible	High	Moderate
	BESS operation	Fire or smoke resulting from battery system malfunction	Negative	High	Site	Long-term	Unlikely	Reversible	High	Major
	Reliable power supply	Improved public health through uninterrupted power for campus services	Positive	Moderate	Local	Long-term	Certain	-	High	Moderate Positive
Occupational	Electrical	Electric shock and	Negative	High	Site	Long-term	Possible	Reversible	High	Major

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
Health and Safety	maintenance	arc flash hazards								
	BESS maintenance	Exposure to battery electrolyte, thermal runaway and fire	Negative	High	Site	Long-term	Unlikely	Reversible	High	Major
	Routine inspection	Slips, trips and falls	Negative	Moderate	Site	Long-term	Possible	Reversible	Moderate	Moderate
	Outdoor maintenance	Heat stress and fatigue	Negative	Moderate	Site	Long-term	Likely	Reversible	Moderate	Moderate
	Routine operation	Improved technical skills and safety awareness among maintenance personnel	Positive	Moderate	Site	Long-term	Certain	-	Moderate	Moderate Positive
Gender, GBV and Social Inclusion	Routine employment	Sustained employment opportunities for qualified women	Positive	Moderate	Local	Long-term	Likely	-	Moderate	Moderate Positive
	Operation and maintenance workforce	Equal participation in technical capacity development	Positive	Moderate	Local	Long-term	Likely	-	Moderate	Moderate Positive
	Workplace interactions	Risk of workplace harassment, discrimination or GBV/SEA/SH	Negative	Low	Site	Long-term	Unlikely	Reversible	High	Minor
	Stakeholder engagement	Continued inclusion of women and	Positive	Moderate	Local	Long-term	Likely	-	Moderate	Moderate Positive

Environmental/Social Component	Operation Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
		vulnerable groups in project monitoring and grievance management								

Table 5.9: Summary of Key Impacts and Receptors for Decommissioning Phase

Environmental/Social Component	Decommissioning Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
Land Resources	Dismantling and removal of PV arrays, BESS, inverter etc.	Temporary disturbance of land surface and soil profile	Negative	Moderate	Site	Short-term	Certain	Reversible	Moderate	Moderate
	Removal of permanent infrastructure	Reinstatement of the sites to a stable condition suitable for an agreed future institutional use.	Positive	Moderate	Site	Long-term	Certain	-	Moderate	Moderate Positive
	Final rehabilitation	Re-establishment of landscaping or vegetation where compatible with the agreed future institutional use.	Positive	Low	Site	Long-term	Likely	-	Low	Minor Positive
Soil Resources	Excavation of foundations and buried	Localized soil disturbance and compaction	Negative	Moderate	Site	Short-term	Certain	Reversible	Moderate	Moderate

Environmental/Social Component	Decommissioning Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	cables									
	Removal of transformers and BESS	Soil contamination from accidental spills of transformer oil or battery electrolyte	Negative	Moderate	Site	Short-term	Possible	Reversible	High	Moderate
	Site restoration	Soil stabilization, removal of project-related contaminated material where present, and re-vegetation/landscaping where appropriate	Positive	Moderate	Site	Long-term	Certain	-	Moderate	Moderate Positive
Groundwater Resources	Removal of oil-filled equipment and batteries	Potential groundwater contamination from accidental leakage of hazardous substances	Negative	Moderate	Site	Short-term	Unlikely	Reversible	High	Moderate
	Site rehabilitation	Removal of project-related sources of contamination risk associated with operational equipment and hazardous materials.	Positive	Moderate	Site	Long-term	Certain	-	High	Moderate Positive
Surface Water and Drainage	Excavation and demolition	Sediment-laden runoff into campus drainage channels	Negative	Moderate	Local	Short-term	Possible	Reversible	Moderate	Moderate

Environmental/Social Component	Decommissioning Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	activities									
Air Quality	Removal of hazardous materials	Pollution of runoff from accidental spills	Negative	Moderate	Local	Short-term	Unlikely	Reversible	High	Moderate
	Demolition, dismantling and excavation	Fugitive dust (PM_{10} and $PM_{2.5}$) emissions	Negative	Moderate	Local	Short-term	Certain	Reversible	Moderate	Moderate
	Movement of heavy vehicles	Exhaust emissions from demolition equipment	Negative	Moderate	Local	Short-term	Likely	Reversible	Moderate	Moderate
	Removal of renewable energy infrastructure	Temporary increase in carbon emissions from demolition equipment	Negative	Low	Local	Short-term	Certain	Reversible	Moderate	Minor
Noise and Vibration	Dismantling of structures and equipment	Increased noise affecting campus activities	Negative	Moderate	Local	Short-term	Certain	Reversible	High	Moderate
	Heavy equipment movement	Localized vibration	Negative	Low	Site	Short-term	Possible	Reversible	Moderate	Minor
Socio-economic Environment	Decommissioning workforce	Temporary employment opportunities	Positive	Moderate	Local	Short-term	Certain	-	Moderate	Moderate Positive
	Procurement of dismantling	Increased business opportunities for recyclers and	Positive	Moderate	Local	Short-term	Certain	-	Moderate	Moderate Positive

Environmental/Social Component	Decommissioning Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	services	contractors								
	Completion of project life	Loss of temporary maintenance and technical jobs	Negative	Low	Local	Long-term	Certain	Reversible	Moderate	Minor
	Removal of energy infrastructure	Temporary disruption to campus energy supply if replacement system is not commissioned	Negative	Moderate	Local	Short-term	Possible	Reversible	High	Moderate
	Site restoration	Availability of land for future institutional development	Positive	High	Local	Long-term	Certain	-	High	Major Positive
Waste Generation and Handling	Removal of PV modules	Generation of photovoltaic panel waste	Negative	High	Site	Short-term	Certain	Reversible	High	Major
	Removal of BESS	Generation of spent lithium-ion batteries (hazardous waste)	Negative	High	Local	Short-term	Certain	Reversible	High	Major
	Removal of electrical equipment	Generation of e-waste (inverters, cables, control panels)	Negative	Moderate	Site	Short-term	Certain	Reversible	Moderate	Moderate
	Demolition activities	Generation of scrap steel, concrete, plastics, timber and packaging waste	Negative	Moderate	Site	Short-term	Certain	Reversible	Moderate	Moderate
	Recovery of	Increased recycling	Positive	Moderate	Regional	Long-term	Certain	-	Moderate	Moderate

Environmental/Social Component	Decommissioning Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	valuable materials	and resource recovery								Positive
Community Health and Safety	Dismantling works	Public exposure to demolition activities	Negative	Moderate	Local	Short-term	Possible	Reversible	High	Moderate
	Heavy vehicle movement	Increased pedestrian and traffic accident risks	Negative	Moderate	Local	Short-term	Possible	Reversible	High	Moderate
	Removal of hazardous equipment	Fire, explosion or accidental release of hazardous substances	Negative	High	Site	Short-term	Unlikely	Reversible	High	Major
	Site restoration	Improved public safety following removal of electrical infrastructure	Positive	Moderate	Local	Long-term	Certain	-	Moderate	Moderate Positive
Occupational Health and Safety	Dismantling electrical equipment	Electric shock and arc flash	Negative	High	Site	Short-term	Possible	Reversible	High	Major
	Removal of PV arrays and structures	Falls from height	Negative	High	Site	Short-term	Possible	Reversible	High	Major
	Removal of batteries	Exposure to electrolyte, thermal runaway and fire	Negative	High	Site	Short-term	Unlikely	Reversible	High	Major
	Manual dismantling and lifting	Musculoskeletal injuries	Negative	Moderate	Site	Short-term	Likely	Reversible	Moderate	Moderate
	Demolition	Slips, trips and falls	Negative	Moderate	Site	Short-term	Likely	Reversible	Moderate	Moderate

Environmental/Social Component	Decommissioning Activity	Potential Impact	Nature	Magnitude	Extent	Duration	Likelihood	Reversibility	Receptor Sensitivity	Significance
	activities									
	Workforce training	Improvement in worker competencies in renewable energy decommissioning	Positive	Moderate	Local	Long-term	Certain	-	Moderate	Moderate Positive
Gender, GBV and Social Inclusion	Recruitment for decommissioning	Continued employment opportunities for women and qualified vulnerable groups	Positive	Moderate	Local	Short-term	Likely	-	Moderate	Moderate Positive
	Contractor activities	Potential exclusion of women from technical decommissioning roles	Negative	Low	Local	Short-term	Possible	Reversible	Moderate	Minor
	Interaction between contractors and university community	Risk of GBV, SEA and SH	Negative	Low	Local	Short-term	Unlikely	Reversible	High	Minor
	Stakeholder engagement	Continued participation of women and vulnerable groups in closure planning and monitoring	Positive	Moderate	Local	Short-term	Likely	-	Moderate	Moderate Positive

The primary objective of the ESIA study was to comprehensively identify and characterize all associated environmental impacts or effects resulting from the proposed university Solar Power Plant. While various approaches exist for predicting and evaluating project environmental impacts, the EIA Procedural Guidelines, the ISO 14001 approach, and the Hazard and Effect Management Process (HEMP), were mainly referenced in the impact identification process chosen for this study.

5.5 Project Phases, Associated Activities and Potential Impacts

A number of project activities would be carried out in phases. These planned activities are what would impact on the environmental components positively or negatively. The utility scale PV-based power plant project activities are grouped into four phases as follows:

Pre-Construction Phase: Involves activities such as award of contract, project design and planning, consultation, recruitment, site marking out etc.
Construction Phase: It involves activities such as mobilization of workforce, transportation of the utility scale PV- based power plant components and other equipment to site, site preparation activities - digging, trenching, bulldozing, grading, soil compaction; and installation of temporary camp and power plant components. This phase and its impacts are usually short termed.
Commissioning Phase: It involves the integrated application of a set of engineering techniques and procedures to check, inspect and test every operational component of the project, from individual functions, such as instruments and equipment, up to complex amalgamations such as modules, subsystems and systems.
Operational Phase: This is usually 'long term', involving activities from post construction to pre-decommissioning. It commences once the power plant has been commissioned for use. Activities include use of natural resources (water for domestic uses and cleaning of solar modules), plant and equipment operations, routine maintenance of equipment and plant.
Decommissioning Phase: It begins once the power plant use is discontinued or project life span has come to an end.

It should be noted that impacts can occur at any time; during these phases mentioned above i.e. pre-construction, construction and operational phases of the project. Some impacts may however occur in some or all phases of the project.
To identify environmental and social aspects of the project, the activities were considered in terms of their 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.

The assessment approach generally involved matching the various activities of the different stages of the proposed project (as described in chapter 3 of this report) with the components of the existing environment. Consequently, the possible changes (and extent of changes) in the environment as a result of the interactions have been identified/ evaluated, hence mitigation measures proffered in order to reduce, offset or ameliorate such changes. The potential/ associated adverse and beneficial impacts of the proposed power plant project on the existing environment were identified at this stage of the ESIA.

The Risk Assessment Matrix (RAM) has been employed in determining risks posed by the identified potential/associated impacts of the project in order to proffer appropriate mitigation measures. In predicting impacts, the experiential/practical 'worst case scenario' approach has been applied to determine the extreme effects of project activities on environmental components, while 'consensus of opinions' has been made use of to determine the importance of affected environmental components. The impact evaluation results make up the pedestal for developing the ESMP of the proposed project.

5.5.1 Discussion on the Identified Impacts for Pre-Construction Phase

The pre-construction phase of the proposed 1-MW Solar Hybrid Power Project at the National Open University of Nigeria (NOUN), Main Campus, Jabi, Abuja comprises activities such as project planning and design, engineering surveys, stakeholder consultations, statutory approvals, contractor mobilization, procurement, site demarcation and preparation for construction. At this stage, no major physical construction activities will occur; consequently, most environmental impacts are expected to be of low magnitude, localized, temporary and readily reversible.

As presented in Tables 5.6, adverse impacts during the pre-construction phase are due to temporary disturbance of land resources during site demarcation, increased vehicular movement associated with surveys and mobilization, minor dust and noise emissions, occupational health and safety risks to survey personnel, and the potential for stakeholder concerns if communication and consultation are inadequate. These impacts are generally assessed as Minor to Moderate before mitigation.

The pre-construction phase also provides an opportunity to establish the environmental and social management framework that will guide subsequent project phases. Activities such as disclosure of project information, stakeholder engagement, grievance redress, implementation of labour management procedures, adoption of gender-responsive employment practices, and development of Health, Safety and Environment (HSE) plans significantly reduce potential project risks before construction commences.

5.5.2 Discussion on the Identified Impacts for Construction Phase

The construction phase is expected to generate the greatest number of adverse environmental and social impacts, primarily due to land disturbance, movement of construction equipment,

temporary disruption of university activities and occupational risks. Nevertheless, because the project is located entirely within the NOUN campus on land already designated for institutional development, no physical displacement, economic displacement or involuntary resettlement is anticipated. A distinct site-specific land-use and traffic impact occurs at Site 2 because approximately 4,401.64 m² of the existing central/main car park is allocated to the project. Construction will therefore reduce available parking space and redistribute parking demand and vehicle/pedestrian movement to other parts of the campus. This impact is long-term for land use and may be Moderate in significance unless alternative parking and circulation arrangements are provided.

The construction phase also presents several beneficial socio-economic impacts, including temporary employment, increased local procurement, and enhanced commercial activities for nearby service providers. These positive impacts are expected to contribute modestly to the local economy and support implementation of Nigeria's Local Content aspirations.

With respect to occupational health and safety, activities such as excavation, lifting operations, installation of photovoltaic modules, electrical works present the highest risks. These are appropriately ranked necessitating appropriate and adequate mitigation measures and plans such as implementation of a comprehensive Health, Safety and Environment (HSE) Management Plan, supervision, and provision of appropriate personal protective equipment etc.

Although the project is relatively small, gender and social inclusion considerations remain important. Potential risks relating to Gender-Based Violence (GBV), Sexual Exploitation and Abuse (SEA) and Sexual Harassment (SH) are assessed as Moderate before mitigation because the presence of contractor personnel within an educational institution necessitates preventive measures. Adoption of a Contractor Code of Conduct, mandatory induction, confidential grievance mechanisms and enforcement of zero-tolerance policies is expected to reduce these risks to Minor.

Waste Generation and Disposal

Construction Phase Waste can be categorized into **Hazardous** and **Non-hazardous** wastes. **Hazardous Waste** are; Scrap Metals, Packaging Materials (such as cartons, pallets, and plastics), Cable offcuts, Excavated Soil, Concrete Debris. While **Non-hazardous** Waste are; used engine oil, Lubricants, Oil-contaminated rags, Paint Containers, Chemical Containers from the project are

Waste generation can also be grouped into solid wastes, liquid (wastewater) and air emissions. Solid wastes would include; wood, metals, food remains, glass, and refuse etc. Liquid wastes include sewage, while gaseous air pollutants (NOx, SOx and CO) would be from exhausts of vehicles. Table 5.10 present a simplified system is practical and cost-effective while maintaining compliance and safety.

Table 5.10: Waste Colour Coding System

S/N	Colour Code	Waste Category	Examples	Handling / Disposal Method
1	**Red**	Hazardous Waste	Used oil, lubricants, oily rags, contaminated PPE, chemical containers, spent/damaged lithium-ion batteries and contaminated soil	Store in sealed, labelled containers and transfer to licensed hazardous-waste/battery handlers or recyclers, as applicable
2	**Yellow**	Electronic waste (potentially hazardous)	Damaged PV modules, inverters, control panels, electrical components, cables and fluorescent lamps	Segregate and transfer to licensed/authorized e-waste recyclers or approved controlled-disposal facilities
3	**Green**	Non-Hazardous Recyclable Waste	Scrap metal, cardboard, plastics, paper, clean wood	Segregate for recycling through authorized recyclers
4	**Blue**	General (Non-Hazardous) Waste	Office waste, non-contaminated packaging and residual non-recyclable waste	Dispose through approved municipal waste system
5	**Brown**	Organic / Biodegradable Waste	Food remains, plant trimmings, landscaping waste	Composting or disposal via approved waste contractor

It should be noted however that during their normal operation, photovoltaic (PV) systems emit no gaseous or liquid pollutants, and no radioactive substances.

5.5.3 Discussion on the Identified Impacts for Operations Phase

The operation phase is characterized by relatively few adverse impacts and numerous long-term positive impacts. The principal environmental benefits arise from the displacement of diesel-powered electricity generation, resulting in improved air quality, reduced greenhouse gas emissions, enhanced energy security, and lower operating costs for the University. These positive impacts are expected to remain Major Positive throughout the operational life of the project.

The principal adverse impacts relate to management of the Battery Energy Storage System (BESS), transformer oil, end-of-life photovoltaic modules, electrical safety, and hazardous

waste management. Although these impacts are generally of Moderate to Major significance before mitigation, they are expected to reduce to Minor or Moderate residual significance through implementation of a robust Operational Environmental and Social Management Plan (ESMP), preventive maintenance programme, Battery Management Plan, Emergency Preparedness and Response Plan, Occupational Health and Safety Management System, and strict compliance with the National Environmental (Battery Control) Regulations, 2024, the National Environmental (Electrical/Electronic Sector) Regulations, 2011, and other applicable Nigerian environmental regulations.

From a socio-economic perspective, the project will provide long-term institutional benefits through reliable electricity supply, improved teaching and research capacity, enhanced ICT services, reduced expenditure on diesel fuel and generator maintenance, and increased resilience of university operations. The operation phase therefore represents the period during which the project's environmental, economic and social benefits are fully realized, provided that environmental and safety management measures are consistently implemented.

5.5.4 Discussion on the Identified Impacts for Decommissioning Phase

The decommissioning phase is expected to generate short-term, localized and largely reversible adverse impacts, primarily associated with dismantling activities, waste generation, occupational hazards, temporary air and noise emissions, and increased movement of heavy vehicles. These impacts are generally assessed as Minor to Major due to risks associated with occupational hazards.

The phase also presents several significant positive impacts, including restoration of institutional land, recovery and recycling of valuable materials, elimination of long-term environmental liabilities associated with ageing infrastructure, and the return of the project site for any other future institutional development. The greatest residual environmental concern relates to the management of spent lithium-ion batteries, photovoltaic modules and electrical/electronic waste, which requires strict compliance with the National Environmental (Battery Control) Regulations, 2024, the National Environmental (Electrical/Electronic Sector) Regulations, 2011, and internationally recognised best practices for hazardous and electronic waste management. Proper implementation of the Decommissioning Environmental and Social Management Plan will ensure that residual impacts remain acceptable and that the project concludes in an environmentally sustainable and socially responsible manner.

The major impacts anticipated may be summarized as:

A. Environmental Impact

Positive

- Re-establishment of managed vegetation and landscaping where included in the approved restoration plan. Given the low baseline ecological sensitivity and absence of threatened species or critical habitat, no significant biodiversity-recovery effect shall be claimed.

- Restoration/reinstatement of the sites to a stable condition suitable for an agreed future institutional use, recognizing that Site 1 was reclaimed land and Site 2 was an existing central/main car park before project development

Negative

- Disturbance to soil profile, and potential contamination from surface runoff during abandonment.
- Potential soil and groundwater contamination through infiltration of accidental oil/chemical spills or poorly managed wastewater during dismantling. Sediment-laden or oil-contaminated runoff should be assessed primarily as a surface-water and drainage impact.
- Pollution resulting from improper management of waste.
- Air quality pollution because of dust and heavy equipment dismantling movement.
- Increased noise levels within community during dismantling activities.

B. Socio-Economic Impacts

Negative

- Loss of employment/source of income due to activity closure.
- Disruption to academic and research activities previously supported by reliable solar power.
- Increased electricity costs if the university reverts fully to grid or diesel power supply.

C. Occupational Health Impacts

Negative

- Risk of injury from dismantling solar panels, mounting structures, and electrical components.
- Electrical shock and arc flash hazards during disconnection of live systems.
- Exposure to dust and hazardous materials during removal and disposal activities.
- Cuts, fractures, and musculoskeletal injuries from handling heavy equipment.
- Increased stress and fatigue due to intensive manual work and tight schedules.

5.6 Risk Assessment

Table 5.11 presents a comprehensive risk assessment for the solar-hybrid power plant project, identifying key environmental and socio-economic risks associated with the project activities. Each risk is evaluated based on several criteria: the likelihood of occurrence (L), frequency of occurrence (F), and potential impact (I). The table also assesses the significance of these impacts, providing a risk rating (R) and corresponding mitigation plans (P) to manage and mitigate these risks effectively.

The table covers a wide range of potential risks, from environmental concerns like air pollution and water contamination to socio-economic impacts such as employment opportunities and local economic growth. Each risk is categorized to provide a clear understanding of its

potential effects and the steps required to mitigate these impacts, ensuring the project is conducted in a sustainable and responsible manner.

Key Elements of the Risk Assessment:

- Risk Description: Brief description of the identified risk.
- **Likelihood (L):** The probability of the risk occurring (Low, Medium, High).
- **Frequency (F):** How often the risk is likely to occur (Low, Medium, High).
- **Impact (I):** The potential severity of the risk's impact (Low, Medium, High).
- **Impact Significance:** Qualitative assessment of the impact's significance, considering both the duration and reversibility (e.g., Moderate, Short Term; Irreversible, Long Term).
- **Risk Rating (R):** Overall assessment of the risk, combining likelihood, frequency, and impact (Low, Medium, High).
- **Mitigation Plan (P):** Recommended strategies and actions to mitigate or manage the identified risk.

The detailed risk assessment aims to ensure that all significant risks are identified, evaluated, and managed through effective mitigation strategies, thereby minimizing negative impacts on the environment and local communities while maximizing the positive outcomes of the project.

Table 5.11: Risk Assessment

Risk Description	Likelihood (L)	Frequency (F)	Impact (I)	Impact Significance	Risk Rating(R)	Mitigation Plan (P)
Air Pollution	Medium	Medium	Medium	Moderate, Short Term	Low	Install emission control systems, regular monitoring
Water Contamination	Low	Low	Medium	Irreversible, Long Term	Low	Implement water treatment facilities, strict waste management
Soil Degradation	Medium	Medium	Medium	Reversable, Long Term	Medium	Minimize land disturbance and restore affected areas.
Deforestation	Low	Low	Medium	Irreversible, Long Term	Medium	Reforestation efforts by limiting vegetation clearing and implement tree replanting.
Major Occupational Hazards.	Medium	Medium	High	Major, Potentially Severe	High	Permit-to-work, LOTO, fall protection,

Risk Description	Likelihood (L)	Frequency (F)	Impact (I)	Impact Significance	Risk Rating(R)	Mitigation Plan (P)
						competent personnel, lifting plans, supervision, PPE and emergency preparedness.
Noise Pollution	Medium	Low	Medium	Short Term, Moderate	Low	Restrict noisy activities to daytime hours.
Employment Opportunities	Medium	Low	Medium	Long Term, Significant	Medium	Prioritize local hires, provide training and skill development
Local Economic Growth	Medium	Medium	Medium	Long Term, Significant	Medium	Support local businesses, invest in community infrastructure
Community Health Risks	Medium	Medium	Medium	Long Term, Significant	Medium	Enforce site safety and restrict public access.
Visual Impact	Medium	Medium	Low	Long Term, Significant	Low	Use proper site layout and vegetative screening.
PV Panel Waste (End-of-Life)	Medium	Medium	Low	Long Term, Significant	Medium	Implement recycling and proper disposal plans.

5.7 Residual Impacts

Residual impacts are the environmental and social impacts that remain after the implementation of all practicable mitigation and management measures identified in the Environmental and Social Management Plan (ESMP). The majority of adverse impacts identified during the pre-construction, construction, operation and decommissioning phases are expected to be reduced from Moderate or Major significance to Minor or Negligible significance through the application of appropriate engineering controls, good construction practices, operational procedures and continuous environmental monitoring.

With respect to the physical environment, residual impacts on land resources, soil, groundwater, surface water, air quality, and noise and vibration are expected to remain Minor or Negligible. Temporary disturbances associated with earthworks, equipment operation, panel cleaning, routine maintenance and eventual decommissioning will be effectively controlled through erosion and sediment control measures, spill prevention and response procedures, proper drainage management, dust suppression, equipment maintenance, waste segregation, and

adherence to approved working hours. Consequently, no significant long-term deterioration of environmental quality is anticipated.

Residual impacts relating to the socio-economic environment are expected to be predominantly positive. The project will continue to provide long-term benefits through improved electricity reliability, enhanced teaching, research and administrative activities, reduced dependence on fossil fuel-powered generators etc. Minor adverse residual impacts, such as temporary restrictions on access during maintenance activities or the eventual loss of temporary construction employment following project completion, are expected to be insignificant and readily manageable through effective planning and stakeholder communication.

Residual risks associated with waste generation and handling will primarily involve end-of-life photovoltaic modules, spent lithium-ion batteries, damaged electrical equipment, used transformer oil and other electrical and electronic wastes. These impacts are expected to remain Minor to Moderate because such wastes will be generated intermittently and in relatively small quantities.

Residual impacts relating to community health and safety and occupational health and safety are also expected to be Minor. Although routine operation and maintenance of the photovoltaic system involve electrical hazards, working at height during installation and maintenance as well as fire hazards pose major risks, they will be effectively managed through implementation of the Occupational Health, Safety and Environment (HSE) Management Plan, permit-to-work procedures, lock-out/tag-out systems, emergency preparedness and response plans, fire detection and suppression systems, regular safety training, and provision of appropriate personal protective equipment (PPE) and its enforced use.

With respect to gender, Gender-Based Violence (GBV), Sexual Exploitation and Abuse (SEA), Sexual Harassment (SH) and social inclusion, residual impacts are expected to remain Negligible to Minor. The relatively small workforce required during construction and operation, combined with the institutional setting of the NOUN campus, substantially reduces the likelihood of gender-related risks. Furthermore, implementation of a Contractor Code of Conduct, Labour Management Procedures, Gender Action Plan, confidential Grievance Redress Mechanism (GRM), mandatory GBV/SEA/SH awareness training, and equal opportunity employment policies will ensure that everyone including women and persons with disabilities, continue to benefit from the project while minimizing social risks. The project is therefore expected to contribute positively to social inclusion, equitable employment opportunities and institutional capacity development.

Overall, following implementation of the recommended mitigation measures, monitoring programs and institutional management commitments, no residual impacts of Major significance are anticipated. The remaining adverse residual impacts are expected to be localized, reversible and manageable, while the long-term environmental, social and economic benefits associated with clean energy generation, improved energy security, reduced

greenhouse gas emissions and enhanced institutional sustainability are expected to remain substantial and significantly outweigh the residual adverse impacts.

5.7.1 Cumulative Impacts

Cumulative impacts refer to the combined environmental and social effects that arise from the proposed project when considered together with the effects of past, existing and reasonably foreseeable developments within the project area over time. They could also result from the incremental interaction of multiple activities, even where each individual impact may be insignificant. Given the relatively small footprint of the proposed project, no significant adverse cumulative impacts are anticipated. During the construction phase, cumulative effects may include temporary increases in traffic congestion, noise, dust emissions and demand for water and other utilities when construction activities coincide with other campus development projects. However, these impacts are expected to be localized, short-term and effectively managed through implementation of the Construction Environmental and Social Management Plan (CESMP), traffic management measures, and coordinated scheduling of construction activities. During the operational phase, the project is expected to contribute positive cumulative impacts by improving the reliability of electricity supply within the university, reducing dependence on diesel generators, lowering greenhouse gas and air pollutant emissions, enhancing energy security, and supporting Nigeria's renewable energy and climate change objectives. These benefits complement national initiatives such as the Energy Transition Plan (ETP), the Renewable Energy Master Plan (REMP) and the Rural Electrification Agency's Desert-to-Power Program, which collectively seek to increase the contribution of renewable energy to Nigeria's electricity mix and reduce carbon emissions (Federal Ministry of Power, 2022; Rural Electrification Agency, 2023). Potential long-term cumulative environmental risks are primarily associated with the management of end-of-life photovoltaic modules, batteries, electrical equipment and other electronic waste generated by renewable energy projects. Nevertheless, these risks are expected to remain low provided that the project implements a comprehensive Waste Management Plan, Battery Management Plan and Decommissioning Plan, and complies with the National Environmental (Battery Control) Regulations, 2024, the National Environmental (Electrical/Electronic Sector) Regulations, 2011, and other applicable environmental regulations. Overall, the cumulative impacts of the proposed project are assessed to be predominantly positive, with no significant adverse cumulative impacts if appropriate mitigation measures are proffered and affectively implemented.

CHAPTER SIX
MITIGATION MEASURES

6.1 Introduction

This chapter presents appropriate and cost-effective mitigation measures to prevent, reduce, control, remedy, or compensate for adverse impacts and enhance the positive benefits of the proposed solar based power plant project in National Open University of Nigeria. These measures aim to reduce impacts to As Low as Reasonably Practicable (ALARP). Residual impacts that may occur despite these mitigation measures are also acknowledged. Subsequently, Chapter Seven will detail management plans to oversee and monitor these mitigation measures through an effective Environmental and Social Management Plan (ESMP).

6.2 Mitigation Objectives and Approach

The primary objectives of mitigation measures are prevention, reduction and control of adverse impacts. The mitigation measures proposed for the project follow the internationally recognized mitigation hierarchy, comprising:

- Avoidance: Preventing adverse impacts through appropriate project planning, design optimization, careful site selection, and adoption of environmentally preferable technologies.
- Minimization: Reducing the magnitude, extent or duration of impacts that cannot be completely avoided through engineering controls, best management practices, and operational procedures.
- Restoration/Rehabilitation: Returning disturbed areas to conditions that are as close as practicable to their original state following construction or decommissioning activities.
- Compensation/Offset: Providing compensation or environmental offsets only where significant residual impacts remain after all practicable mitigation measures have been implemented.

The implementation of this hierarchy is intended to ensure that environmental and social impacts are reduced to As Low As Reasonably Practicable (ALARP) throughout the project life cycle.

Table 6.1: Summary of Mitigation Approach.

Project Phase	Mitigation Hierarchy	Approach
Pre-construction Phase	Avoidance and minimization	• Micro-siting: changing the layout of project infrastructure to avoid sensitive areas • Re-routing, marking or burying powerlines to avoid collision risks and barrier effects
Construction Phase	Avoidance	• Confine clearing, excavation, lay-down and equipment movement to approved work areas and existing access routes. • Schedule deliveries and disruptive activities to avoid peak campus traffic, examinations, major university events and

Project Phase	Mitigation Hierarchy	Approach
		other sensitive academic periods where practicable. • Avoid unnecessary removal of ornamental trees and vegetation outside the approved project footprint and keep existing drainage channels unobstructed.
	Minimization	• Abatement controls to reduce emissions and pollutants (noise, erosion, waste) created during construction • Operational controls to manage and regulate contractor activity, such as exclusion of fencing around sensitive areas, designated machinery and lay-down areas, minimizing vegetation loss and disturbance to soil
	Restoration and rehabilitation	• Repair of degradation or damage to biodiversity features and ecosystem services from project-related impacts that cannot be completely avoided and/or minimized by re-vegetating of temporary-use and lay down areas as soon as reasonably practicable after construction activities are complete
Operational Phase	Minimization	• Physical controls involving modification to infrastructure, or its operation, to reduce impacts (e.g. modifications to solar technology and their associated foundations, and modifying security perimeter fencing and overhead transmission lines) • Apply water-efficient PV cleaning, spill containment, preventive maintenance, waste segregation and licensed end-of-life battery/PV/e-waste management. • Maintain BESS monitoring, fire detection/suppression, emergency isolation and electrical safety systems in accordance with the approved design and manufacturer requirements. • Operational controls to manage and regulate contractor activity such as managing the timing of vegetation control activities at suitable intervals
Decommissioning Phase	Avoidance	• Scheduling: changing t h e timing of decommissioning activities to avoid disturbing biodiversity during sensitive periods (e.g. during breeding seasons). Remove project infrastructure no longer required, remediate project-related contamination where present, stabilize disturbed ground and restore the sites to conditions compatible with the future institutional land use agreed with NOUN and relevant authorities.
	Minimization	• Abatement controls to reduce emissions and pollutants (noise, erosion, waste) during decommissioning and repowering • Operational controls to manage and regulate contractor activity through, for example, exclusion fencing around sensitive areas, designated machinery and lay-down areas)

In proffering mitigation measures for the negative impacts identified in Chapter Five, preference has been given to avoidance and prevention. Where avoidance is not practicable, specific engineering, environmental, health and safety, traffic, social and operational controls are proposed to minimize impacts and manage residual risks. Tables 6.2–6.5 present the mitigation measures for the adverse impacts identified for the pre-construction, construction, operation and decommissioning phases respectively

Table 6. 2: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Pre-construction Phase)

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
Land Resources	Temporary disturbance of land during site demarcation and surveying	REA/EPC Contractor/ Supervising Engineer ● shall ensure that site demarcation is restricted strictly to the approved project footprint ● shall avoid unnecessary clearing of vegetation outside approved work areas. ● shall verify all site boundaries before commencement of any preparatory activities. ● shall ensure that all existing campus infrastructure and landscaped areas are protected throughout pre-construction activities.	Negligible
	Alteration of existing land utilization	REA/EPC Contractor/ Supervising Engineer ● shall ensure that all project facilities conform to the approved NOUN Campus Master Plan. ● shall ensure that temporary work areas are confined within designated construction zones. ● shall ensure that areas not required for project implementation remain undisturbed.	Negligible
Soil Resources	Localized soil disturbance during preliminary investigations	REA/EPC Contractor/ Supervising Engineer ● shall minimize excavation during geotechnical investigations. ● shall ensure that excavated materials are kept within designated areas and away from drains; ● shall ensure that all investigation holes are backfilled, compacted and made safe immediately after completion; and disturbed surfaces are stabilized against erosion.	Negligible
Groundwater Resources	Accidental contamination from fuels and lubricants during site investigations	REA/EPC Contractor/ Supervising Engineer ● shall ensure that refueling of equipment is undertaken only within designated areas. ● shall ensure that spill kits are available during all field investigations. ● shall ensure that any accidental spill is cleaned immediately in accordance	Negligible

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		with the Spill Response Procedure.	
Surface Water Resources	Sediment transport into nearby drains during preliminary site works	REA/EPC Contractor/ Supervising Engineer ● Shall ensure that existing drainage channels remain unobstructed. ● shall ensure that soil stockpiles are located away from drainage paths. Temporary erosion control measures shall be installed where necessary.	Negligible
Air Quality	Dust emissions generated during site reconnaissance and demarcation	REA/EPC Contractor/ Supervising Engineer ● shall ensure that vehicle movements are limited to existing access roads. ● shall ensure that dust suppression measures are implemented where visible dust is generated. ● shall ensure that vehicle speeds within the project area do not exceed 20 km/h.	Negligible
Noise and Vibration	Minor noise generated by survey vehicles and equipment	REA/EPC Contractor/ Supervising Engineer ensure that: ● site activities are restricted to daytime hours. ● survey equipment and vehicles maintained in good operating condition. ● Unnecessary idling of vehicles are be prohibited.	Negligible
Socio-economic Environment	Community concerns regarding project implementation	REA/EPC Contractor/ Supervising Engineer ensure that: ● Stakeholder Engagement Plan is implemented before mobilization. ● Project information is disclosed to the University Community and relevant stakeholders. ● A functional Grievance Redress Mechanism (GRM) is established prior to construction. ● All grievances are documented and resolved within stipulated timelines.	Minor
	Unrealistic employment expectations	REA/EPC Contractor/ Supervising Engineer ensure that: ● Employment procedures are transparent and merit-based. ● Recruitment criteria are publicly communicated before mobilization. ● Preference is given to qualified local personnel where practicable.	Negligible

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
Waste Generation and Handling	Generation of minor domestic and office waste during mobilization	REA/EPC Contractor/ Supervising Engineer ensure that: ● Waste generated during mobilization are segregated at source. ● Waste are collected in appropriate and covered containers. ● Waste shall be disposed of only through approved waste contractors.	Negligible
Community Health and Safety	Increased movement of survey vehicles within campus	REA/EPC Contractor/ Supervising Engineer ensure that: ● Drivers comply with campus speed limits. ● Traffic warning signs are erected where necessary. ● Pedestrian safety are prioritized at all times.	Negligible
Occupational Health and Safety	Minor injuries during surveys and site investigations	REA/EPC Contractor/ Supervising Engineer ensure that: ● All personnel receive HSE induction before commencing work. ● Appropriate PPE are provided and worn at all times. ● First aid facilities accompany field teams. ● Daily toolbox meetings are conducted prior to field activities.	Minor
Traffic / Campus Roads	Slight increase in campus vehicle movement during mobilization and site demarcation.	REA/EPC Contractor/Supervising Engineer shall ensure that: • mobilization vehicles use designated campus routes and comply with the approved campus speed limit of 20 km/h within work areas; • deliveries and survey movements are scheduled outside peak traffic periods and sensitive academic events where practicable; • unnecessary vehicle trips and idling are avoided; and • traffic warning signs or marshals are deployed at conflict points when required.	Negligible
Gender, GBV and Social Inclusion	Risk of exclusion of women and vulnerable groups from consultations	REA/EPC Contractor/ Supervising Engineer ensure that: ● Stakeholder consultations are equitable in terms of participation	Minor
	Risk of GBV, SEA and SH associated with	REA/EPC Contractor/ Supervising Engineer ensure that: ● All personnel shall sign and comply with a Code of Conduct prohibiting GBV, SEA and SH.	Negligible

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
	contractor mobilization	● Mandatory GBV/SEA/SH awareness training is conducted before mobilization. ● Confidential reporting channels shall be established and maintained throughout the project. ● Allegations of misconduct shall be investigated promptly and appropriate disciplinary action taken where necessary.	

Table 6. 3: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Construction Phase)

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
Land Resources	Permanent loss of land within the project footprint	REA/EPC Contractor/Supervising Engineer shall ensure that: ● all construction activities are confined strictly to the approved project footprint; ● unnecessary occupation of adjacent land is prohibited; ● temporary work areas are restored immediately after use; ● existing campus infrastructure, roads, walkways and landscaped areas are protected from construction activities; ● all disturbed areas are rehabilitated immediately following completion of construction activities.	Minor
	Change in land use and land utilization	REA/EPC Contractor/Supervising Engineer shall ensure that: ● construction activities conform to the approved NOUN Campus Master Plan; ● no unauthorized expansion of the project footprint occurs; ● access to adjoining university facilities is maintained throughout construction; ● temporary storage yards are removed immediately after construction.	Minor
Soil Resources	Soil compaction, erosion and degradation	REA/EPC Contractor/Supervising Engineer shall ensure that: ● topsoil is stripped separately and preserved for reinstatement; ● construction vehicles use designated access routes only; ● exposed surfaces are stabilized immediately after earthworks; ● erosion control measures including silt fences and sandbags are installed where required;	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		● all excavated areas are reinstated promptly following installation works.	
	Soil contamination from fuels, oils and chemicals	REA/EPC Contractor/Supervising Engineer shall ensure that: ● fuel, lubricants and chemicals are stored within bunded areas capable of containing at least 110% of the largest container volume; ● refueling is undertaken only within designated areas; ● spill kits are available at all work locations; ● all spills are immediately contained, cleaned and documented; ● contaminated soil is excavated and disposed of through approved facilities.	Minor
Groundwater Resources	Groundwater contamination	REA/EPC Contractor/Supervising Engineer shall ensure that: ● hazardous materials are not stored close to drainage channels or water points; ● wastewater is not discharged onto bare ground; ● equipment maintenance is undertaken only in designated maintenance areas; ● regular inspections are carried out for leakage from equipment and fuel storage facilities.	Minor
Surface Water Resources	Sedimentation and pollution of campus drainage	REA/EPC Contractor/Supervising Engineer shall ensure that: ● existing drainage channels remain unobstructed; ● sediment barriers are installed before commencement of earthworks; ● concrete wash water is collected and disposed of appropriately; ● runoff from construction areas is controlled to prevent off-site sediment transport; ● drainage channels are inspected after heavy rainfall events.	Minor
Traffic / Parking / Access	Reduction of parking capacity, redistribution of parking demand, temporary congestion and pedestrian/vehicle conflict on internal campus routes.	REA/EPC Contractor/Supervising Engineer shall implement the Construction Traffic Management Plan and ensure that: • alternative parking arrangements approved during pre-construction remain available and clearly signed; • delivery routes and times are coordinated with NOUN Management and avoid peak campus traffic, examinations, convocations and other major events where practicable; • traffic marshals are used for reversing, oversized deliveries and conflict points; • construction vehicles comply with campus speed limits and do not obstruct emergency access, walkways or building entrances; and	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		• safe, clearly marked pedestrian routes are maintained around the work areas.	
Air Quality	Dust generation	REA/EPC Contractor/Supervising Engineer shall ensure that: ● exposed surfaces are watered regularly during dry weather; ● haulage vehicles transporting friable materials are covered with tarpaulins; ● construction vehicles observe a maximum speed limit of 20 km/h within the project site; ● unnecessary idling of vehicles is prohibited; ● stockpiles are kept to the minimum practicable height and covered where necessary.	Minor
	Exhaust emissions	REA/EPC Contractor/Supervising Engineer shall ensure that: ● all construction equipment is maintained according to manufacturers' specifications; ● visibly smoking equipment is removed from service until repaired; ● low-emission equipment is used wherever practicable; ● equipment idling time is minimized.	Minor
Noise and Vibration	Noise from construction machinery	REA/EPC Contractor/Supervising Engineer shall ensure that: ● noisy activities are restricted to approved daytime working hours;equipment silencers and mufflers are maintained in good condition; ● generators are fitted with acoustic enclosures where practicable; advance notice is provided to the university community before particularly noisy activities commence; ● noise levels are periodically monitored.	Minor
	Ground vibration	REA/EPC Contractor/Supervising Engineer shall ensure that: ● heavy equipment is operated in accordance with manufacturers' specifications; ● unnecessary vibration-generating activities are avoided; ● vibration-sensitive university facilities are protected where necessary.	Negligible
Socio-economic Environment	Temporary disruption of campus activities	REA/EPC Contractor/Supervising Engineer shall ensure that: ● construction scheduling minimizes disruption to academic and administrative activities; ● access to offices, lecture facilities and essential services is maintained at all times;	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		● temporary diversions are clearly signposted; ● regular stakeholder communication is maintained throughout construction.	
	Local employment expectations	REA/EPC Contractor/Supervising Engineer shall ensure that: ● recruitment is transparent, merit-based and non-discriminatory; ● qualified local labour is given preference where practicable; ● employment opportunities are publicly communicated; ● labour disputes are addressed through the established grievance mechanism.	Minor
Waste Generation and Handling	Generation of construction waste	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Construction Waste Management Plan is implemented throughout construction; ● wastes are segregated into recyclable, reusable, hazardous and non-hazardous categories; ● recyclable materials are recovered wherever practicable; ● wastes are stored in labeled containers; ● wastes are transported only by licensed waste contractors to approved disposal facilities.	Minor
	Hazardous waste generation	REA/EPC Contractor/Supervising Engineer shall ensure that: ● hazardous wastes including used oils, contaminated rags, spent filters and chemical containers are stored separately; ● hazardous waste inventories are maintained; ● hazardous wastes are transferred only to FMEnv-approved facilities ● hazardous waste handling complies with applicable Nigerian environmental regulations.	Minor
Community Health and Safety	Increased traffic accidents	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Traffic Management Plan is implemented before mobilization; ● trained traffic marshals are deployed where required; ● warning signs and speed control devices are installed; ● all drivers comply with campus traffic regulations; ● emergency vehicle access is maintained throughout construction.	Minor
	Public exposure to construction hazards	REA/EPC Contractor/Supervising Engineer shall ensure that: ● the construction site is securely fenced; ● warning signs are displayed in English and appropriate local languages	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		where necessary; ● unauthorized access is prevented; ● adequate lighting and security are provided throughout construction.	
Occupational Health and Safety	Injuries to construction workers	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Project Health, Safety and Environment (HSE) Plan is implemented before commencement of construction; ● all workers receive site-specific HSE induction and daily toolbox talks; ● appropriate PPE is provided and its use strictly enforced; ● permit-to-work systems are implemented for high-risk activities; ● first aid facilities, emergency response equipment and trained first aiders are available on site at all times; ● all incidents and near misses are reported, investigated and corrective actions implemented.	Minor
	Electrical hazards during installation	REA/EPC Contractor/Supervising Engineer shall ensure that: ● only qualified electrical personnel undertake electrical installation works ● lock-out/tag-out procedures are implemented before generations; ● electrical tools are inspected regularly; ● live electrical work is prohibited unless specifically authorized under a permit-to-work system.	Minor
Gender, GBV and Social Inclusion	Gender inequality in employment	REA/EPC Contractor/Supervising Engineer shall ensure that: ● recruitment practices promote equal employment opportunities for qualified women and men; ● discrimination based on gender, disability, ethnicity, religion or other protected characteristics is prohibited; ● women are encouraged to participate in skilled and supervisory positions where qualified;employment records are periodically reviewed for compliance with gender inclusion objectives.	Minor
	Risk of GBV, SEA and SH	REA/EPC Contractor/Supervising Engineer shall ensure that: ● all workers sign and comply with a Code of Conduct addressing GBV, SEA and SH ● mandatory awareness training on GBV, SEA and SH is conducted before mobilization and periodically throughout construction;	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		● confidential reporting mechanisms are maintained and accessible to workers and the university community; ● all reported incidents are investigated promptly and appropriate disciplinary measures are implemented;survivor-centred referral pathways are established where required.	

Table 6. 4: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Operation Phase)

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
Land Resources	Long-term occupation of project land and restriction of alternative land use	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● project activities remain within the approved operational footprint; ● unnecessary expansion of operational facilities is prohibited; ● landscaped and vegetated areas surrounding the facility are maintained; ● periodic inspections are undertaken to identify and correct land degradation.	Minor
	Soil erosion around foundations and drainage channels	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● drainage systems remain functional at all times; ● erosion-prone areas are stabilized immediately; ● vegetation cover is maintained around exposed areas ● corrective maintenance is undertaken following heavy rainfall events.	Negligible
Soil Resources	Soil contamination from transformer oil, lubricants and battery electrolyte leakage	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● transformers and BESS are inspected routinely for leaks; ● secondary containment systems are maintained in good condition; ● spill response equipment remains available at all times; ● contaminated soil is removed and remediated immediately following any spill.	Minor
Groundwater Resources	Groundwater contamination from accidental spills	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● hazardous materials are stored within bunded facilities; ● wastewater is not discharged onto bare ground; ● leaks are detected and repaired promptly	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		● groundwater quality is periodically monitored where required.	
Surface Water Resources	Surface runoff contamination	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● stormwater drainage systems remain free from obstruction; ● maintenance activities are undertaken away from drainage channels wherever practicable; ● oils, chemicals and cleaning materials are prevented from entering campus drains; ● drainage channels are inspected routinely.	Minor
Air Quality	Dust generation during maintenance activities	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● maintenance activities generating dust are minimized; ● water is sprinkled on exposed surfaces where necessary ● maintenance vehicles comply with approved speed limits; ● unnecessary vehicle movement is avoided.	Negligible
	Minor exhaust emissions from maintenance vehicles	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● maintenance vehicles are regularly serviced; ● unnecessary engine idling is prohibited; ● low-emission vehicles are used where practicable.	Negligible
Noise and Vibration	Noise generated during equipment maintenance	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● maintenance activities are undertaken during normal working hours; ● equipment is maintained in good operating condition; ● defective equipment generating excessive noise is repaired immediately; ● nearby university users are informed of planned noisy maintenance works where necessary.	Minor
Socio-economic Environment	Temporary interruption of electricity supply during maintenance	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● preventive maintenance schedules are prepared and implemented; ● maintenance activities are planned to minimize disruption to academic and administrative activities;	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		● users receive advance notice of planned outages; ● emergency backup arrangements are available where required.	
	Long-term employment opportunities	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● operational employment opportunities remain transparent and merit-based;periodic technical training is provided to operational personnel; ● local technical capacity is strengthened through continuous professional development.	Major Positive
	Improved institutional energy security	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● the hybrid system is operated in accordance with manufacturers' specifications; ● preventive maintenance programmes are fully implemented; ● system performance is monitored continuously to maximize energy reliability.	Major Positive
Waste Generation and Handling	Generation of domestic and maintenance waste	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● wastes are segregated at source; ● recyclable materials are recovered wherever practicable; ● waste containers remain properly labeled and covered; ● only licensed waste contractors are engaged for waste disposal.	Minor
	Generation of spent PV modules, batteries and electronic waste	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● a Battery Management Plan and E-waste Management Plan are implemented throughout operation; ● defective batteries and PV modules are stored safely pending collection; ● all hazardous and electronic wastes are transferred only to FMEnv-approved or licensed recycling/recovery facilities; ● accurate waste inventories are maintained.	Minor
Community Health and Safety	Public exposure to electrical hazards	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● the solar farm remains securely fenced throughout operation;• warning signs	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		remain visible and legible; ● access to high-voltage equipment is restricted to authorized personnel only; ● emergency contact information is displayed prominently.	
	Fire and emergency incidents	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● Fire Detection and Suppression Systems remain operational at all times; ● emergency response drills are conducted periodically; ● fire extinguishers are inspected and serviced regularly; ● emergency response procedures are reviewed annually.	Minor
Occupational Health and Safety	Electrical shock, arc flash and working-at-height hazards	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● only trained and authorized personnel undertake maintenance activities; ● lock-out/tag-out procedures are strictly implemented before maintenance; ● PPE appropriate to the task is provided and worn; ● permit-to-work systems are maintained for high-risk activities; ● routine HSE audits are conducted throughout operation.	Minor
	Battery-related hazards including thermal runaway	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: ● the BESS is operated strictly in accordance with manufacturers' specifications; ● battery rooms remain adequately ventilated and temperature controlled; ● battery monitoring systems remain functional; ● emergency isolation procedures are tested periodically.	Minor
Gender, GBV and Social Inclusion	Unequal employment opportunities	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that: equal opportunity employment policies remain in force throughout operation; recruitment, promotion and training opportunities remain free from discrimination; women and vulnerable groups continue to have equitable access to employment and training opportunities.	Minor
	Risk of GBV, SEA and SH	REA/NOUN/EPC Contractor (where applicable)/Supervising Engineer shall ensure that:	Negligible

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		● the Code of Conduct remains enforceable throughout operation;periodic GBV/SEA/SH awareness training is conducted for operational staff; ● confidential grievance and reporting mechanisms remain operational; ● all complaints are investigated promptly and appropriate corrective action implemented.	

Table 6. 5: Mitigation Measures for the Potential Negative Impacts of the proposed Project (Decommissioning Phase)

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
Land Resources	Temporary land disturbance and removal of project infrastructure	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Decommissioning and Site Restoration Plan is prepared and approved before dismantling commences; ● dismantling activities are confined to the approved project footprint; ● unnecessary disturbance of adjacent university facilities and landscaped areas is prohibited; ● all foundations, concrete debris and underground structures no longer required are removed where practicable; ● disturbed land is restored to conditions compatible with the approved post-project land use.	Minor
	Residual alteration of land use	REA/EPC Contractor/Supervising Engineer shall ensure that: ● the site is restored in accordance with the approved closure objectives and NOUN Campus Master Plan; ● all temporary facilities are removed; ● the restored site is stabilized and suitable for future institutional development or landscaping.	Negligible
Soil Resources	Soil erosion and contamination during dismantling	REA/EPC Contractor/Supervising Engineer shall ensure that: ● topsoil is conserved where practicable and reused during restoration; ● erosion control measures are maintained until the site is fully stabilized; ● spills of fuel, oil and chemicals are prevented and immediately remediated; ● contaminated soils are excavated and disposed of at approved facilities where required.	Minor
Groundwater Resources	Groundwater contamination	REA/EPC Contractor/Supervising Engineer shall ensure that: ● dismantling equipment is maintained in good working condition to prevent	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
	from accidental spills	leakages; ● hazardous substances are stored within bunded containment areas; ● refueling and maintenance activities are undertaken only in designated areas; ● spill response equipment is readily available throughout decommissioning.	
Surface Water Resources	Sedimentation and contamination of storm-water drains	REA/EPC Contractor/Supervising Engineer shall ensure that: ● erosion and sediment control measures remain operational throughout dismantling; ● wastes and debris are prevented from entering drainage channels; ● wastewater generated during dismantling is properly collected and managed; ● drainage systems are inspected and cleaned before project closure.	Minor
Air Quality	Dust emissions during dismantling and transportation	REA/EPC Contractor/Supervising Engineer shall ensure that: ● exposed surfaces are sprinkled with water where necessary to suppress dust; ● demolition debris is promptly collected and transported; ● haulage vehicles transporting debris are adequately covered; ● unnecessary idling of equipment is prohibited.	Minor
	Exhaust emissions from dismantling equipment	REA/EPC Contractor/Supervising Engineer shall ensure that: ● all machinery is serviced regularly; ● low-emission equipment is used where practicable; ● equipment with excessive smoke emissions is removed from service until repaired.	Negligible
Noise and Vibration	Noise and vibration generated during dismantling	REA/EPC Contractor/Supervising Engineer shall ensure that: ● dismantling activities are restricted to approved daytime working hours; ● equipment is maintained with functional silencers and mufflers; ● nearby university users are informed before particularly noisy activities; ● noise monitoring is undertaken where required.	Minor
Socio-economic Environment	Loss of temporary employment following project closure	REA/EPC Contractor/Supervising Engineer shall ensure that: ● affected workers receive adequate notice before contract termination; ● labour disengagement complies with applicable Nigerian labour legislation; ● opportunities for redeployment or retraining are explored where practicable; ● final employment benefits are paid promptly in accordance with contractual obligations.	Minor
	Temporary	REA/EPC Contractor/Supervising Engineer shall ensure that:	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
	disruption of campus activities	● dismantling schedules are coordinated with NOUN management; ● access to academic and administrative facilities is maintained; ● temporary traffic diversions are clearly communicated to the university community.	
Waste Generation and Handling	Generation of demolition debris	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Decommissioning Waste Management Plan is implemented before dismantling begins; ● reusable materials are recovered wherever practicable; ● recyclable materials are segregated and transferred to authorized recycling facilities; ● non-recyclable wastes are disposed of through licensed waste contractors only.	Minor
	Generation of hazardous wastes including PV modules, lithium-ion batteries, transformers, cables and electronic equipment	REA/EPC Contractor/Supervising Engineer shall ensure that: ● all photovoltaic modules, batteries, electrical equipment and associated hazardous materials are inventoried before removal; ● damaged PV panels and batteries are handled in accordance with manufacturers' recommendations and applicable Nigerian regulations; ● hazardous and electronic wastes are transferred only to FMEnv-approved or licensed recycling, recovery or disposal facilities; ● waste tracking documentation is maintained until final disposal or recycling is completed	Minor
Community Health and Safety	Public exposure to dismantling activities	REA/EPC Contractor/Supervising Engineer shall ensure that: ● the project site remains securely fenced throughout decommissioning; ● warning signs and barricades are installed around active work areas; ● traffic management measures remain operational during equipment removal; ● emergency access routes remain unobstructed at all times.	Minor
	Increased traffic associated with removal of equipment	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Traffic Management Plan is implemented throughout dismantling; ● haulage routes are coordinated with NOUN Management; ● drivers comply with campus speed limits and traffic regulations; ● oversized loads are transported during periods of minimal campus activity	Minor

Receptors	Impact	Mitigation Measures	Impact Significance After Mitigation
		where practicable.	
Occupational Health and Safety	Injuries during dismantling and lifting operations	REA/EPC Contractor/Supervising Engineer shall ensure that: ● a Decommissioning Health, Safety and Environment (HSE) Plan is implemented before dismantling commences; ● only trained and competent personnel undertake dismantling activities; ● lifting operations are supervised by qualified personnel; ● permit-to-work procedures are implemented for high-risk tasks; ● PPE is provided and worn at all times; ● emergency response equipment remains available throughout decommissioning.	Minor
	Electrical hazards during equipment removal	REA/EPC Contractor/Supervising Engineer shall ensure that: ● all electrical systems are isolated, tested and certified de-energized before dismantling; ● lock-out/tag-out procedures are strictly implemented; ● only authorised electrical personnel disconnect electrical equipment; ● electrical safety inspections are undertaken throughout decommissioning.	Minor
Gender, GBV and Social Inclusion	Gender discrimination during workforce disengagement	REA/EPC Contractor/Supervising Engineer shall ensure that: ● workforce disengagement procedures are fair, transparent and non-discriminatory; ● all workers are treated equitably regardless of gender, disability, ethnicity or religion; ● grievances relating to employment termination are managed through the established grievance mechanism.	Negligible
	GBV, SEA/SH and social conflict associated with workforce demobilization	REA/EPC Contractor/Supervising Engineer shall ensure that: ● the Code of Conduct remains enforceable until all personnel have demobilized; ● GBV/SEA/SH awareness programmes continue throughout decommissioning ● confidential grievance reporting mechanisms remain functional until project closure; ● all allegations are investigated promptly and appropriate corrective action implemented.	Negligible

6.3 Summary of Mitigation Measures

Discussion on the Mitigation Measures for the Potential Negative Impacts of the proposed Project (Pre-construction Phase)

The adverse impacts identified during the pre-construction phase are generally low in magnitude, localized and temporary, and are largely associated with project planning, surveys, mobilization, stakeholder engagement and preliminary site preparation. Nevertheless, the implementation of the mitigation measures outlined in Table 6.2 will ensure that these impacts remain at Negligible or Minor residual significance. Particular emphasis shall be placed on early stakeholder engagement, protection of existing campus infrastructure, implementation of occupational health and safety procedures, and establishment of effective grievance redress and gender-responsive management systems before commencement of construction activities. These early interventions will provide the institutional and environmental foundation necessary for the successful implementation of the subsequent construction phase.

Discussion on the Mitigation Measures for the Potential Negative Impacts of the proposed Project (Construction Phase)

The construction phase presents the highest potential for adverse environmental and social impacts because it involves civil works, equipment installation, increased workforce presence, equipment movement, installation of PV/BESS/electrical infrastructure, testing and commissioning, temporary increase in workforce and traffic and intensive use of machinery and materials. As shown in Table 6.3, the principal risks relate to land disturbance, soil erosion, air emissions, noise, waste generation, occupational and community health and safety, and social issues including gender, GBV/SEA/SH and inclusion, including the loss and redistribution of parking at Site 2. Implementation of the above mitigation commitments by the REA, EPC Contractor and Supervising Engineer is expected to reduce all identified adverse impacts from Moderate or Major significance before mitigation to Minor or Negligible residual significance, while ensuring compliance with applicable Nigerian environmental legislation and recognized international environmental and social good practice.

Discussion on the Mitigation Measures for the Potential Negative Impacts of the proposed Project (Operation Phase)

The operational phase of the proposed 1-MW Solar Hybrid Power Project is expected to generate predominantly positive environmental and socio-economic impacts through the provision of reliable and clean electricity to the National Open University of Nigeria (NOUN), Main Campus. Nevertheless, routine operation and maintenance activities, including photovoltaic (PV) panel cleaning, Battery Energy Storage System (BESS) operation, electrical equipment maintenance, waste generation, traffic associated with maintenance personnel, and emergency situations, have the potential to generate localized environmental and social impacts

The operation phase is characterized by low-intensity, long-term activities associated with electricity generation, routine inspection, preventive maintenance, panel cleaning, battery management and system monitoring. Unlike the construction phase, most environmental impacts during operation are localized, predictable and readily manageable through effective

operational controls and maintenance procedures. The implementation of the mitigation measures presented in Table 6.4 will ensure that residual adverse impacts on land, water resources, air quality, noise, waste management, occupational health and safety, community health and safety, and gender and social inclusion remain Minor or Negligible throughout the operational life of the project. At the same time, the project is expected to deliver significant positive residual impacts by improving energy reliability, reducing dependence on fossil fuel-based electricity generation, lowering greenhouse gas emissions, strengthening institutional resilience, and supporting Nigeria's renewable energy and energy transition objectives. These measures will contribute to the sustainable operation of the facility while ensuring continued compliance with applicable environmental and social requirements.

Discussion on the Mitigation Measures for the Potential Negative Impacts of the proposed Project (Decommissioning Phase)

At the end of the operational life of the proposed 1-MW Solar Hybrid Power Project, decommissioning activities will involve the dismantling and removal of photovoltaic modules, Battery Energy Storage System (BESS), transformers, inverter stations, support structures, underground and overhead electrical infrastructure, ancillary buildings, fencing and associated facilities. These activities may generate environmental and social impacts similar to those experienced during construction, including land disturbance, waste generation, noise, dust, occupational hazards and community safety risks. However, implementation of the mitigation measures presented in Table 6.5 will ensure that all decommissioning activities are undertaken in an environmentally responsible, safe and socially acceptable manner while restoring the project site for future beneficial use.

CHAPTER SEVEN
ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN

7.1 Introduction

The potential environmental and social impacts associated with the proposed 1 MW Solar Photovoltaic (PV) Power Plant to be developed within the premises of the National Open University of Nigeria (NOUN) Main Campus, under the Rural Electrification Agency (REA) Desert-to-Power Initiative (Nigeria Electrification Project Phase II), have been evaluated in Chapter Five of this ESIA.

The assessment confirms that most identified impacts are localized, temporary (during construction), and manageable. These include:

- Short-term dust emissions and elevated noise levels during construction;
- Fugitive dust (including PM10 and PM2.5), equipment exhaust emissions, construction noise and localized vibration;
-
- Minor vegetation clearance within the approved project footprint;
- Temporary traffic increase;
- Occupational health and safety risks to workers;
- Community health and safety concerns, including GBV risk and labour influx considerations;
- Potential soil, groundwater and surface-water/drainage impacts from erosion, sediment and accidental spills relative to the established baseline, water demand for PV cleaning, and generation of construction, operational, battery, PV and other electrical/electronic waste streams.

The analysis further shows that with the implementation of the mitigation measures outlined in Chapter Six, the adverse impacts will not be significant and can be reduced to as low as reasonably practicable (ALARP). However, mitigation commitments alone are insufficient unless they are translated into structured management actions, clearly assigned responsibilities, supported by financial resources, and integrated into each phase of Project implementation.

This Chapter therefore presents the Environmental and Social Management Plan (ESMP) for the proposed Project. It provides:

- Phase-specific management measures;
- Monitoring requirements and performance indicators;
- Institutional roles and responsibilities;
- Implementation timelines; and
- Cost provisions for mitigation and monitoring.

In addition, it outlines the framework for supplementary management plans (e.g., Occupational Health and Safety Plan, Waste Management Plan, Traffic Management Plan, and GBV Action Plan) to be developed and implemented under this ESMP.

The ESMP shall serve as the principal environmental management document throughout the project life cycle and shall be implemented during the pre-construction, construction, and operation phases while decommissioning phase will be discussed in Chapter Nine. The ESMP implementation will ensure that adverse environmental and social impacts remain within acceptable limits while enhancing the positive benefits associated with improved energy reliability, reduced greenhouse gas emissions and sustainable institutional development.

7.2 Objectives of the ESMP

The ESMP serves as the operational framework for ensuring that environmental and social considerations are effectively integrated into the planning, construction, operation, and eventual decommissioning of the Project. It promotes proactive risk management rather than reactive correction and ensures that environmental performance and social safeguards are embedded in day-to-day decision-making.

The ESMP specifically aims to:

- Promote sound environmental stewardship and social responsibility throughout the Project lifecycle;
- Ensure compliance with applicable Nigerian environmental regulations, safeguard policies, and institutional requirements;
- Integrate environmental and social considerations into engineering design, procurement, contractor obligations, and operational procedures;
- Provide a clear action plan for implementing mitigation and enhancement measures identified in the ESIA;
- Define roles and responsibilities of REA, NOUN management, the EPC and O&M Contractors, the Supervising Engineer, and relevant environmental/regulatory authorities;
- Establish a structured monitoring and reporting system for environmental and social performance;
- Ensure proper documentation of monitoring results, audits, incidents, corrective actions, and non-compliance management;
- Facilitate transparency and accountability through stakeholder engagement and grievance redress mechanisms.

Through these objectives, the ESMP provides assurance that environmental risks, health and safety hazards, and social concerns are systematically identified, minimized, and managed within acceptable thresholds.

7.3 Institutional Framework for ESMP Implementation

The successful implementation of the ESMP will depend on clearly defined institutional responsibilities and effective coordination among REA as Project Proponent, NOUN as institutional host, the EPC Contractor during construction, the O&M Contractor during operation, the Supervising Engineer, and relevant regulatory authorities including FMEnv and AEPB. The institutional arrangements proposed for the Project are presented in Table 7.1.

Table 7.1: Roles, Responsibilities and Accountabilities for ESMP Implementation

Institution	Principal Responsibilities
African Development Bank (AfDB)	Provide financing and implementation oversight; review periodic environmental and social performance reports; verify compliance with the ESMP and applicable safeguard requirements; review significant environmental and social incidents and corrective action plans; ensure that project implementation remains consistent with the Bank's environmental and social policies and financing conditions
Rural Electrification Agency (REA)	Overall Project Proponent; ensure adequate funding for ESMP implementation; incorporate environmental and social requirements into contract documents; supervise overall ESMP implementation; liaise with FMEnv and funding institutions; ensure compliance with applicable environmental and social safeguard requirements; review periodic environmental performance reports.
National Open University of Nigeria (NOUN)	Provide institutional support during project implementation; facilitate stakeholder engagement within the University Community; coordinate access to project facilities; monitor operational environmental performance after project commissioning; support emergency preparedness and grievance management.
Engineering, Procurement and Construction (EPC) Contractor	Implement all mitigation measures contained in the ESMP; prepare site-specific Construction Environmental and Social Management Plan (CESMP); implement Occupational Health and Safety (OHS) procedures; manage wastes; maintain environmental monitoring records; implement emergency preparedness measures; submit periodic compliance reports.
Supervising Engineer	Supervise implementation of the ESMP; verify contractor compliance; undertake routine environmental inspections; certify environmental performance; recommend corrective actions where non-compliance is observed; submit environmental supervision reports to REA.
Federal Ministry of Environment (FMEnv)	Review and approve the ESIA; undertake periodic compliance inspections; monitor compliance with environmental legislation; issue environmental directives where necessary; participate in post-approval environmental audits.
Abuja Environmental Protection Board (AEPB)	Provide FCT-level environmental oversight and compliance monitoring within Abuja; participate in inspections as applicable; support environmental sanitation/waste oversight; and receive or act on relevant environmental compliance information within its mandate.
National Environmental Standards and Regulations Enforcement	Monitor compliance with applicable national environmental regulations, particularly those relating to hazardous waste, e-waste and battery management, where applicable.

Institution	Principal Responsibilities
Agency (NESREA)	
Abuja Municipal Area Council (AMAC)	Support community liaison, local environmental sanitation initiatives, emergency response coordination where required and collaboration with neighbouring communities.

7.3.1 Communication and Reporting Framework

An effective communication and reporting framework shall be maintained throughout project implementation to facilitate coordination among all implementing agencies. The EPC Contractor/Supervising Engineer shall submit monthly/consolidated quarterly Environmental, Health and Safety (EHS) reports to the REA. REA shall, in turn, provide periodic compliance reports to the Federal Ministry of Environment and other relevant regulatory authorities, as required by statutory approvals and funding agreements. Environmental incidents, emergencies and significant non-compliance shall be reported immediately through the established communication channels, while lessons learned and corrective actions shall be communicated to all relevant parties to promote continual improvement in environmental and social performance.

7.4 Environmental Management Measures

7.4.1 Environmental Management Measures for all phases of the project

Tables 7.2 to 7.4 present the environmental and social management measures required for the pre-construction, construction (including testing and commissioning), and operation phases. The matrices have been synchronized with the adverse impacts identified in Chapter Five and the corresponding mitigation commitments in Chapter Six. Environmental management measures for decommissioning are presented in Chapter Eight.

Table 7.2: Environmental Management Measures for the Pre-construction Phase of the Proposed Project

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
Land Resources	Temporary land disturbance during surveys and site demarcation	Restrict all activities to the approved project footprint; clearly demarcate work boundaries before mobilization; minimize vegetation clearance.	Area disturbed outside approved footprint	Site inspection; GPS verification	Weekly until mobilization	REA / EPC Contractor	Supervising Engineer / NOUN	Inspection reports; photographic records	**333.33**
	Change in land use and land utilization	Ensure project implementation conforms to the approved NOUN Campus Master Plan and approved project layout.	Compliance with approved site layout	Review of engineering drawings; field verification	Once before mobilization	REA	Supervising Engineer	Approved layout plan; compliance checklist	**133.33**
Soil Resources	Localized soil disturbance	Minimize excavation during investigations; preserve topsoil where removed; reinstate disturbed areas immediately.	Number of disturbed areas restored	Visual inspection	Weekly	EPC Contractor	Supervising Engineer	Site inspection reports	**200.00**
Ground	Accidental	Designate	Number of	Site	Weekly	EPC Contractor	Supervising	Spill register;	**233.33**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
water	contamination from fuels and lubricants	refueling areas; provide spill kits; prohibit indiscriminate disposal of oils and chemicals.	spill incidents	inspection; incident register			Engineer	inspection reports	
Surface Water	Sediment movement into drains	Protect drainage channels; install temporary erosion controls where necessary; prevent stockpiling near drainage paths.	Evidence of sediment entering drains	Visual inspection after rainfall	Weekly and after rainfall	EPC Contractor	Supervising Engineer	Inspection records	**200.00**
Air Quality	Dust generation during surveys	Restrict vehicle movement to existing roads; apply water where necessary; enforce 20 km/h speed limit.	Visible dust levels; dust complaints	Site observation; complaint log	Weekly	EPC Contractor	Supervising Engineer	Inspection reports; GRM register	**200.00**
Noise and Vibration	Noise from survey activities	Restrict activities to daytime hours; maintain equipment; avoid unnecessary idling.	Number of noise complaints	Observation; stakeholder feedback	Weekly	EPC Contractor	Supervising Engineer	Complaint register	**133.33**
Socio-	Community	Implement	Number of	Attendance	Monthly	REA / NOUN	Supervising	Meeting	**1,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
economic Environment	concerns and misinformation	Stakeholder Engagement Plan; disclose project information; establish Grievance Redress Mechanism (GRM).	stakeholder meetings; grievances resolved	records; GRM review			Engineer	minutes; GRM register	
	Unrealistic employment expectations	Publicly communicate recruitment procedures; adopt transparent and merit-based recruitment.	Recruitment complaints	Review of recruitment records	Once before mobilization	REA / EPC Contractor	Supervising Engineer	Recruitment records	**200.00**
Waste Generation and Handling	Domestic waste from mobilization activities	Provide labelled waste bins; segregate waste at source; engage approved waste contractor.	Waste segregation rate	Waste inspection	Weekly	EPC Contractor	Supervising Engineer	Waste manifests; inspection reports	**266.67**
Community Health and Safety	Increased movement of survey vehicles	Implement Traffic Management Plan; install warning signs; enforce speed limits.	Traffic incidents	Traffic observation; incident records	Weekly	EPC Contractor	Supervising Engineer / FRSC	Traffic log; incident reports	**333.33**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
Occupational Health and Safety	Minor injuries during surveys	Implement HSE induction; provide PPE; conduct daily toolbox talks; maintain first aid facilities.	PPE compliance; LTIs; toolbox talks conducted	Site inspection; HSE audit	Daily	EPC Contractor	Supervising Engineer / REA	HSE reports; attendance sheets	**800.00**
Gender, GBV and Social Inclusion	Exclusion of women and vulnerable groups	Ensure inclusive consultations; provide equal opportunity participation; maintain accessible consultation venues.	Percentage of women and vulnerable persons participating	Attendance analysis	Every consultation	REA / NOUN	Supervising Engineer	Attendance registers; consultation reports	**333.33**
	Risk of GBV, SEA and SH	Implement Code of Conduct; conduct GBV/SEA/SH awareness training; establish confidential reporting mechanism and referral pathway.	Workers signing Code of Conduct; personnel trained; GBV complaints addressed	Records review; audit	Before mobilisation and quarterly	REA / EPC Contractor	Supervising Engineer	Training records; signed Codes of Conduct; confidential GBV register	**666.67**

Table 7.3: Environmental Management Measures for the Construction Phase of the Proposed Project

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
Land Resources	Permanent land take and restriction of land use	Restrict construction activities to the approved footprint; clearly demarcate work boundaries; rehabilitate all temporary work areas after construction.	Area disturbed outside approved footprint	Site inspection; GPS verification	Weekly	EPC Contractor	Supervising Engineer / REA	Site inspection reports; photographs	**666.67**
	Unnecessary occupation of adjacent university land	Maintain temporary storage, parking and material stockpiles within designated areas only.	Encroachment incidents	Site inspection	Weekly	EPC Contractor	Supervising Engineer	Inspection reports	**333.33**
Soil Resources	Soil erosion and compaction	Strip and preserve topsoil; install erosion control measures; restore disturbed surfaces immediately after construction.	Erosion features observed; restored areas	Visual inspection	Weekly and after rainfall	EPC Contractor	Supervising Engineer	Inspection records	**1,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
	Soil contamination from fuel, oil and lubricants	Store fuels within bunded areas; undertake refueling only in designated locations; maintain spill kits; remediate contaminated soils immediately.	Spill incidents; contaminated soil volume	Site inspection; spill register	Daily inspection; monthly reporting	EPC Contractor	Supervising Engineer / REA	Spill reports; waste manifests	**1,333.33**
Ground water	Groundwater contamination	Maintain bunded chemical storage; prohibit discharge of wastewater onto bare ground; inspect storage facilities routinely.	Evidence of contamination; spill incidents	Inspection; groundwater sampling (where required)	Monthly	EPC Contractor	Supervising Engineer	Monitoring reports	**1,000.00**
Surface Water Resources	Sedimentation and pollution of drainage channels	Install silt fences and sediment traps; protect drainage channels; prevent concrete wash water from entering drains.	Drainage condition; turbidity observations	Site inspection after rainfall	Weekly and after storms	EPC Contractor	Supervising Engineer	Inspection reports	**1,000.00**
Air Quality	Dust generation	Water exposed surfaces; cover haulage trucks;	Dust complaints; visible dust	Visual inspection; complaint	Daily	EPC Contractor	Supervising Engineer	Daily HSE reports	**1,333.33**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		enforce 20 km/h speed limit; minimise exposed stockpiles.		register					
	Exhaust emissions	Maintain construction equipment; prohibit excessive idling; remove visibly smoking equipment from service.	Equipment maintenance records; visible smoke	Inspection	Weekly	EPC Contractor	Supervising Engineer	Maintenance records	**533.33**
Noise and Vibration	Noise nuisance	Restrict noisy works to daytime hours; maintain silencers; notify NOUN before high-noise activities.	Noise complaints; measured noise levels	Noise meter; complaint register	Weekly	EPC Contractor	Supervising Engineer	Noise monitoring reports	**800.00**
	Ground vibration	Operate heavy equipment in accordance with manufacturer's recommendations; avoid unnecessary vibration.	Vibration complaints	Site observation	Weekly	EPC Contractor	Supervising Engineer	Inspection records	**333.33**
Socio-economic Environment	Temporary disruption of university activities	Schedule works in consultation with NOUN; maintain pedestrian and vehicular access;	Number of disruptions; stakeholder complaints	Consultation records	Weekly	EPC Contractor / NOUN	REA / Supervising Engineer	Meeting minutes; GRM records	**666.67**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		provide advance notice of disruptions.							
	Local employment expectations	Implement transparent recruitment; prioritise qualified local labour where practicable; communicate recruitment procedures publicly.	Local workforce percentage; recruitment complaints	Employment records	Monthly	EPC Contractor	REA / Supervising Engineer	Employment register	**333.33**
Waste Generation and Handling	Construction waste generation	Implement Construction Waste Management Plan; segregate waste; recycle reusable materials; dispose of waste through approved contractors.	Waste segregation rate; waste volumes	Waste audits	Weekly	EPC Contractor	Supervising Engineer	Waste manifests	**1,333.33**
	Hazardous waste generation	Segregate hazardous wastes; maintain inventories; store in labelled containers; dispose through licensed facilities.	Hazardous waste inventory	Waste inspection	Monthly	EPC Contractor	Supervising Engineer	Hazardous waste register	**1,000.00**
Community	Increased	Implement Traffic	Traffic	Traffic	Daily	EPC Contractor	Supervising	Traffic logs	**1,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
Health and Safety	traffic accidents	Management Plan; deploy traffic marshals; install warning signs; enforce speed limits.	incidents	inspections			Engineer / FRSC		
	Public exposure to construction hazards	Fence work areas; install warning signage; restrict public access; maintain emergency response arrangements.	Unauthorized access incidents	Site inspection	Daily	EPC Contractor	Supervising Engineer	HSE inspection reports	**666.67**
Occupational Health and Safety	Worker injuries	Implement Construction HSE Plan; provide PPE; conduct daily toolbox talks; implement permit-to-work system; provide first aid and emergency response equipment.	PPE compliance; Lost Time Injury (LTIs); toolbox talks; incidents	HSE inspections and audits	Daily	EPC Contractor	Supervising Engineer / REA	HSE reports; accident register	**3,333.33**
	Electrical hazards	Restrict electrical work to competent personnel; implement lock-out/tag-out procedures; inspect	Electrical incidents	Site inspection	Daily	EPC Contractor	Supervising Engineer	Electrical safety records	**666.67**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		electrical tools routinely.							
Gender, GBV and Social Inclusion	Gender inequality in employment	Apply equal opportunity recruitment; encourage participation of qualified women; prohibit discrimination.	Female participation rate	Employment audit	Quarterly	EPC Contractor	REA / Supervising Engineer	Employment records	**333.33**
	GBV, SEA and SH risks	Implement Workers' Code of Conduct; conduct mandatory GBV/SEA/SH training; establish confidential grievance mechanism and referral pathway; enforce disciplinary measures for violations.	Percentage of workforce trained; Code of Conduct compliance; GBV complaints resolved	Training records; GRM audit	Quarterly	EPC Contractor	REA / Supervising Engineer	Signed Codes of Conduct; training records; confidential GBV register	**1,000.00**

Table 7.4: Environmental Management Measures for the Operation Phase of the Proposed Project

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
Land Resources	Long-term occupation of project land	Maintain project activities within approved operational footprint; maintain landscaped areas; rehabilitate disturbed areas promptly.	Evidence of land degradation	Site inspection	Quarterly	NOUN / REA	REA / Supervising Engineer	Inspection reports	**333.33**
Soil Resources	Soil contamination from transformer oil or battery electrolyte leakage	Inspect transformers and BESS routinely; maintain bunded areas; clean spills immediately; remediate contaminated soils.	Spill incidents; contaminated soil occurrences	Site inspection; spill register	Monthly	NOUN	REA	Spill register	**533.33**
Groundwater Resources	Groundwater contamination	Maintain spill prevention measures; prohibit discharge of contaminated wastewater; periodically inspect	Groundwater quality; spill incidents	Water quality monitoring; inspections	Annually	NOUN	REA / FMEnv	Laboratory reports	**666.67**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		drainage and containment systems.							
Surface Water Resources	Pollution of stormwater drainage	Maintain drainage infrastructure; prevent discharge of oils and chemicals into drains; inspect drainage channels regularly.	Drainage condition	Visual inspection	Quarterly	NOUN	REA	Inspection reports	**333.33**
Air Quality	Minor emissions from maintenance vehicles	Maintain maintenance vehicles; minimize vehicle idling; schedule maintenance efficiently.	Visible smoke; maintenance records	Inspection	Quarterly	NOUN	REA	Vehicle maintenance records	**200.00**
	Dust generated during maintenance	Wet dusty surfaces where necessary; minimize disturbance during maintenance works.	Dust complaints	Visual inspection	As required	NOUN	REA	Complaint register	**133.33**
Noise and Vibration	Noise from inverters, transformers and maintenance	Maintain equipment in accordance with manufacturers' specifications; undertake noisy	Noise levels; complaints	Noise monitoring	Quarterly	NOUN	REA	Noise monitoring reports	**400.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
	activities	maintenance during working hours.							
Socio-economic Environment	Temporary interruption of electricity supply during maintenance	Implement preventive maintenance schedule; notify users before planned outages; maintain standby arrangements where necessary.	Number of planned outages; user complaints	Maintenance records	Quarterly	NOUN	REA	Maintenance logs	**333.33**
	Improved electricity supply and institutional productivity	Maintain high system availability through preventive maintenance and performance monitoring.	System availability (%)	Operational performance monitoring	Monthly	NOUN	REA	SCADA/O&M reports	
Waste Generation and Handling	Domestic waste generation	Provide labelled waste receptacles; segregate waste; engage approved waste contractor.	Waste segregation rate	Waste inspection	Monthly	NOUN	REA	Waste manifests	**266.67**
	End-of-life batteries, PV modules and electronic waste	Implement Battery Management Plan and E-waste Management Plan; maintain inventories; transfer	Quantity of e-waste; recycling rate	Waste inventory; audit	Annually	NOUN	REA / FMEnv	Waste manifests; recycling certificates	**1,333.33**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		waste only to licensed recyclers.							
Community Health and Safety	Public exposure to electrical hazards	Maintain perimeter fencing; display warning signage; restrict access to unauthorized personnel; inspect security measures regularly.	Unauthorized access incidents	Site inspection	Monthly	NOUN	REA	Security reports	**333.33**
	Fire and emergency incidents	Maintain fire detection and suppression systems; conduct emergency drills; inspect firefighting equipment routinely.	Number of emergency drills; equipment inspection status	Emergency preparedness audit	Bi-annually	NOUN	REA	Drill reports; inspection records	**1,000.00**
Occupational Health and Safety	Electrical shock and maintenance-related injuries	Implement Operational HSE Plan; enforce permit-to-work system; implement lock-out/tag-out procedures; provide PPE; conduct routine HSE training.	Number of Lost Time Injuries (LTIs); PPE compliance; HSE training completed	HSE audit	Monthly	NOUN	REA	HSE reports; training records	**1,666.67**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
	Battery thermal runaway	Maintain Battery Management System (BMS); monitor battery temperature continuously; inspect ventilation systems; implement emergency isolation procedures.	Battery alarms; thermal incidents	BMS monitoring	Continuous	NOUN	REA	BMS records	
Gender, GBV and Social Inclusion	Workplace discrimination	Maintain equal opportunity employment policy; ensure equitable access to training and promotion.	Gender participation statistics	HR Audit	Annually	NOUN	REA	HR records	**200.00**
Gender, GBV and Social Inclusion	GBV, SEA and SH risks	Maintain Workers' Code of Conduct; continue GBV awareness training; maintain confidential reporting and survivor-centred grievance mechanisms.	Personnel trained; complaints resolved	Training records; GRM audit	Annually	NOUN	REA	Training records; confidential GRM register	**333.33**
Climate Change	Reduced greenhouse	Optimist system performance;	Annual energy	Energy production	Quarterly and	NOUN / REA	AfDB / REA	Annual sustainability	

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
	gas emissions through renewable energy generation	monitor annual energy generation and avoided emissions; maintain high plant availability.	generation (MWh); estimated CO_2 emissions avoided	records	Annually			reports	

Table 7.5: Environmental and Social Monitoring Programme

Environmental Component / Matrix	Sampling Location(s)	Monitoring Method	Parameters to be Monitored	Compliance Requirement	Frequency	Responsible Party	Project Phase	Estimated Cost (US$)
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 / World Bank EHS Guidelines	Monthly monitoring; Monthly reporting	EPC Contractor	Construction Phase	**1,000.00**
Groundwater Quality	University borehole(s)	Thermometer, water sampler, turbidity meter, pH meter, AAS	Temperature, pH, salinity, TDS, conductivity, DO, BOD, TOC, COD, NO_3, PO_4, chloride, sulphate, microbiology, heavy metals, TSS, turbidity	FMEnv / WHO Standards	Quarterly monitoring and reporting	EPC Contractor (Construction)O&M Contractor (Operation)	Construction & Operation Phases	**4,000.00**
Soil Quality	Unpaved areas within plant site	Composite soil sampling and laboratory analysis	pH, moisture, TOC, THC, TPH, NO_3, PO_4, chloride, sulphate, microbiology, heavy metals	NESREA / World Bank Guidelines	Quarterly monitoring and reporting	EPC Contractor (Construction)O&M Contractor (Operation)	Construction & Operation Phases	**4,000.00**
Solid Waste Management	Construction and operational areas	Waste tracking documentation; inspection of storage and disposal practices	Packaging waste, scrap metals, e-waste, general solid waste	FMEnv / NESREA / World Bank	Monthly monitoring; Quarterly reporting	EPC Contractor (Construction)O&M Contractor (Operation)	Construction & Operation Phases	**2,000.00**
Health and Safety Compliance	Workers and operational areas	Site inspection; PPE compliance observation	Compliance with OHS Plan; use of PPE; unsafe	FMEnv / NESREA / World Bank	Daily monitoring; Quarterly	EPC Contractor (Construction)O&M Contractor	Construction & Operation Phases	**2,000.00**

Environmental Component / Matrix	Sampling Location(s)	Monitoring Method	Parameters to be Monitored	Compliance Requirement	Frequency	Responsible Party	Project Phase	Estimated Cost (US$)
			conditions	EHS Guidelines	reporting	(Operation)		
Training and Capacity Building	Workforce	Review of training records and attendance registers	Compliance with Training Plan; induction and refresher training	World Bank EHS Guidelines	Quarterly monitoring and reporting	EPC Contractor (Construction)O&M Contractor (Operation)	Construction & Operation Phases	**2,000.00**
General Housekeeping	Construction sheds and plant areas	Visual inspection	Cleanliness, waste segregation, site aesthetics	FMEnv / NESREA / World Bank	Daily monitoring; Quarterly reporting	EPC Contractor (Construction)O&M Contractor (Operation)	Construction & Operation Phases	**2,000.00**
Stakeholder Engagement	• University community• Regulatory agencies	Review of consultation records; grievance log review	Implementation of Stakeholder Engagement Plan and GRM	FMEnv / NESREA / World Bank	Quarterly monitoring and reporting	EPC Contractor (Construction)O&M Contractor (Operation)	Construction & Operation Phases	**2,000.00**

7.4.2 Environmental Monitoring Program

Environmental and social monitoring shall be undertaken to ensure compliance with applicable regulatory requirements and to assess the effectiveness of mitigation and management measures outlined in this ESMP.

Monitoring will serve the following purposes:

- Verify compliance with FMEnv, NESREA, and AEPB environmental regulations;
- Assess the performance of mitigation measures implemented by the EPC and O&M Contractors;
- Detect any emerging environmental or social risks at an early stage;
- Provide documented evidence of environmental and social performance;
- Support continuous improvement in Project environmental management.

Monitoring activities shall be conducted during the construction and operational phases, as applicable. The estimated cost of implementing the environmental monitoring program is summarized in Table 7.5.

Table 7.6 Environmental and Social Compliance Reporting

Report	Preparation and Review		Submitted To	Frequency
Daily HSE Report	EPC Contractor/ Supervising Engineer		REA	Daily
Monthly ESMP Compliance Report	EPC Contractor/ Supervising Engineer		REA	Monthly
Quarterly Environmental and Social Performance Report	REA/AfDB Task Team		FMEnv, AfDB	Quarterly
Annual Environmental Monitoring Report	NOUN / REA	FMEnv	FMEnv, AfDB	Annually
Incident/Accident Report	EPC Contractor	REA	FMEnv, AfDB (for significant incidents), relevant emergency agencies	Within 24 hours of occurrence
Environmental Audit Report	Independent Environmental Auditor	REA	FMEnv, AfDB	As required by approval conditions

7.5 Additional Management Plans

This section provides a framework for additional management plans to be developed and implemented in support of this ESMP for the proposed 1-MW Solar Hybrid Power Project at the National Open University of Nigeria (NOUN). As the Project progresses from pre-construction through construction (including testing and commissioning) to operation, these management plans shall be expanded into site-specific procedures and implementation guidelines for REA, NOUN, the EPC Contractor, the O&M Contractor, subcontractors and University representatives.

All supporting management documents shall be prepared in accordance with:

- The World Bank General Environmental, Health and Safety (EHS) Guidelines;
- The African Development Bank (AfDB) Integrated Safeguards System (ISS, 2023) and applicable good international industry practice;
- Applicable Nigerian environmental regulations;
- Federal Ministry of Environment (FMEnv) requirements;
- NESREA regulations;
- AEPB environmental and social regulatory requirements;
- Other applicable national and local standards.

An overview of the key additional management plans is presented below.

7.5.1 Stakeholder Engagement Plan (SEP)

A Stakeholder Engagement Plan (SEP) shall be developed and implemented throughout the lifecycle of the proposed Project. The SEP will serve as a structured mechanism for ensuring transparent, inclusive, and continuous engagement between REA, NOUN, contractors, and relevant stakeholders.

❖ **Objectives of the SEP**

The key objectives of the Stakeholder Engagement Plan include:

- Ensuring stakeholder inclusion and participation across all phases of the Project (pre-construction, construction, operation, and decommissioning);
- Promoting open, transparent, and culturally appropriate communication processes;
- Ensuring stakeholders are adequately informed about Project activities, timelines, risks, and benefits;
- Building and maintaining productive relationships between REA, NOUN, contractors, and stakeholders;
- Engaging vulnerable groups using inclusive consultation approaches;
- Providing opportunities for stakeholders to express concerns and provide feedback;
- Managing stakeholder expectations to avoid misinformation or unrealistic assumptions regarding Project benefits;
- Ensuring compliance with local regulatory requirements and international best practices;
- Ensuring stakeholder participation is free from coercion, intimidation, or manipulation.

❖ **REA's Commitment to Stakeholder Engagement**

REA is committed to implementing stakeholder engagement as an integral part of Project delivery. To this end:

- Responsibility for SEP implementation shall be clearly assigned within REA-PMU and the Contractor's management structure;
- Adequate human and financial resources shall be allocated for stakeholder engagement activities;
- Stakeholder engagement activities shall be documented and periodically reviewed;
- Engagement outcomes shall inform decision-making and Project implementation adjustments where necessary.

❖ **Key Components of the SEP**

In line with the Environmental and Social Management Framework (ESMF) applicable to REA-supported projects, an effective SEP shall:

1. Describe regulatory, lender, and institutional requirements for consultation and disclosure;
2. Identify and prioritize key stakeholder groups, with emphasis on:
   - Affected University communities,
   - Campus staff and students,
   - Nearby residents (if applicable),
   - Vendors or users of affected areas,
   - Regulatory agencies;
2. Provide a structured engagement strategy and timetable for information sharing and consultation;
3. Define roles, responsibilities, and resources required for implementation;
4. Outline grievance redress mechanisms (GRM) and reporting channels;
5. Describe how stakeholder engagement is integrated into the overall ESMP and Project management system.

A model SEP framework is available within REA's Environmental and Social Management Framework (ESMF) and shall be adapted to suit the NOUN Project context.

7.5.1.1 Grievance Redress Mechanism (GRM)

A Grievance Redress Mechanism (GRM) has been developed under REA's Environmental and Social Management Framework (ESMF), and the proposed 1-MW Solar PV Power Plant at National Open University of Nigeria (NOUN) shall adopt and operationalize this framework for the current Project. The GRM provides a structured, transparent, and accessible system for receiving and resolving Project-related complaints in a timely and fair manner. It establishes a formal process for:

- Receiving complaints from affected stakeholders;
- Registering and acknowledging grievances;
- Investigating issues raised;
- Proposing and implementing corrective actions;
- Providing feedback to complainants; and
- Documenting resolution outcomes.

The GRM shall be communicated clearly to all relevant stakeholders including University staff, students, contractors, vendors, and surrounding communities (where applicable).

Information on how to submit complaints shall be displayed at strategic locations within the Project area and campus.

The mechanism shall:

- Provide multiple reporting channels (in-person submission, phone contact, email, grievance forms, suggestion boxes);
- Ensure confidentiality for sensitive grievances, particularly those related to GBV/SEA;
- Maintain a grievance register to track the status and resolution timeline of complaints;
- Establish defined response timelines to ensure timely resolution;
- Remain functional throughout the Project lifecycle, including pre-construction, construction, operation, and decommissioning.

Periodic summaries of grievances received and resolved shall form part of ESMP monitoring reports and be reviewed by REA-PMU and NOUN management.

7.5.2 Traffic Management Plan (TMP)

The Traffic Management Plan (TMP) shall be developed to ensure safe movement of vehicles, equipment, and personnel associated with the Project, particularly during mobilization and construction activities within the NOUN campus. Given that the Project is located within an academic environment with high pedestrian activity, special emphasis shall be placed on protecting students, staff, and visitors from traffic-related risks.

The TMP shall aim to:

- Prevent road traffic accidents;
- Minimize disruption to normal campus activities;
- Protect public and University road infrastructure;
- Reduce dust and noise generated by vehicular movement.

Key measures to be included in the TMP shall include:

- Emphasizing defensive driving and safety awareness among all Project drivers;
- Maintain the alternative parking arrangement approved before Site 2 is occupied, clearly sign designated replacement parking areas, and communicate changes to campus users;
- Maintain safe, clearly marked pedestrian routes and uninterrupted emergency access, including access around the Senate Building, Central Library, Convocation Arena, DPP Building and other affected campus facilities;
- Ensuring that drivers possess valid licenses and have demonstrated competency;
- Establishing and enforcing a maximum speed limit of 20 km/hr within campus areas;
- Scheduling deliveries to avoid peak academic hours where feasible;
- Limiting trip duration and arranging driver rosters to prevent fatigue;
- Installing warning signs, barriers, and temporary traffic control measures;
- Establishing a documented procedure for reporting, investigating, and addressing traffic incidents.

The TMP shall be reviewed periodically to reflect site conditions and operational realities.

7.5.3 Waste Management Plan (WMP)

The Waste Management Plan (WMP) shall ensure that all wastes generated during Project implementation and operation are managed in accordance with national regulations and international best practice. The WMP shall apply to both hazardous and non-hazardous waste streams and shall aim to minimize environmental pollution, prevent soil and groundwater contamination, and promote resource efficiency.

The Plan shall follow the waste management hierarchy:

1. **Prevention** – Avoid generation of waste through efficient procurement and proper planning.
2. **Reduction** – Minimize waste through improved material handling and storage.
3. **Reuse** – Reuse materials where technically and economically feasible.
4. **Recycling** – Segregate recyclable materials (e.g., scrap metals, cables, packaging materials) and transfer them to licensed recyclers.
5. **Disposal** – Dispose of non-recyclable waste at approved and licensed disposal facilities.

The WMP shall specifically address:

- Management of packaging materials from PV modules and electrical components;
- Storage and disposal of e-waste (e.g., damaged PV panels, inverter components);
- Handling and recycling of spent batteries under Extended Producer Responsibility (EPR) principles;
- Safe storage of hazardous materials on impervious surfaces with secondary containment;
- Maintenance of waste tracking documentation and consignment records.

Regular inspections shall be conducted to verify compliance with the WMP.

7.5.4 Occupational Health and Safety (OHS) Plan

The Occupational Health and Safety (OHS) Plan shall establish a comprehensive framework to safeguard workers, contractors, and authorized visitors throughout the Project lifecycle. The OHS Plan shall be aligned with the World Bank General EHS Guidelines and applicable Nigerian occupational safety regulations.

Key elements of the OHS Plan shall include:

- Systematic identification of potential hazards such as electrical risks, working at height, equipment handling, fire hazards, and manual lifting injuries;
- Risk assessment procedures and implementation of mitigation measures to eliminate or minimize exposure;
- Provision of appropriate Personal Protective Equipment (PPE) at no cost to workers;
- Mandatory induction training and periodic refresher training on safety procedures;
- Emergency preparedness and response procedures, including fire drills and evacuation protocols;
- Availability of first aid kits and trained first aid personnel;
- Incident reporting, investigation, and corrective action procedures;
- Safety briefing requirements for third parties accessing the site.

The OHS Plan shall promote a safety-first culture and continuous improvement in health and safety performance.

7.5.5 Local Employment Management Plan (LEMP)

The Local Employment Management Plan (LEMP) shall aim to maximize local economic benefits arising from the Project while promoting fairness and non-discrimination in recruitment processes.

The LEMP shall:

- Establish realistic targets for engagement of local labour, particularly for semi-skilled and unskilled roles;
- Encourage internship or training opportunities for NOUN students where feasible;
- Ensure employment opportunities are first communicated within the University and local community before wider advertisement;
- Communicate available employment and training opportunities transparently within NOUN and to the relevant local labour pool before wider recruitment, where practicable, without displacing merit-based selection requirements;
- Promote equal opportunity employment and prohibit discrimination;
- Maintain verifiable employment and training records;
- Monitor workforce composition and report periodically on local employment performance.

The Plan shall support skills transfer, capacity development, and positive community relations.

7.5.6 Erosion Control Management Plan

The Erosion Control Management Plan shall provide measures to prevent soil erosion, sedimentation, and stormwater-related impacts during construction activities. Given the site's drainage characteristics and seasonal rainfall patterns, proactive erosion control shall be integrated into construction planning.

The Plan shall include:

- Limiting vegetation clearing strictly to approved Project footprints;
- Controlling slopes of cut and fill areas in accordance with final design specifications;
- Locating temporary stockpiles in stable, flat areas away from drainage channels;
- Installing silt traps, sediment barriers, or similar control measures where necessary;
- Protecting exposed soils using temporary coverings such as bio-membranes or plastic sheeting;
- Prompt stabilization and re-vegetation of disturbed areas.

Regular site inspections shall ensure erosion control measures remain effective, particularly after rainfall events.

7.5.7 Water Conservation Plan

The Water Conservation Plan shall ensure efficient and sustainable use of water resources during both construction and operational phases of the Project. Although water demand for the Project is relatively low, responsible water management shall be maintained to avoid unnecessary abstraction and wastage.

The Plan shall include:

- Minimization of water use during construction activities;
- Controlled abstraction of groundwater for PV panel cleaning;
- Monitoring and documentation of water usage volumes;
- Adoption of efficient cleaning techniques to reduce water consumption;
- Prohibition of chemical cleaning agents that could contaminate soil or groundwater;
- Periodic review of water use efficiency and conservation performance.

The Plan shall ensure that groundwater abstraction remains within sustainable limits and does not adversely affect local aquifer conditions.

7.5.8 Emergency Preparedness and Response Plan (EPRP)

An Emergency Preparedness and Response Plan (EPRP) shall be developed and implemented for the proposed 1-MW Solar PV Power Plant at NOUN to ensure readiness and effective response to emergency situations that may arise during construction and operation. The EPRP shall establish a structured framework for preventing, managing, and responding to emergencies in a manner that safeguards human life, property, and the environment. The Plan shall be aligned with applicable national regulations, World Bank General EHS Guidelines, and recognized international best practices.

As part of the EPRP:

- The fire protection system for the Project shall be designed in accordance with applicable national fire safety regulations and relevant standards comparable to the National Fire Protection Association (NFPA) requirements.
- Grounding and lightning protection systems shall be installed and tested to ensure that ground potential gradients are maintained within safe limits under both normal and fault conditions.
- Electrical isolation and emergency shutdown procedures shall be clearly defined and displayed within the control room and inverter stations.

The EPRP shall include procedures for addressing reasonably foreseeable emergency scenarios, including but not limited to:

- Fire outbreaks (in inverter stations, battery storage systems, control room);
- Electrical faults and arc flash incidents;
- Spill or release of hazardous substances (e.g., lubricants, fuels, battery electrolyte);
- Medical emergencies;
- Extreme weather events (e.g., heavy rainfall, windstorms);
- Security-related incidents.

The Plan shall address the following aspects:

- Identification of potential emergency scenarios and development of specific response procedures for each scenario;
- Designation and training of emergency response personnel;
- Identification of emergency contact numbers (fire service, medical services, University security, REA-PMU);
- Establishment of clear communication and reporting protocols;

- Provision of emergency equipment and facilities (fire extinguishers, first aid kits, spill kits, PPE, emergency signage);
- Development of decontamination and site clean-up procedures to contain and reduce environmental impacts;
- Identification of risks associated with uncontrolled release of hazardous materials and preparation of spill prevention and response procedures.

The spill prevention, control, and response component shall include:

- Training of personnel on spill prevention and response;
- Routine inspection of secondary containment structures;
- Standard operating procedures (SOPs) for transfer and storage of hazardous materials;
- Availability of appropriate PPE and spill response equipment at designated locations.

Regular drills and simulation exercises shall be conducted to test the effectiveness of the EPRP and improve response capacity.

7.5.9 REA Gender-Based Violence (GBV) Action Plan

The GBV Action Plan shall be implemented throughout the Project lifecycle to prevent, mitigate, and respond to potential GBV/SEA risks associated with Project activities. The Plan builds upon the GBV risk assessment conducted as part of this ESIA and integrates mitigation measures within the ESMP framework.

Key components of the GBV Action Plan include:

- Conducting and updating a GBV risk assessment as necessary;
- Integrating GBV risk management measures into contractual obligations;
- Requiring REA-PMU to define GBV compliance requirements in contractor bidding documents, including mandatory hiring of a Gender/GBV Officer;
- Evaluating contractor GBV response protocols prior to contract award;
- Ensuring GBV-sensitive reporting channels are embedded within the Project GRM;
- Informing Project-affected stakeholders (University community and nearby users) about GBV risks and reporting mechanisms;
- Ensuring all workers sign and understand a Code of Conduct (CoC) prohibiting GBV/SEA;
- Conducting mandatory induction and periodic refresher training on acceptable behavior and workplace ethics;
- Providing separate sanitation facilities for men and women and installing GBV-free signage at the Project site.

Timely and consistent implementation of the GBV Action Plan shall significantly reduce the likelihood of GBV/SEA risks during both construction and operation phases and promote a safe working and learning environment within NOUN.

7.5.10 Cost for Implementation of Additional Management Plans

Table 7.7 presents a summary of the additional management plans required to support effective implementation of the ESMP. These plans shall be developed primarily during

the pre-construction phase to ensure that adequate systems, procedures, and institutional arrangements are in place before commencement of physical works. The estimated costs reflect preparation, documentation, stakeholder consultation (where required), and initial training/awareness activities associated with each plan.

Table 7.7: Summary of Additional Management Plans

S/N	Management Plan	Timing for Development	Estimated Cost (US$)
1	Emergency Preparedness and Response Plan (EPRP)	Pre-Construction	*2,500*
2	Traffic Management Plan (TMP)	Pre-Construction	*2,500*
3	Waste Management Plan (WMP)	Pre-Construction	*3,500*
4	Occupational Health and Safety (OHS) Plan	Pre-Construction	*2,500*
5	Local Employment Management Plan (LEMP)	Pre-Construction	*2,000*
6	Erosion and Sediment Control Plan	Pre-Construction	*2,500*
7	Water Conservation Plan	Pre-Construction	*1,500*
8	Gender-Based Violence (GBV) Action Plan	Pre-Construction	*2,500*
Total Estimated Cost			***19,500***

7.6 Training, Awareness and Capacity Building

Effective implementation of the Environmental and Social Management Plan (ESMP) depends not only on the existence of mitigation measures but also on the competence, awareness, and commitment of personnel responsible for executing them. Therefore, structured training, awareness creation, and institutional capacity strengthening shall form a core component of Project implementation. REA-PMU, in collaboration with NOUN management and the Contractors, shall identify, plan, implement, and document training needs for personnel whose activities may significantly influence environmental and social performance. Training programs shall be tailored to the specific responsibilities of staff during the pre-construction, construction, commissioning, and operational phases.

The objectives of the training and capacity-building program include:

- Ensuring clear understanding of ESMP mitigation measures;
- Strengthening institutional capacity for environmental and social monitoring;
- Promoting occupational health and safety compliance;
- Enhancing emergency preparedness and response capability;
- Improving record-keeping and reporting practices;
- Promoting responsible behavior and ethical conduct among workers.

Training shall be delivered through induction sessions, refresher courses, toolbox talks, workshops, and practical demonstrations, depending on the subject matter and target audience. In addition to Project personnel, members of the University community and relevant stakeholders shall receive awareness training on environmental protection, safety, grievance redress mechanisms, and GBV risk mitigation. This shall promote shared responsibility and transparency in ESMP implementation.

Table 7.8: Institutional Capacity Strengthening Plan

Target Audience	Training Overview	Estimated Cost (US$)
NOUN Site Engineer, EPC Contractor and Sub-contractors, O&M Contractor	• Capacity building at the PMU In-depth understanding of ESMP mitigation measures. • Training on emergency response procedures. • Training on Health, Environment, Safety and Security (HESS) Management Plan. • Reporting, monitoring, and documentation requirements.	*1,200*
University Community / Local Stakeholders	• General environmental awareness. • Community health and safety measures. • Overview of grievance redress procedures. • Awareness on GBV/SEA risk mitigation measures.	*700*
Total		***1,900***

7.7 Implementation Schedule and Reporting

The ESMP shall be implemented as an integrated component of Project execution, beginning from the planning and design stage and continuing through construction, commissioning, operation, and eventual decommissioning. Implementation at early planning stages ensures that environmental and social considerations are incorporated into procurement decisions, contractor mobilization, and engineering design. This proactive approach reduces risks, enhances compliance, and promotes sustainable project outcomes.

During Project implementation, designated environmental and social officers shall conduct routine inspections and monitoring activities in accordance with the Environmental Monitoring Program. Findings from these inspections shall be documented and communicated to relevant authorities within REA-PMU and NOUN management.

Where non-compliance or emerging risks are identified:

- Immediate corrective actions shall be initiated;
- Root causes shall be investigated;
- Preventive measures shall be implemented to avoid recurrence.

REA shall maintain open communication with regulatory authorities, including:

- Federal Ministry of Environment (FMEnv);
- National Environmental Standards and Regulations Enforcement Agency (NESREA);
- Abuja Environmental Protection Board.

Periodic reports shall be submitted to regulators as required, and documentation shall be maintained to demonstrate compliance with applicable environmental and social obligations.

Key documentation to be maintained includes:

- Environmental monitoring records;
- Health and safety inspection reports;
- Training attendance registers;
- Incident and accident logs;
- Grievance registers and resolution records;
- Waste tracking documentation;
- Corrective action reports.

Proper reporting and documentation will ensure transparency, accountability, and continuous improvement in environmental and social performance.

7.8 ESMP Costing

Effective implementation of the ESMP requires adequate financial provision to support mitigation measures, monitoring activities, management plan preparation, training programs, and institutional strengthening.
The estimated ESMP cost covers:

- Environmental and social mitigation during all Project phases;
- Development of additional management plans;
- Capacity building and awareness programmes;
- Environmental and social monitoring activities.

These cost estimates are based on anticipated resource requirements, monitoring frequency, regulatory compliance obligations, and administrative support needs. The costs shall be incorporated into the overall project budget to ensure availability of funds for timely implementation.

Table 7.9: Cost of ESMP Implementation

S/N	ESMP Activities	Cost (USD)
1	Pre-Construction Phase Implementation (disclosure, staffing, approvals, early monitoring)	*5,666.67*
2	Construction Phase ESMP Implementation (monitoring, mitigation execution, supervision, reporting)	*18,000*
3	Operational Phase ESMP Implementation (monitoring, waste management oversight, safety compliance)	*8,000*
4	Commissioning Phase ESMP Activities (inspection, testing oversight, reporting)	*500*
5	Direct Mitigation Measures (environmental controls, erosion measures, safety controls, signage, etc.)	*6,100*
6	Capacity Building and Training	*1,900*
7	Additional Management Plans	*19,500*
TOTAL ESTIMATED ESMP COST		***59,666.67***

7.9 Stakeholder Engagement

Stakeholder engagement is a continuous, systematic, and inclusive process of information sharing, consultation, and collaboration between the Project Proponent and stakeholders who may be affected by or have an interest in the Project. It involves proactive disclosure of relevant information, active listening, meaningful dialogue, and incorporation of stakeholder feedback into project planning and decision-making.

Effective stakeholder engagement ensures that:

- Stakeholders are adequately informed about the nature, scope, and objectives of the project;
- Environmental and social risks are clearly communicated;
- Potential impacts are understood by affected communities;
- Concerns are identified early and addressed appropriately;
- Trust and constructive relationships are built over time.

Consultation is a critical element of engagement and must go beyond one-time meetings. It should be conducted in a manner that is culturally appropriate, inclusive, gender-sensitive, and accessible to vulnerable groups. Information disclosed must be understandable, using clear language and suitable formats. Stakeholders must receive sufficient information prior to consultation sessions to allow them to meaningfully participate in discussions and provide informed input.

For the proposed project at NOUN, stakeholder engagement was designed to:

- Facilitate early dialogue during the ESIA process;
- Identify community expectations and potential concerns;
- Integrate local knowledge into environmental and social baseline assessments;
- Strengthen transparency and accountability in project development.

Engagement activities shall continue throughout construction, operation, and decommissioning phases to ensure sustained communication and responsiveness.

7.9.1 Objectives of Stakeholder Engagement

The stakeholder engagement process for the proposed Project at NOUN was structured to align with Nigerian regulatory requirements and international best practice.
The specific objectives include:

- Informing and educating stakeholders about the proposed Solar PV Project, including its technical scope and anticipated benefits;
- Gathering local knowledge and context-specific information to strengthen baseline environmental and social assessments;
- Identifying locally important environmental and social concerns;
- Providing stakeholders with an opportunity to influence Project planning and mitigation measures;
- Ensuring transparency in environmental and social decision-making;
- Laying the foundation for long-term collaboration and communication.

The engagement process is not limited to the ESIA stage but shall continue throughout the Project lifecycle to ensure sustained stakeholder involvement and responsiveness.

7.9.2 Stakeholder Identification and Analysis

Stakeholders are defined as individuals, groups, or institutions who:

- Are directly or indirectly affected by the Project;
- Have interests in the Project's outcomes; or
- Have the ability to influence Project implementation, either positively or negatively.

Stakeholders for the proposed Project may include:

- University management and staff;
- Students and campus residents;
- Local government authorities;
- Regulatory agencies;
- Contractors and service providers;
- Vulnerable groups, including women, youth, elderly persons, and persons with disabilities.

Stakeholder identification was undertaken systematically to ensure that no relevant group was excluded. Stakeholders were analyzed based on:

- Level of influence over Project decisions;
- Degree of interest in Project outcomes;
- Proximity to Project activities;
- Potential vulnerability to adverse impacts.

This analytical approach ensures that engagement strategies are tailored appropriately, with greater emphasis placed on groups that are highly affected or particularly vulnerable.

The EPC Contractor shall develop and implement a comprehensive Stakeholder Engagement Plan (SEP), which shall:

- Identify key stakeholder groups;
- Define engagement methods and frequency;
- Assign responsibilities for engagement activities;
- Establish monitoring and reporting procedures.

The SEP shall be maintained and updated throughout the Project lifecycle to reflect changing circumstances or stakeholder dynamics. A detailed list of identified stakeholders for the Project is presented in Table 7.10.

Table 7.10: Identified Stakeholders Associated with the Proposed Project

Stakeholder Group and Interest in the Proposed Project	Stakeholder Name	International	National	State	Local	Connection to the Proposed Project
Project Sponsor / Financier	AfDB	✓				Provides financial and technical support for Project implementation under the Energizing Education Programme

Stakeholder Group and Interest in the Proposed Project	Stakeholder Name	International	National	State	Local	Connection to the Proposed Project
						(EEP). Ensures compliance with World Bank safeguard policies.
Regulatory Authorities	Federal Ministry of Environment (FMEnv)		✓			Oversees ESIA process; ensures compliance with national environmental regulations; reviews and approves environmental documentation.
	National Environmental Standards and Regulations Enforcement Agency (NESREA)		✓			Monitors compliance with national environmental standards during operation; enforces environmental regulations.
	Federal Ministry of Power (Department of Renewable Energy)		✓			Coordinates renewable energy policy implementation and supports federal renewable energy initiatives.
	Abuja Environmental Protection Board			✓		Oversees environmental protection and compliance at state level; conducts inspections and monitoring.
	Abuja Environmental Protection Board)			✓		Responsible for waste management regulation and environmental

Stakeholder Group and Interest in the Proposed Project	Stakeholder Name	International	National	State	Local	Connection to the Proposed Project
						sanitation oversight within the State.
	Abuja Municipal Area Council				✓	Local administrative authority within whose jurisdiction the Project site is located.
University Representatives	NOUN Management				✓	Direct Project beneficiaries; institutional host of the Solar PV plant.
	Department of Works and Physical Planning (NOUN)				✓	Responsible for infrastructure planning, site oversight, and ESMP supervision.
	NOUN Student Union Government				✓	Represents student body; direct beneficiary of improved electricity supply.

7.9.3 Stakeholder Register

A comprehensive Stakeholder Register shall be developed and maintained for the Project as part of the Stakeholder Engagement Plan (SEP). The Stakeholder Register will serve as a structured database for documenting all stakeholder-related information and engagement activities throughout the Project lifecycle.

The register shall include, at a minimum:

- Name of stakeholder (individual, group, or institution);
- Stakeholder category and level (international, national, state, local);
- Contact details (where appropriate);
- Date and method of engagement (meeting, consultation, email, workshop, etc.);
- Key issues raised or concerns expressed;
- Agreed follow-up actions;
- Responsible party for follow-up;
- Status of resolution or response.

The Stakeholder Register will ensure systematic tracking of stakeholder interactions and provide evidence of compliance with engagement requirements under both national regulations and World Bank safeguard policies.
The register shall be updated regularly during:

- Pre-construction;
- Construction;
- Operation; and
- Decommissioning phases.

It shall also serve as an internal monitoring tool to evaluate the effectiveness of engagement activities and to ensure that stakeholder concerns are addressed in a timely and transparent manner.

7.9.4 Stakeholder Engagement Process

REA-PMU shall adopt a proactive, structured, and continuous approach to stakeholder engagement, aimed at building and maintaining mutually beneficial relationships with all relevant stakeholders throughout the Project lifecycle.
The engagement process shall:

- Comply with applicable Nigerian laws and regulations;
- Align with World Bank safeguard requirements;
- Be transparent, inclusive, and culturally appropriate;
- Be free of manipulation, interference, coercion, and intimidation;
- Be conducted using information that is timely, relevant, understandable, and accessible.

Stakeholder engagement shall be undertaken using various methods, including:

- Public meetings and consultation sessions;
- Focus group discussions;
- Workshops and technical briefings;
- Disclosure of Project information through appropriate media;
- Continuous communication through designated focal persons.

Effective stakeholder engagement is built on mutual trust, respect, and open communication. It strengthens Project governance and improves environmental and social performance. The engagement process enhances Project implementation in the following ways:

• Managing Costs
Early and effective engagement helps REA anticipate concerns and resolve issues before they escalate into disputes, project delays, or reputational risks. By proactively addressing stakeholder concerns, the Project can avoid potential financial losses and administrative burdens.

• Managing Risk
Engagement allows REA and affected communities to identify environmental and social risks at an early stage. This enables the development of appropriate mitigation measures, reducing the likelihood of conflict, regulatory penalties, or operational disruptions.

• Enhancing Institutional Reputation

Transparent engagement and adherence to environmental and social safeguards strengthen REA's institutional credibility. Demonstrating commitment to environmental protection, social responsibility, and human rights enhances public trust and supports continued collaboration with development partners such as the World Bank.

• Avoiding Conflict
Open dialogue fosters understanding of local priorities, land-use concerns, and community expectations. Addressing these issues early reduces the risk of misunderstandings, grievances, and disputes.

• Improving Policy and Decision-Making
Stakeholder feedback provides valuable insights into community perceptions and local realities. This information can inform improvements in Project design, mitigation measures, and corporate policies.

• Identifying, Monitoring, and Reporting Impacts
Engagement facilitates ongoing monitoring of Project impacts and ensures that mitigation measures remain responsive to stakeholder concerns. It also supports transparent reporting on environmental and social performance.

• Managing Stakeholder Expectations
Continuous consultation enables REA to clarify Project scope, benefits, and limitations, thereby preventing unrealistic expectations. Clear communication helps align stakeholder understanding with Project realities. Through this structured and inclusive engagement approach, REA aims to promote long-term cooperation, minimize risks, and enhance the sustainability of the 1-MW Solar PV Project at NOUN.

Table 7.11 presents the key elements of the Stakeholder Engagement Programme to be implemented by REA-PMU for the proposed Project. The engagement programme is designed to ensure continuous, structured, and transparent interaction with stakeholders throughout the Project lifecycle. The programme incorporates identification, consultation, disclosure, grievance management, and reporting mechanisms to ensure compliance with both national regulatory requirements and international best practice standards.

Table 7.11: 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 and periodically update a Stakeholder Register throughout the Project lifecycle. Stakeholder mapping shall be reviewed on a need basis, particularly when new stakeholders emerge or when Project activities expand or change.
Information Disclosure	REA shall ensure that relevant environmental and social information is disclosed to stakeholders in a timely, understandable, and accessible manner. Information shall be communicated through appropriate channels such as meetings, notices, reports, and digital platforms. Continuous communication shall be maintained throughout Project implementation.

Stakeholder Engagement Activity	Approach
Stakeholder Consultation	REA shall conduct consultations with stakeholders on issues of mutual concern, including environmental and social risks, mitigation measures, and Project progress. Consultations shall be documented, and records shall be maintained as evidence of engagement. Feedback received shall be considered in decision-making processes.
Negotiation and Partnerships	REA shall adopt a stakeholder management approach that promotes mutual respect and shared value creation. Where appropriate, partnerships shall be established with institutions, community groups, and regulatory bodies to enhance Project sustainability and social acceptance.
Grievance Management	REA shall establish and maintain appropriate channels through which stakeholders can raise concerns or grievances. The Grievance Redress Mechanism (GRM) shall be transparent, accessible, and responsive. All grievances shall be documented, tracked, and resolved within defined timelines.
Stakeholder Involvement	REA shall promote procedures that enable direct stakeholder involvement in relevant Project-related activities, particularly those affecting community welfare. This may include participatory consultations, feedback sessions, and community monitoring activities to foster transparency and credibility.
Reporting to Stakeholders	REA shall establish a structured reporting system to disclose information on environmental, social, and economic performance. Reports may include monitoring results, implementation progress, and corrective actions taken. Information shall be shared periodically and upon request where appropriate.
Management Functions	REA shall build and maintain adequate internal capacity to manage stakeholder engagement effectively. This includes assigning clear responsibilities, tracking commitments, maintaining documentation, and reporting on engagement outcomes. Continuous improvement of engagement processes shall be encouraged.

7.9.5 Stakeholder Engagement Tools and Communication

REA recognizes that effective stakeholder engagement requires tailored communication strategies that reflect the interests, level of influence, and information needs of different stakeholder groups. A “one-size-fits-all” approach is not appropriate for a project of this nature. Therefore, REA shall adopt a flexible and inclusive communication framework designed to promote transparency, participation, and trust throughout the Project lifecycle. The engagement approach shall ensure that information is disclosed in a timely, understandable, and culturally appropriate manner. Communication channels will be selected based on stakeholder characteristics, literacy levels, accessibility considerations, and the sensitivity of the subject matter. Special consideration shall be given to vulnerable groups to ensure equitable access to information and participation opportunities. Table 7.12 presents the engagement tools and communication methods that may be adopted by REA during the Project lifecycle.

Table 7.12: Stakeholder Engagement Tools and Communication

Medium	Most Appropriate Application
Stakeholder Meetings / One-on-One Consultations	REA shall, on a need basis, hold individual consultation meetings with key stakeholders including regulatory authorities, university management, and community representatives. These meetings will be used to: ● Solicit views and opinions; ● Discuss stakeholder concerns confidentially where necessary; ● Provide feedback on Project developments; ● Build and maintain constructive working relationships.
Focus Group Discussions (FGDs)	REA shall organize FGDs to bring together small groups of stakeholders with shared interests. FGDs will have clearly defined objectives and will be structured to generate meaningful dialogue on specific environmental or social issues.
Workshops	Workshops shall be conducted to address specific environmental and social themes such as waste management, GBV awareness, occupational health and safety, and stakeholder participation. Participatory tools will be used to facilitate brainstorming, problem-solving, and development of practical recommendations.
Forums / Town Hall Meetings	REA may organize broader stakeholder forums where multiple stakeholder categories are represented. These forums promote transparency, collective dialogue, and consensus building, particularly where issues are complex or potentially contentious.
Written / Visual / Electronic Communication	REA shall use appropriate written and digital channels to disseminate information. These may include: ● Project newsletters; ● Emails and official correspondence; ● Executive Summary of the ESIA; ● Notices and print media publications; ● Surveys and feedback forms; ● Institutional websites and digital platforms where applicable.

Table 7.13 presents the consultation approaches applicable to major stakeholder groups. The frequency and depth of engagement shall be determined based on Project phase, stakeholder interest, and regulatory requirements.

Table 7.13: Stakeholder Group Consultation Methods

Stakeholder Group	Consultation Method
Government and Regulators	● Email exchanges and formal correspondence ● One-on-one consultations ● Formal review meetings ● Compliance reporting ● Environmental and social performance reports ● Audit submissions
Project Financiers (AFDB)	● Formal review meetings ● Compliance reporting ● Environmental and social performance reports

Stakeholder Group	Consultation Method
Project Beneficiaries (NOUN Management, Physical Planning Department, Students)	• Formal meetings • One-on-one consultations • Information circulars and notices • Strategic collaboration sessions • Information Centre/Help Desk (where applicable)
Employees (EPC and O&M Contractors)	• Phone / email / text messaging / digital platforms • Workshops and toolbox meetings • Focus group discussions • Surveys and feedback mechanisms • Departmental meetings • Performance appraisals • Capacity-building trainings

7.9.6 Principles for Effective Stakeholder Engagement

Stakeholder engagement for the proposed Project is guided by internationally recognized best practice principles. These principles define the core values that underpin all interactions with stakeholders and ensure that engagement is meaningful, ethical, and outcome oriented. For the 1-MW Solar PV Project at NOUN, stakeholder engagement shall be implemented in accordance with the following principles:

- **Commitment:**
  REA-PMU demonstrates commitment by recognizing the importance of identifying, understanding, and engaging relevant stakeholders throughout the Project lifecycle. Engagement activities shall not be treated as a one-off requirement but as a continuous process integrated into Project planning and implementation.

- **Integrity:**
  Engagement shall be conducted in good faith, with honesty and consistency. Information provided to stakeholders shall be accurate, reliable, and not misleading. This approach fosters mutual respect and strengthens long-term relationships.

- **Respect:**
  The rights, values, cultural norms, and interests of stakeholders shall be acknowledged and respected. Special attention shall be given to vulnerable groups to ensure that their voices are heard and considered in decision-making processes.

- **Transparency:**
  Stakeholder concerns shall be addressed in a timely, open, and clear manner. Decisions affecting stakeholders shall be communicated promptly, and justification for such decisions shall be provided where necessary.

- **Inclusiveness:**
  Broad participation shall be encouraged by providing accessible and appropriate consultation opportunities. Engagement methods shall be adapted to ensure

effective participation across different literacy levels, gender groups, and socio-economic categories.

- **Trust:**
  Trust shall be built and maintained through open dialogue, consistent communication, responsiveness to concerns, and visible implementation of agreed mitigation measures.

These guiding principles will ensure that stakeholder engagement for the Project remains constructive, transparent, and aligned with both national requirements and international standards.

7.9.7 Summary of Previous Stakeholder Engagement Activities

As part of the ESIA process, initial stakeholder consultations were conducted to introduce the Project, gather relevant information, and identify potential environmental and social concerns at an early stage. These early consultations helped shape the impact assessment process and informed the development of mitigation measures and management plans.

The engagement with NOUN representatives was conducted on the 3rd of July, 2026, the entire university community including all University Staff (both academic and non - academic), project employees and contractors, were accorded the opportunity to participate actively in the consultation process. This was to obtain baseline information, identify potential concerns and incorporate local perspectives into the ESIA process. However, no students participated because the institution was not in academic session as at the time of the survey. However, stakeholder engagements are expected to be continuous throughout the project lifespan.

Engagement activities included formal meetings, one-on-one consultations, and interactive discussions designed to encourage stakeholder participation and feedback.

The consultations served multiple objectives, including:

- Providing stakeholders with background information on the proposed Solar PV Project;
- Explaining the scope, objectives, and anticipated benefits of the Project;
- Identifying key environmental and social concerns;
- Gathering local knowledge to support the ESIA baseline assessment; and
- Establishing an early foundation for ongoing stakeholder engagement.

Prior to consultations, notification letters and Background Information Documents (BIDs) were issued to the stakeholders to ensure informed participation. Stakeholder feedback received during these consultations was documented and incorporated into the ESIA process, particularly in the identification of potential impacts and development of mitigation measures. The engagement process demonstrated stakeholder interest in the Project and highlighted the importance of continued communication throughout construction and operational phases.

Table 7.14: Initial Stakeholder Consultation Findings at NOUN

Stakeholder	Priority Issues	Key Comments	Response
Abuja Environmental Protection Board	ESIA process and stakeholder consultation	• The Project is a welcome development. • All relevant Project information should be clearly presented in the ESIA report. • All relevant stakeholders must be identified and consulted. • Impact identification and analysis must be comprehensive. • Interactions with biophysical and socio-economic components must be assessed. • Youth employment opportunities should be considered.	• Relevant stakeholders have been identified and will continue to be consulted throughout the ESIA process. • The ESIA includes a detailed impact assessment covering physical, biological, and socio-economic components. • Mitigation measures have been developed to address identified impacts. • A percentage of the workforce will be drawn from the host community. • A Waste Management Plan, including e-waste management, will be developed and implemented.
NOUN Vice Chancellor	Sustainability and institutional commitment	• The University is committed to ensuring sustainability of the Project. • Adequate security arrangements will be provided. • Female students should not be marginalized.	• All concerns noted and integrated into planning. • Gender inclusion measures are incorporated into the ESMP and GBV Action Plan. • Sustainability measures will be implemented through proper O&M arrangements.
NOUN Director of Physical Planning and Development	Land availability, infrastructure and waste management	• The selected site has been approved by the University. • No security concerns associated with the site. • Alternative farmlands will be provided to affected farmers. • Waste is currently managed through designated disposal systems.	• Waste Management Plan will include e-waste provisions. • Livelihood Restoration Plan (LRP) will address farmer displacement. • Skill acquisition opportunities will be integrated during Project development.

Stakeholder	Priority Issues	Key Comments	Response
NOUN Teaching Hospital Representatives	Reliable power supply and technical sustainability	• The Hospital requires steady 24-hour electricity. • Equipment must be of high quality. • Engineers should be trained for operation and maintenance. • Voltage supply must meet demand.	• The Project is designed to provide reliable and stable electricity. • Only certified and quality-assured components will be installed. • Training opportunities will be provided. • An energy audit was conducted to determine appropriate capacity and voltage requirements.
NOUN Principal Architect	Improved power supply and student involvement	• Current electricity supply is inadequate. • The Project is a welcome development. • Students would be willing to participate engagement but are not available.	• Engagement will continue during Project implementation and the students will be availed the opportunity to partake. • Concerns have been noted and integrated into ESMP commitments.
AMAC Representatives	Community benefits and employment	• The Project is a welcome development. • Local employment opportunities are expected.	• A percentage of the workforce will be sourced from the host community. • Local content considerations will be applied where feasible.

7.10 Management Function and Grievance Mechanism

The Grievance Redress Mechanism (GRM) shall be implemented throughout the pre-construction, construction, operation and decommissioning phases of the project and shall be coordinated by the Rural Electrification Agency (REA) in collaboration with the National Open University of Nigeria (NOUN). The mechanism aims to ensure that grievances are addressed promptly, fairly, confidentially and without fear of retaliation. Effective stakeholder engagement requires a clearly defined management structure supported by institutional commitment, adequate resources, and accountability mechanisms. For the proposed Project, REA-PMU shall ensure that stakeholder engagement and grievance management are fully integrated into the overall Project governance framework.

7.10.1 Management Commitment

REA is committed to implementing stakeholder engagement as an integral component of Project planning, construction, operation, and eventual decommissioning. Stakeholder engagement shall not be treated as a compliance formality, but as a strategic management tool to promote transparency, reduce risks, and enhance Project sustainability. To ensure effective implementation of the Stakeholder Engagement Plan (SEP), REA shall:

- Assign clear responsibilities for stakeholder engagement within its organizational structure;

- Define reporting lines and decision-making authority for stakeholder-related matters;
- Allocate adequate financial and human resources for SEP implementation; and
- Integrate stakeholder engagement into routine Project management processes.

The management structure for implementing the SEP shall include the following key elements:

Systems
REA shall implement stakeholder engagement activities in a structured and systematic manner. Engagement schedules, documentation procedures, and grievance tracking systems shall be maintained to ensure predictability, transparency, and accountability. This systematic approach is intended to foster long-term trust between the Project and its stakeholders.

Structure
REA shall establish a stakeholder-focused structure within the Project Management Unit (PMU). This structure will ensure that stakeholder concerns and grievances are addressed promptly and efficiently. Clear authority shall be granted to designated officers to facilitate timely decision-making and feedback.

Skills
REA shall ensure that personnel responsible for stakeholder engagement possess the necessary technical, communication, and conflict-resolution skills. Where required, capacity-building programmes shall be conducted to strengthen internal capacity in stakeholder management, grievance handling, gender-sensitive communication, and community relations.

7.10.2 Roles and Responsibilities

REA shall assign responsibility for organizing and conducting stakeholder consultation to competent individuals with relevant qualifications and experience in environmental and social management. The key responsibilities shall include:

- The **REA Project Management Unit (PMU)** shall have overall responsibility for oversight of the SEP implementation and grievance management framework.
- The **NOUN Community Liaison Officer (CLO)** shall serve as the primary focal point for stakeholder engagement at the University level. The CLO shall facilitate stakeholder meetings and consultations; Maintain the stakeholder engagement register; Receive and document grievances at the University level; Monitor implementation of stakeholder engagement activities; and Report periodically to the REA-PMU on stakeholder concerns and grievance resolution status.

This defined structure ensures clear accountability and an effective communication channel between stakeholders, the University, and REA-PMU.

7.10.3 Grievance Redress Mechanism (GRM)

A Grievance Redress Mechanism (GRM) has been developed by REA for implementation across all components of the Nigeria Electrification Project (NEP), including the Energizing Education Programme (EEP) under which this Project falls. The GRM provides

a formal, structured process through which Project Affected Persons (PAPs), community members, workers, and other stakeholders may raise concerns or complaints related to Project activities.

The objectives of the GRM are to:

- Provide accessible and transparent channels for grievance submission;
- Ensure grievances are addressed in a fair, timely, and cost-effective manner;
- Prevent minor issues from escalating into major disputes;
- Strengthen stakeholder trust and accountability; and
- Promote continuous improvement in Project implementation.

The GRM is designed to be:

- Legitimate and transparent;
- Culturally appropriate and easily accessible;
- Inclusive of vulnerable groups and persons living with disabilities;
- Free of intimidation, retaliation, or discrimination.

❖ **Key Components of the GRM**

The GRM framework includes the following elements:

- **Identification of Core Institutional Structures** for the EEP, including roles of REA-PMU, University representatives, and community-based structures;
- **Grievance Uptake Points**, including clearly defined communication channels such as: Physical complaint registers; Email and telephone contacts; Community Liaison Officer (CLO); Dedicated grievance boxes where applicable;
- **Defined Timelines** for acknowledgment, investigation, and resolution of grievances;
- **PMU-Level Grievance Redress Committee (GRC)** with clearly defined membership and responsibilities;
- **Community-Based Grievance Redress Committee**, where applicable, to address grievances at the lowest possible level before escalation;
- A structured **GRM process flow** outlining escalation procedures where grievances cannot be resolved at the initial level.

The GRM shall be communicated to stakeholders during consultation meetings and displayed at appropriate locations within the Project area to ensure accessibility. - (Kindly refer REA-NEP in-house explicit budget implementation)

All grievances received shall be:

- Logged in a grievance register;
- Categorized based on type and severity;
- Investigated in a timely manner;
- Resolved within established timeframes; and
- Documented with evidence of closure.

Periodic reports on grievance trends and resolution status shall be submitted to REA-PMU and made available to regulatory authorities upon request. The steps and timeline involved for resolving a complaint received is described on Table 7.15

Table 7.15: Grievance Resolution Procedure

Steps	Activity	Timeline
1	Receive complaint	Day 0
2	Register complaint and assign reference number	Within 24 hours
3	Acknowledge receipt to complainant	Within 48 hours
4	Preliminary screening and classification	Within 3 working days
5	Investigation by Grievance Committee	Within 7 working days
6	Decision and proposed corrective action	Within 14 working days
7	Communicate outcome to complainant	Within 15 working days
8	Implement corrective action	Within 30 working days
9	Close grievance after complainant confirms satisfaction	Immediately after resolution
10	Appeal to higher authority if unresolved	Within 14 days of decision

7.10.4 Special Procedures for GBV/SEA/SH Cases

Complaints relating to Gender-Based Violence (GBV), Sexual Exploitation and Abuse (SEA) or Sexual Harassment (SH) shall:

- be handled confidentially;
- not be discussed during general GRC meetings;
- be managed only by trained GBV focal persons;
- follow survivor-centred principles;
- be referred immediately to appropriate support services;
- protect survivor identity;
- comply with Nigerian law and AfDB safeguard requirements

7.10.5 Grievance Redress Mechanism (GRM) Tools

There are several tools that will be adopted throughout the project lifecycle to facilitate effective grievance management, documentation, monitoring and reporting. These include:

- Grievance Registration Form
- Grievance Register
- Grievance Investigation Form
- Corrective Action Tracking Register
- Grievance Resolution Acceptance Form
- Monthly GRM Performance Monitoring Sheet
- GBV/SEA/SH Confidential Reporting Form
- Stakeholder Complaint Log

CHAPTER EIGHT
REMEDIATION PLAN AFTER DECOMMISSIONING / CLOSURE

8.1 Introduction

This chapter outlines the approach to decommissioning and post-closure remediation of the proposed 1-MW Solar Hybrid Power Plant at the National Open University of Nigeria (NOUN). It describes the anticipated decommissioning activities, identifies potential environmental and social impacts associated with such activities, and presents management and remediation measures to ensure that the Project site is restored to a safe and environmentally acceptable condition.

Although solar PV facilities are generally characterized by low operational emissions and limited long-term environmental risks, proper end-of-life planning is essential to prevent contamination, ensure safe dismantling of electrical systems, and promote responsible material recovery and recycling.

This chapter therefore provides:

- An overview of decommissioning activities;
- A framework for managing environmental and social risks during closure;
- Measures for remediation and site restoration;
- Provisions for used battery management;
- Alignment with applicable national regulations and international good practice.

8.2 Decommissioning Activities

Decommissioning refers to the structured and systematic process of shutting down operations and removing all operational assets at the end of a project's useful life. The design life of the proposed Solar PV power plant is approximately **25 years**, which may be extended depending on maintenance, component upgrades, and technological improvements. Even after 25 years, PV modules may retain up to 80–90% of their rated generation capacity; however, economic, technical, and institutional considerations may necessitate full decommissioning. The associated renewable energy training facilities may have a longer structural lifespan (up to 40 years or more), subject to maintenance and continued institutional use.

Decommissioning activities will typically include the following:

- **Dismantling and removal of PV panels and associated infrastructure**, including mounting structures, DC/AC cabling, inverters, transformers, combiner boxes, batteries (where applicable), and control systems;
- **Removal of sub-surface installations**, such as underground cables, conduits, and foundations where required;
- **Management of waste streams** generated during dismantling;
- **Site rehabilitation and restoration**, including remediation of any impacted environmental components (e.g., soil disturbance areas).

The Plan aims to ensure safe dismantling of all project infrastructure; minimise adverse environmental and social impacts; maximise reuse and recycling of recoverable materials;

ensure environmentally sound management of hazardous wastes; protect workers; and restore the project site for future beneficial use.

All decommissioning activities shall be conducted in accordance with the Environmental Impact Assessment Act, the National Environmental Regulations, the National Environmental (Battery Control) Regulations, 2024, the Basel Convention, the AfDB Integrated Safeguards System (ISS, 2023) and recognized international good industry practice.

8.3 Management of Decommissioning Activities

In the event of decommissioning, the Rural Electrification Agency – Project Management Unit (REA-PMU), in conjunction with the leadership of NOUN, shall ensure that the Project site is left in a safe, stable, and environmentally acceptable condition. A formal Decommissioning, Abandonment, and Closure Program shall be developed and implemented. Key tasks will include:

- Evacuation of dismantled PV panels and associated electrical components (e.g., inverters, control devices) to manufacturers or licensed recycling facilities;
- Transportation of spent batteries to certified recycling or take-back facilities;
- Restoration of the Project site to baseline conditions as far as practicable, in compliance with legislative and regulatory requirements;
- Assessment of any residual environmental impacts;
- Post-decommissioning environmental monitoring where necessary.

Decommissioning activities shall only commence after consultation with relevant stakeholders, including regulatory authorities. Activities shall be implemented in line with the National Guidelines for Decommissioning of Facilities in Nigeria (2017) issued by the Federal Ministry of Environment (FMEnv).

8.3.1 Decommissioning Planning Requirements

An updated Decommissioning Plan shall be developed prior to closure. The plan shall reflect prevailing legal requirements, best practicable environmental options, technological advancements, and cost considerations at the time of closure.

The Decommissioning Plan shall include, at a minimum:

- Description of the site and infrastructure to be decommissioned;
- Scope, objectives, intended end-state, and strategy;
- Detailed schedule of decommissioning activities;
- Estimated decommissioning cost;
- Inventory of anticipated waste streams and proposed handling methods;
- Roles, responsibilities, and qualifications of the decommissioning team;
- Health, Safety and Environment (HSE) management procedures.

The Plan shall be submitted to FMEnv and other relevant regulatory authorities for approval prior to implementation.

8.3.2 Evaluation of Decommissioning Options

A detailed evaluation of decommissioning alternatives shall be undertaken to determine the most environmentally sound and cost-effective option. Options may include:

- Facility mothballing (temporary suspension);
- Partial decommissioning;
- Complete removal and site restoration.

The evaluation shall consider environmental, safety, technical, and socio-economic factors before selecting the preferred option.

8.3.3 Risk Assessment and Safety

A comprehensive risk assessment shall be conducted to ensure that no hazardous materials, unstable structures, or environmental liabilities remain on site.

This shall include:

- Hazard identification and analysis;
- Electrical safety risk assessment;
- Soil and groundwater contamination risk evaluation;
- Structural stability assessment.

An appropriate Health, Safety and Environment (HSE) Plan shall be implemented to ensure that decommissioning activities are conducted safely and in compliance with relevant laws and international standards. Third-party notifications shall be undertaken prior to demolition activities, and dismantling shall be executed in a phased and controlled manner.

8.3.4 Socio-Economic Considerations

Decommissioning may have socio-economic implications, particularly related to the termination of employment at the end of the operational phase.

To minimize adverse effects:

- Employees shall be informed well in advance about decommissioning timelines and implications;
- Capacity-building programs shall be implemented to prepare staff for alternative employment opportunities;
- Training shall be provided in areas such as equipment dismantling, environmental monitoring, and rehabilitation activities;
- Skills acquired during Project implementation shall be transferable to other sectors.

Community engagement shall continue during decommissioning to manage expectations and maintain transparency.

8.3.5 Waste Management During Decommissioning

A dedicated Waste Management Plan for decommissioning shall be developed.
Options for redundant structures and equipment will include:

- Complete dismantling and recycling;

- Return of components to manufacturers under take-back schemes;
- Disposal through licensed waste handlers.

A detailed inventory of recyclable materials shall be maintained, and waste tracking documentation shall be recorded. Environmental and social management measures for decommissioning impacts are presented in Table 8.1.

8.3.6 Used Battery Management at Decommissioning Phase

Lithium-ion batteries reaching end-of-life are classified as hazardous waste due to their chemical composition and potential fire risk. During decommissioning, used batteries shall be:

- Disconnected safely by qualified personnel;
- Fully discharged in accordance with manufacturer instructions;
- Stored separately from other dismantled materials;
- Packaged in approved, fire-resistant containers;
- Labelled appropriately for transport.

Damaged or thermally unstable batteries require specialized handling procedures due to flammability risks. Currently, lithium-ion battery recycling capacity in Nigeria remains limited, as most domestic recyclers focus on lead-acid batteries. This presents a logistical and regulatory challenge. To address this, the Project shall adopt the Extended Producer Responsibility (EPR) approach. Under this arrangement:

- Battery manufacturers or suppliers shall be responsible for take-back, recycling, and final disposal;
- Recycling costs shall be internalized within procurement agreements;
- Take-back clauses shall be included in supply contracts.

During decommissioning, batteries shall be removed, discharged, packaged, and transported in accordance with manufacturer guidelines and regulatory requirements. Furthermore, NOUN shall be encouraged to develop an End-of-Life Electrical Components Management Plan, which will include:

- Procedures for safe handling and temporary storage;
- Identification of certified recycling companies (including NESREA-certified operators);
- Documentation and tracking of all battery disposals;
- Compliance with national hazardous waste regulations.

This approach ensures environmentally sound disposal while minimizing environmental liability and fire risk.

8.4 Abandonment Plan

Prior to site abandonment, the Rural Electrification Agency – Project Management Unit (REA-PMU) shall develop and implement a structured Abandonment Plan to ensure that the Project site is left in a safe, stable, and environmentally acceptable condition. The Abandonment Plan shall form part of the overall Decommissioning, Abandonment and Closure Program and shall be implemented only after regulatory notification and approval where required.

The Plan shall incorporate, at a minimum, the following elements:

a. **Identification of components to be abandoned and/or removed**, including PV modules, mounting structures, underground cables, transformers, inverters, battery storage systems, fencing, and ancillary facilities;

b. **Specification of proposed abandonment or reuse methods**, including:
   - Reuse of serviceable components within the University where feasible;
   - Recycling of recoverable materials (e.g., aluminum frames, steel structures, copper cables);
   - Safe disposal of non-recyclable materials through licensed waste management facilities;

c. **Implementation of environmental mitigation measures** to address potential impacts associated with abandonment activities, including:
   - Prevention of soil contamination during removal of equipment;
   - Control of dust and noise during dismantling;
   - Safe handling of hazardous materials such as oils, lubricants, and batteries;

d. **Site rehabilitation and restoration measures**, including:
   - Removal of residual debris and concrete foundations where required;
   - Backfilling and compaction of excavated areas;
   - Re-grading of disturbed land surfaces;
   - Re-vegetation using native plant species to promote ecological recovery;
   - Stabilization of soils to prevent erosion.

The objective of the Abandonment Plan is to return the Project site to its original or an agreed post-project land use condition, as far as reasonably practicable.

8.5 Roles, Responsibilities and Accountabilities for Decommissioning Phase

Effective implementation of environmental and social measures during the decommissioning phase requires clear allocation of responsibilities and well-defined reporting lines. The decommissioning phase shall be managed through coordinated oversight between REA-PMU, NOUN management, regulatory authorities, and the appointed decommissioning contractor(s). The key personnel and institutions with major roles in the implementation and monitoring of environmental and social measures during decommissioning are outlined below.

A. Contractor(s) Engaged for Decommissioning Activities

The appointed contractor(s) shall be directly responsible for executing decommissioning works in compliance with the approved Decommissioning and Abandonment Plan.
Responsibilities shall include:

- Implementing all environmental and social mitigation measures identified in the Decommissioning Plan;
- Ensuring safe dismantling, handling, packaging, and transportation of all project components;
- Managing waste streams in accordance with national regulations and approved waste management procedures;

- Maintaining records of waste disposal, recycling, and material recovery;
- Ensuring compliance with occupational health and safety requirements;
- Reporting environmental incidents, near misses, and non-compliance issues to REA-PMU and NOUN management;
- Preparing periodic progress reports on decommissioning environmental and social performance.

B. REA – Project Management Unit (REA-PMU)

REA-PMU shall retain overall oversight responsibility for the decommissioning phase.
Its responsibilities shall include:

- Supervising the activities of the contractor(s) engaged for decommissioning;
- Ensuring that all recommended environmental and social mitigation measures are implemented;
- Reviewing decommissioning progress reports and environmental monitoring results;
- Coordinating engagement with regulatory authorities;
- Discussing environmental and social management improvements with NOUN management to address non-compliance and emerging issues;
- Ensuring that the Project site is restored in accordance with approved regulatory standards.

C. NOUN Site Engineer/Project Manager

The NOUN Site Engineer (or designated Project Manager) shall provide on-site monitoring and coordination support during decommissioning.
Responsibilities shall include:

- Directly monitoring contractor activities to ensure compliance with approved environmental and social management measures;
- Conducting routine site inspections;
- Verifying safe handling and removal of equipment and hazardous materials;
- Reporting contractor performance and compliance status to the Director of Works and Physical Planning;
- Liaising with REA-PMU on environmental and social performance matters.

D. Director of Works and Physical Planning – NOUN

The Director of Works and Physical Planning shall provide institutional oversight on behalf of the University.
Responsibilities shall include:

- Joint supervision of contractor activities during decommissioning;
- Reviewing compliance reports submitted by the Site Engineer;
- Advising REA-PMU on corrective actions and improvement measures;
- Ensuring that post-decommissioning land use aligns with University development plans;
- Confirming that site restoration meets acceptable standards before formal closure.

E. Federal Ministry of Environment (FMEnv) and Abuja Environmental Protection Board (AEPB)

Regulatory authorities shall provide independent oversight and approval functions.
Their responsibilities shall include:

- Reviewing and approving the Decommissioning and Abandonment Plan prior to implementation;
- Conducting compliance inspections during decommissioning activities;
- Monitoring implementation of environmental and social mitigation measures;
- Reviewing environmental monitoring results and waste disposal documentation;
- Recommending corrective measures in cases of non-compliance;
- Providing regulatory clearance for final site closure, where required.

F. Reporting and Accountability Framework

The reporting structure during decommissioning shall generally follow this hierarchy:

1. Decommissioning Contractor → Reports to REA-PMU and NOUN Site Engineer
2. NOUN Site Engineer → Reports to Director of NOUN Projects and Planning
3. REA-PMU → Coordinates with NOUN Management and Regulatory Authorities
4. FMEnv and Abuja Environmental Protection Board (AEPB) → Provide regulatory oversight and approval

This structured accountability framework ensures transparency, regulatory compliance, and effective management of environmental and social risks during Project closure.

8.6 Monitoring Requirements

Environmental and social monitoring during decommissioning shall focus on waste management, hazardous materials handling, occupational health and safety, environmental restoration and post-decommissioning site rehabilitation. Daily monitoring shall cover worker safety, waste segregation, dust suppression and spill prevention. Weekly inspections shall verify erosion control, drainage protection, noise management and traffic safety. Upon completion of decommissioning, an environmental site inspection and restoration audit shall be undertaken to confirm that the project site has been restored to a condition acceptable to the Federal Ministry of Environment and the National Open University of Nigeria. Table 8.1 shows the implementation plan environmental management measures to be taken for the for the decommissioning activities. Considering that this project is anticipated to have a minimum lifespan of 25 years, the Decommissioning Plan will be subjected to update and review as at the period for decommissioning.

Table 8.1: Environmental Management Measures for the Decommissioning Phase of the Proposed Project

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
Land Resources	Long-term alteration of land use	Develop and implement a Site Restoration Plan; remove all redundant infrastructure unless retained for future use; restore land in accordance with NOUN Master Plan.	Percentage of land restored	Site inspection	Monthly	NOUN	REA	Site restoration report	**2,000.00**
Soil Resources	Soil contamination from transformer oil, batteries and equipment	Drain oils prior to dismantling; isolate battery systems; provide spill kits; remediate contaminated soil immediately.	Spill incidents; contaminated soil area	Site inspection; spill register	Daily	Decommissioning Contractor	REA	Spill reports	**1,666.67**
Ground water	Groundwater contamination	Prevent leakage of oils, electrolytes and chemicals; inspect containment systems; monitor	Water quality results	Laboratory analysis	Before and after decommissioning	NOUN	REA / FMEnv	Laboratory reports	**1,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		groundwater where necessary.							
Surface Water	Sediment runoff and pollution	Install erosion and sediment controls; prohibit discharge of contaminated runoff; maintain drainage channels.	Turbidity; drainage condition	Site inspection	Weekly and after rainfall	Contractor	REA	Inspection reports	**1,000.00**
Air Quality	Dust from demolition and dismantling	Wet exposed surfaces; cover haulage trucks; minimise material stockpiles; enforce speed limits.	Visible dust; complaints	Site inspection	Daily	Contractor	REA	HSE reports	**1,000.00**
	Exhaust emissions	Maintain dismantling equipment; prohibit excessive idling; service vehicles regularly.	Visible smoke	Equipment inspection	Weekly	Contractor	REA	Maintenance records	**533.33**
Noise and Vibration	Noise from dismantling equipment	Restrict noisy activities to daytime hours; maintain equipment	Noise complaints	Noise monitoring	Weekly	Contractor	REA	Noise reports	**800.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		silencers; notify NOUN before major dismantling activities.							
Socio-economic Environment	Temporary disruption of university activities	Schedule dismantling during periods of minimal campus activities where practicable; maintain access routes; communicate work schedules.	Number of complaints	Consultation records	Weekly	Contractor / NOUN	REA	Consultation records	**666.67**
	Loss of temporary employment	Provide advance notice of demobilization; ensure payment of all contractual entitlements; provide skills documentation and referrals where feasible.	Labour disputes	HR audit	Monthly	Contractor	REA	Employment records	**533.33**
Waste Generation and Handling	Large quantities of demolition waste	Prepare and implement a Decommissioning Waste Management	Recycling rate	Waste audit	Weekly	Contractor	REA	Waste manifests	**2,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		Plan; maximize reuse and recycling; segregate wastes at source.							
	Damaged PV modules	Remove carefully; package to prevent breakage; transfer only to licensed PV recycling facilities.	Quantity recycled	Waste inventory	Throughout decommissioning	Contractor	REA / FMEnv	Recycling certificates	**1,333.33**
Waste Generation and Handling	End-of-life lithium-ion batteries	Remove under manufacturer's procedures; isolate battery terminals; transport using approved hazardous materials procedures; recycle through licensed facilities.	Battery inventory	Waste audit	Throughout decommissioning	Contractor	REA / FMEnv	Battery manifests	**3,333.33**
	Large quantities of demolition waste	Prepare and implement a Decommissioning Waste	Recycling rate	Waste audit	Weekly	Contractor	REA	Waste manifests	**2,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
		Management Plan; maximise reuse and recycling; segregate wastes at source.							
	Damaged PV modules	Remove carefully; package to prevent breakage; transfer only to licensed PV recycling facilities.	Quantity recycled	Waste inventory	Throughout decommissioning	Contractor	REA / FMEnv	Recycling certificates	**1,333.33**
	End-of-life lithium-ion batteries	Remove under manufacturer's procedures; isolate battery terminals; transport using approved hazardous materials procedures; recycle through licensed facilities.	Battery inventory	Waste audit	Throughout decommissioning	Contractor	REA / FMEnv	Battery manifests	**3,333.33**
	Large quantities of demolition	Prepare and implement a Decommissionin	Recycling rate	Waste audit	Weekly	Contractor	REA	Waste manifests	**2,000.00**

Receptor	Impact	Mitigation Measure	Monitoring			Party(ies) for Implementation	Party(ies) for Monitoring	Means of Verification	Estimated Cost (USD)
			Indicator	Method	Frequency				
	waste	g Waste Management Plan; maximize reuse and recycling; segregate wastes at source.							
	Damaged PV modules	Remove carefully; package to prevent breakage; transfer only to licensed PV recycling facilities.	Quantity recycled	Waste inventory	Throughout decommissioning	Contractor	REA / FMEnv	Recycling certificates	**1,333.33**
	End-of-life lithium-ion batteries	Remove under manufacturer's procedures; isolate battery terminals; transport using approved hazardous materials procedures; recycle through licensed facilities.	Battery inventory	Waste audit	Throughout decommissioning	Contractor	REA / FMEnv	Battery manifests	**3,333.33**

CHAPTER NINE
SUMMARY AND CONCLUSION

9.1 Summary

This Environmental and Social Impact Assessment (ESIA) was conducted for the proposed 1-Megawatt (1-MW) Solar Photovoltaic (PV) Power Plant at the National Open University of Nigeria (NOUN) Main Campus, Jabi, Abuja - FCT. The study comprehensively evaluated the potential environmental, social, and health impacts associated with the Project across its entire lifecycle, namely: pre-construction, construction, operation, and decommissioning phases. The findings of the assessment confirm that the Project will result in minimal adverse environmental and social impacts while delivering significant long-term environmental, institutional, and socio-economic benefits. The proposed facility is strategically aligned with Nigeria's renewable energy transition objectives and climate commitments. It contributes directly to:

- Nigeria's renewable energy development targets;
- Nationally Determined Contributions (NDCs) under the Paris Agreement; and
- The Federal Government's commitment to achieving net-zero greenhouse gas emissions by 2060.

The project is expected to deliver substantial long-term environmental and socio-economic benefits through improved energy reliability, reduced greenhouse gas emissions, enhanced institutional productivity, and strengthened energy security for the university community. These benefits significantly outweigh the anticipated adverse environmental and social impacts.

The project will be sited entirely on land owned by the University, and no involuntary land acquisition, physical displacement or economic displacement of surrounding communities will be required. The project will be sited across two locations within the university campus with both sites operating in a complementary manner. Both sites are characterized by relatively flat to gently undulating terrain, good accessibility through the existing campus road network, and proximity to existing electrical infrastructure, thereby reducing the need for extensive earthworks and new access roads.

Baseline environmental investigations indicate that the project site is located within an already developed institutional environment with limited ecological sensitivity. The vegetation is predominantly composed of ornamental plants, managed lawns and secondary vegetation typical of an urban campus landscape. No nationally protected ecosystems or habitats of high conservation value were identified within the project footprint. Similarly, no flora or fauna species classified as Critically Endangered (CR) or Endangered (EN) by the International Union for Conservation of Nature (IUCN) were recorded within the project site during the field survey.

Environmental impacts during construction are localized, temporary, and manageable. These include minor vegetation clearing, dust emissions, temporary increase in ambient noise levels, and increased vehicular movement within the campus. No impacts of sufficient magnitude were identified that would prevent Project implementation. During operation, the Solar PV facility will operate without combustion processes, without fuel storage risks, and without routine atmospheric emissions. Operational noise levels will be minimal. The Project will also enhance campus infrastructure and security through the installation of 244 additional streetlights, thereby improving illumination and reducing vulnerability to opportunistic crime. Furthermore, the facility will support academic development, research activities, and renewable energy capacity building within the University.

The ESIA identified both positive and negative interactions with the receiving environment. The key positive impacts include improved electricity reliability, reduced operational costs, enhanced security, climate mitigation benefits, institutional capacity strengthening, and local employment generation. The identified negative impacts are limited to minor and moderate risks such as temporary dust and noise, occupational health and safety risks, minor vegetation disturbance, and potential waste management concerns. All such impacts can be effectively mitigated through the implementation of appropriate control measures. An Environmental and Social Management Plan (ESMP) has been developed to guide mitigation, monitoring, reporting, and institutional oversight. The Rural Electrification Agency (REA) Project Management Unit, supported by Environmental and Social Safeguards Specialists, will oversee ESMP implementation. Stakeholder consultations conducted with University management, staff, students, regulatory authorities, and community representatives demonstrated broad institutional and community support for the Project. Overall, the ESIA confirms that the proposed 1-MW Solar Hybrid Power Plant represents a technically viable, environmentally sustainable, and socially beneficial investment.

Bolben Energy and Environmental Services Limited assert that all environmental and social impacts have been comprehensively identified and assessed. The mitigation measures outlined in the ESMP are sufficient to address identified impacts when implemented accordingly. The proposed 1-MW Solar Photovoltaic facility represents a strategic investment in renewable energy, institutional sustainability, and climate resilience that merits approval and implementation.

9.2 Conclusion

Based on the comprehensive assessment undertaken, the proposed 1-Megawatt Solar Photovoltaic Power Plant at the National Open University of Nigeria (NOUN) Main Campus, Abuja, is environmentally acceptable and socially desirable. The Project will significantly improve electricity reliability within the University, reduce long-term energy costs, eliminate greenhouse gas emissions associated with diesel generation, strengthen institutional resilience, and contribute to Nigeria's renewable energy and climate objectives. The adverse impacts identified during the ESIA are minor to moderate in significance, localized in nature, and largely temporary. Importantly, these impacts can be mitigated to as low as reasonably practicable through strict implementation of the mitigation measures and management plans outlined in this report. No irreversible environmental damage or significant ecological disruption is anticipated.

The Federal Government of Nigeria, through the Rural Electrification Agency, has demonstrated institutional commitment to ensuring compliance with the Environmental Impact Assessment Act, Cap E12, Laws of the Federation of Nigeria, 2004, the Environmental Impact Assessment Procedures and Charges Regulations, 2021, relevant Federal Ministry of Environment (FMEnv) sectoral guidelines, the National Environmental Regulations, the National Environmental (Battery Control) Regulations, 2024, the AfDB Integrated Safeguards System (ISS, 2023) and other applicable national and international environmental and social safeguard requirements.

Given the strong environmental, social, economic, and climate benefits associated with the Project, and subject to full implementation of the ESMP, the proposed 1-MW Solar PV Power Plant is recommended for environmental approval and regulatory clearance.

REFERENCE

Adelaide Hills Council. (2017). *Example risk assessment template*. https://www.ahc.sa.gov.au/assets/downloads/services/event-support/COUNCIL-EventsToolkit-Risk-Assessment-template-Feb-2017.pdf

African Development Bank (AfDB). (2023). *Environmental and Social Framework (ESF)*. African Development Bank Group. https://www.afdb.org

African Development Bank (AfDB). (2022). *Grievance Redress Mechanism (GRM) Framework for the Nigeria Electrification Project (NEP)*. African Development Bank.

Alsema, E.A., de Wild- Scholton, M.J., & Fthenakis, V.M. (2006)

Argonne National Laboratory. (2013). *An overview of potential environmental, cultural and socioeconomic impacts and mitigation measures for utility-scale solar energy development*. U.S. Department of Energy. http://www.evs.anl.gov/downloads/Solar_Environmental_Impact_Summary.pdf

Association of New Jersey Environmental Commissions (ANJEC). (2012). *Solar siting and sustainable land use: A white paper*. http://www.anjec.org/pdfs/SolarWhitePaper2012.pdf

Bailey, K.D. (1994). *Methods of Social Research (4th ed.).* The Free Press

BRE National Solar Centre. (2014). *Biodiversity guidance for solar developments*. Building Research Establishment (BRE). http://www.bre.co.uk/filelibrary/pdf/Brochures/NSCBiodiversityGuidance.pdf

California Department of Fish and Wildlife. (n.d.). *Habitat description: Wet meadow (WTM)*. https://nrm.dfg.ca.gov

Clancy, H. (2015, August 7). Solar farms could make fertile habitats for bees and butterflies. *GreenBiz*. https://www.greenbiz.com

Department of Public Service. (2016). *Comprehensive energy plan*. Government of Vermont.

DCE Solar. (n.d.). *A guide to safely installing solar panel arrays to any property type*. http://www.dcesolar.com/docs/InstallingSolarPanelArrays.pdf

Energy Commission of Nigeria. *National Policy on Energy (Revised Edition).*

Energy Commission of Nigeria. *Technical support for national energy planning and implementation of the Energy Transition Plan*.

Federal Capital Development Authority, 2024
Federal Capital Territory Administration (FCTA). *FCTA – About the Federal Capital Territory.*

Finegan, D. P., Scheel, M., Robinson, J. B., et al. (2015). *In-operando high-speed tomography of lithium-ion batteries during thermal runaway. Nature Communications, 6, 6924*.

Federal Government of Nigeria. (2004). *Environmental Impact Assessment Act, Cap E12 Laws of the Federation of Nigeria 2004*. Abuja: Government Printer.

Federal Ministry of Environment (FMEnv). (2020). *National Environmental (Permitting and Licensing System) Regulations*. Abuja: FMEnv.

Federal Ministry of Environment (FMEnv). (2023). *Environmental Impact Assessment procedural guidelines*. Environmental Assessment Department. https://ead.gov.ng

Federal Ministry of Environment (FMEnv). (2016). *National Policy on the Environment.* Abuja, Nigeria

Federal Ministry of Power. *National Energy Sector Policy and Planning documents*.

Federal Ministry of Power. (2022). *Nigeria Energy Transition Plan*. Government of Nigeria.

Goodenough, J. B., & Park, K. S. (2013). *The Li-ion rechargeable battery:* A perspective. Journal of the American Chemical Society.

Green Mountain Power. (2023). *About solar power*. http://www.greenmountainpower.com

Ibrahim, Mika Paul, Benneth C. Oyinna, Roland Uhunmwangho, Stella I. Orakwue, and Kenneth E. Okedu. *"Geographical Information System (GIS) Study of Energy Potential in the Federal Capital Territory (FCT), Nigeria." Academia Green Energy 2, no. 4 (2025). doi:10.20935/AcadEnergy8066*.

International Energy Agency (IEA). (2024). *Energy Storage – Tracking Clean Energy Progress. Paris: IEA*.

International Renewable Energy Agency (IRENA). (2017). *Electricity Storage and Renewables: Costs and Markets to 2030. Abu Dhabi:* IRENA.

Kothari, C.R. (2004). *Research Methodology: Methods and Techniques (2nd ed.).*

Linden, D., & Reddy, T. B. (Eds.). (2011). *Linden's Handbook of Batteries (4th ed.). New York: McGraw-Hill*.

Maryland Department of the Environment. (2000). *Stormwater design guidance: Solar panel installations*.

Mondal, A. K., & Bansal, K. (2015). *Structural analysis of solar panel cleaning robotic arm. Current Science, 108(*6), 1047–1052.

National Bureau of Statistics, 2023;

National Fire Protection Association (NFPA). (2023). NFPA 855: *Standard for the Installation of Stationary Energy Storage Systems.* Quincy, MA: NFPA.

National Open University of Nigeria. *National Open University of Nigeria at a Glance (Third Edition Handbook)*

National Renewable Energy Laboratory (NREL). (2021). *Battery Lifetime Analysis and Simulation Tools. Golden, Colorado*: NREL.

Natural Resources Board. (2010). *Vermont wetland rules*.

New York State Department of Agriculture and Markets. (2019). *Guidelines for solar energy projects: Construction mitigation for agricultural lands*.

NiMet, 2024. *State of the Climate in Nigeria.*

Nigerian Geological Survey Agency, 2025.

Nigeria Zip Codes. (2023). *Abuja - FCT postal codes*. https://nigeriazipcodes.com

Nigerian Electricity Regulatory Commission (NERC). (2022). *Mini-grid regulation and renewable energy guidelines*. Abuja: NERC.

Nitta, N., Wu, F., Lee, J. T., & Yushin, G. (2015). *Li-ion battery materials: Present and future. Materials Today, 18(5), 252–26*4

Parker, G., & Greene, L. (2014). *Biodiversity guidance for solar developments*. BRE National Solar Centre.

Rahn, C. D., & Wang, C. Y. (2013). *Battery Systems Engineering. Hoboken, NJ:* John Wiley & Sons

Rural Electrification Agency (REA). (2023). *Energizing Education Programme (EEP) Phase III project documentation*. Abuja: REA.

Sandia National Laboratories. (2020). *Energy Storage Systems Handbook. Albuquerque, New Mexico*: Sandia National Laboratories.

Solar Siting Task Force. (2016). *Solar Siting Task Force Report*.

Stephens, P. D. (1999). Stand-Alone Solar Electric Systems: *The Earthscan Expert Handbook for Planning, Design and Installation. London*: Earthscan Publications.

Ter-Gazarian, A. (2011). *Electric Energy Storage (2nd ed.).* London: Institution of Engineering and Technology (IET)

The Nature Conservancy. (2015). *Laurentian-Acadian wet meadow shrub swamp*.

U.S. Energy Information Administration. (2023). *Electric power monthly*. https://www.eia.gov

Vermont Department of Environmental Conservation. (2010). *Vermont wetland evaluation form*.

Vermont Public Service Board. (2012). *Citizens' guide to Section 248 process*.

Watershed Management Division. (2011). *Wetlands: Open space and aesthetics*.

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 NATIONAL OPEN UNIVERSITY OF NIGERIA (NOUN) HEADQUARTERS JABI, ABUJA FCT.

The Federal Government of Nigeria (FGN), through the Rural Electrification Agency (REA), is implementing the Energizing Education Programme (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.Marital Status: Married ☑ Single ☐ Separated ☐ Widowed ☐

5. Household size: Large (Above 9) ☐ Medium (5-8) ☐ Small (2 – 4) ☐

6. Religion: (a) Christianity ☑ b) Islam ☐ (c) Traditional ☐ (d) Other (specify).....

7. Education: (a) Informal Education ☐ (d) NCE/ND ☐
(b) Primary School ☐ (e) HND/B.Sc. ☑
(c) Secondary School ☐ (f) Others (Specify) .....

8. Occupation: (a) Student ☐ (b) Teaching Staff ☐ (c) Non-teaching Staff ☑ (d) Trader ☐
(d) Others (Specify) .....

9. Monthly Income: (a) #0 - #30, 000 ☐ (b) #31, 000- #60,000 ☐ (c) # 61, 000-#90, 000 ☐
(d) #120,000 and above ☑

10. Duration of stay in the institution/community (a) 1-5 Yrs. ☐ (b) 6–10 Yrs. ☐ (c) 11–19 ☑
(d) 20 and above ☐

11. Types of language spoken in the communities; English ☑ Hausa ☐ Gbagyi ☐ Yoruba ☐
Igbo ☐ Others.....

Section B: Health Status

12.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).....

13. Condition of the health facility within the Institution/community; Very Good ☑ Good ☐
Fair ☐ Poor ☐

14. 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		

15. 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) .....

16. How do you think these impacts can be averted .....

1

Section C: Gender Based Violence

17. Have you or anyone in your household had experienced gender-based violence?
(a) YES ☐ (b) NO ☐

18. Do you think men and women have equal access to economic opportunities in your institution/community? (a) YES ☑ (b) NO ☐

19. Do you believe that cultural norms in your institution/community influence the prevalence of GBV? (a) YES ☐ (b) NO ☐

20. Are there adequate support services available for survivors of GBV in your institution/community? (a) YES ☑ (b) NO ☐

Section D: Public Services

21. 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) .....

22. Condition of portable water within the institution/community: Very Good ☑ Good ☐ Fair ☐
Poor ☐

23. 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) .....

24. Condition of public electricity within the institution/community: Very Good ☐ Good ☑ Fair ☐
Poor ☐

25. Sanitation facility in the institution/community; Water closet ☑ Pit Latrine ☐
Open Defecation ☐ Others ☐

26. What is the most available/affordable source of cooking? (a) Gas cooker ☑ (b) Stove ☐
(c) Firewood ☐ (d) Charcoal ☐ (e) Others (specify) .....

27. What are the educational institutions available in your institution/community? (a) Primary school ☐
(b) Secondary school ☐ (c) Tertiary Institution ☑ (d) Others (specify).....

28. 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

29. 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) .....

30. 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

31. Do you think the institution management members are fully aware of the proposed project?
(a)YES ☐ (b) NO ☐

32. What do you think is the socio-economic benefit of the project?

_____

_____

33. 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 ...None.....

34. Which neighboring institution/communities do you think will benefit from the new developmental project?

.....

2

APPENDIX II: CHAIN OF CUSTODY AND LAB ACCREDITATIONS

BIO-METRICS GEO CONSULT LTD
ADDRESS: Plot 12, Rachel T. Owolabi Close, Gaduwa, Abuja
Tel: 08033153422, 09161440089 Email: biometricsgeo2@gmail.com
RC 719096

CHAIN OF CUSTODY:

PROJECT TITLE	ESIA Of the Proposed 2MW Solar Power Project At National Open University Headquarters Jabi Abuja
DATE OF SUBMISSION	6th July, 2026.
ORGANIZATION	Bolben Energy & Environmental Services Limited
CONTACT/ADDRESS	Cetec Plaza Jabi Abuja
EMAIL	admin@bolben-org & ceo@bolben.org
FIELD SAMPLER: NAME	Engr. Dr. Nurudeen Oyewole Ahmed SIGNATURE:
DATE OF SAMPLING	6th July 2026
SAMPLING LOCATION	NOUN HQ Jabi FCT Abuja

SAMPLE TYPE	Number Of Sample	Material Used For Sampling	Preservation Used	Sample Id	Analysis To Be Done
Soil	10	Ziplock	/	/	Environmental
Water	6	plastic	/	/	Parameters

6th July, 2026. Hanni Sunday

PROJECT TITLE	
DATE OF SUBMISSION	
ORGANIZATION	
CONTACT/ADDRESS	
EMAIL	
FIELD SAMPLER: NAME	SIGNATURE:
DATE OF SAMPLING	
SAMPLING LOCATION	

SAMPLE TYPE	Number Of Sample	Material Used For Sampling	Preservation Used	Sample Id	Analysis To Be Done

CHAIN OF CUSTODY AND LAB ACCREDITATION CONTINUUATION……











APPENDIX III: LABORATORY ANALYSIS RESULTS (GROUNDWATER SAMPLES)

BIO-METRICS GEO CONSULT

CERTICATE OF ANALYSIS

CLIENT: BOLBEN ENERGY& ENVIRONMENTAL SERVICES NIGERIA LIMITED.

SAMPLE LOCATION: JABI FCT ABUJA.

SAMPLE TYPE : GROUND WATER

DATE SAMPLED: 6TH JULY, 2026

DATE ANALYZED: 7TH - 13TH JULY, 2026

LAB NUMBER:BMGCL/BAL/26/07/037-040.

METHOD REFERENCE: APHA (Standard Methods), AOAC.

PROJECT: ESIA OF NIGERIA ELECTRIFICATION PROJECT (NEP) UNDER RURAL ELECTRIFICATION AGENCY FOR 2MW POWERED PROJECT @NOUN HEADQUARTERS ABUJA.

I hereby certify that the above described sample was analysed in the same condition received by us and stated here under, are our findings.

S/N	PARAMETERS	UNIT	TEST METHOD	LIMIT FOR GROUNDWATER	G1 L1	G2 L2	G3 L3	G4 L4
			PHYSICO- CHEMICAL PARAMETERS					
1	pH		APHA 4500-H+	6.5 -8.5	6.990	7.280	7.190	6.840
2	TEMPERATURE	°C	APHA 2550B	AMBIENT	27.900	27.900	27.900	27.900
3	TURBIDITY	NTU	APHA 2130B	≤ 5	4.000	0.000	0.000	0.000
4	TOTAL DISSOLVED SOLIDS	mg/l	APHA 2540C	≤ 500	25.900	53.200	51.800	253.800
5	CONDUCTIVITY	µS/cm	APHA 2510B	≤ 1000	37.000	76.000	74.000	362.000
6	TOTAL HARDNESS	mg/l	APHA 2340C	≤ 150	414.633	365.853	292.682	487.804
7	MAGNESIUM HARDNESS	mg/l	APHA 2340C	NS	146.341	146.340	121.950	195.122
8	CALCIUM HARDNESS	mg/l	APHA 2340C	NS	268.292	219.512	170.731	292.682
9	ALKALINITY	mg/l	APHA 2320B	≤ 100	80.000	20.000	40.000	140.000
10	TOTAL SUSPENDED SOLID	mg/l	APHA 2540D	NS	0.020	0.012	0.014	0.019
11	TOTAL SOLID	mg/l	APHA 2540B	NS	6.990	7.280	7.190	253.819
12	SALINITY	ppt	APHA 2510B	NS	0.037	0.036	0.038	0.037
			MAJOR IONS					
13	CARBONATE	mg/l	APHA 2320 B	NS	0.07	0.04	0.06	0.091
14	BICARBONATE	mg/l	APHA 2320 B	NS	79.92	19.95	39.93	139.906
15	CALCIUM	mg/l	APHA 3500-Ca B	≤ 75	107.332	87.98	68.629	117.307
16	MAGNESIUM	mg/l	APHA 3500-Mg B	≤30	35.376	30.375	29.646	47.434
17	CHLORIDE	mg/l	APHA 4500-Cl B	≤250	31.586	21.057	31.585	31.586
18	SULPHATE	mg/l	APHA 4500-SO_4^{2-} E	≤100	14.308	9.231	1.077	6.462
19	NITRATE	mg/l	APHA 4500-NO_3 B	≤50	1.345	1.092	1.05	1.513
22	AMMONIUM	mg/l	APHA 4500-NH_4+ B	NS	1.17	2.05	1.21	0.990

LABORATORY ANALYSIS RESULTS (GROUNDWATER SAMPLES) continuation……

23	PHOSPHATE	mg/l	APHA 4500-P04	NS	0.00	0.00	0.00	0.000
24	NITRITE	mg/l	APHA 4500-NO2 B	≤0.2	0.051	0.074	0.026	0.088
				METALS				
25	IRON	mg/l	APHA 3500-Fe B	≤0.2	0.448	0.676	1.095	0.267
26	SODIUM	mg/l	APHA 3500-Na B	100	0.15	0.098	0.121	0.994
27	POTASSIUM	mg/l	APHA 3500-K B	20	10.781	10.664	9.844	10.781
28	MANGANESE	mg/l	APHA 3500-Mn B	≤3.0	0.002	0.004	0.002	0.000
29	ZINC	mg/l	APHA 3111B	≤0.5	0.085	0.045	0.02	0.154
30	COPPER	mg/l	APHA 3111B	≤1.0	0.376	0.531	0.518	0.538
31	LEAD	mg/l	APHA 3111B	≤0.01	0.000	0.138	0.158	0.203
32	CADMIUM	mg/l	APHA 3111B	≤0.003	0.126	0.075	0.184	0.301
33	CHROMIUM	mg/l	APHA 3111B	≤0.05	0.000	0.000	0.000	0.000
34	ARSENIC	mg/l	APHA 3111B	≤0.01	0.004	0.004	0.004	0.005
				MICROBIAL PARAMETERS				
35	TOTAL BACTERIAL COUNT	cfu/ml	APHA 9215B	≤100	2.8×10^4	1.0×10^5	5.0×10^4	5.0×10^5
36	TOTAL COLIFORM	cfu/ml	APHA 9222B	0.00	ND	1.0×10^4	ND	ND
37	TOTAL FUNGI	cfu/ml	APHA 9222D	0.00	ND	1.0×10^3	ND	5.0×10^5
38	FEACAL COLIFORM	cfu/ml	APHA 9222E	0.00	ND	ND	ND	ND
				STANDARD: NATIONAL ENVIRONMENTAL (SURFACE AND GROUND WATER QUALITY CONTROL) REGULATIONS, 2011				

NOTE:
mg/l = milligram per litre
µS/cm = micro Siemens per centimetre
cfu/ml = colony forming unit per milliliter.
NS = Not stated
ND = Not Detected
TNTC = Too numerous to count

FUNMI SUNDAY
ANALYST

CHECKED AND APPROVED BY

DR. EUNICE AJAYI
MD

LABORATORY ANALYSIS RESULTS (SURFACE WATER SAMPLES) continuation……

BIO-METRICS GEO CONSULT
ADDRESS: ADDRESS; Plot 12, Racheal T. Owolabi Street Gaduwa, Abuja.
EMAIL: biometricsgeo@gmail.com, TEL: 09161440089, +2348033153422.

CERTICATE OF ANALYSIS

CLIENT: BOLBEN ENERGY& ENVIRONMNETAL SERVICES NIGERIA LIMITED.

SAMPLE LOCATION: JABI FCT.ABUJA.

SAMPLE TYPE : SURFACE WATER

DATE SAMPLED: 6TH JULY, 2026

DATE ANALYZED: 7TH - 15TH JULY, 2026

LAB NUMBER:BMGCL/EAL/26/07/641-642

PROJECT: ESIA OF NIGERIA ELECTRIFICATION PROJECT (NEP) UNDER RURAL ELECTRIFICATION AGENCY FOR 2MW POWERED PROJECT @NOUN HEADQUARTERS ABUJA.

I hereby certify that the above described samples were analysed in the same condition received by us and stated here under, are our findings.

S/N	PARAMETERS	UNIT	TEST METHODS	LIMIT FOR SURFACE WATER	S1 L1	S2 L2
			PHYSICO- CHEMICAL PARAMETERS			
1	pH		APHA 4500 -H+	6.0-9.0	6.83	6.85
2	TEMPERATURE	°C	APHA 2550 B	AMBIENT	27.900	27.900
3	TURBIDITY	NTU	APHA 2130 B	≤30	22.000	16.000
4	CONDUCTIVITY	µS/cm	APHA 2510B	1000	328.000	734.000
5	TOTAL SUSPENDED SOLIDS	mg/l	APHA 2540 D	≤30	1.430	1.760
6	DISSOLVED OXYGEN	mg/l	APHA 450-O G	≥5	7.040	7.100
7	BIOCHEMICAL OXYGEN DEMAND	mg/l	APHA 5210 C	≤10	21.384	28.512
8	CHEMICAL OXYGEN DEMAND	mg/l	APHA 5220 D	≤40	35.64	47.52
9	TOTAL DISSOLVED SOLIDS	mg/l	APHA 2540 D	NS	229.600	513.800
10	TOTAL SOLIDS	mg/l	APHA 2540 D	NS	231.030	515.560
11	TOTAL HARDNESS	mg/l	APHA 2340 C	500.00	365.85	439.02
12	MAGNESIUM HARDNESS	mg/l	APHA 3500-Ca B	NS	170.731	195.122
13	CALCIUM HARDNESS	mg/l	APHA 3500-Ca B	NS	195.122	243.902
14	TOTAL ALKALINITY	mg/l	APHA 2320 B	NS	100.00	220.00

LABORATORY ANALYSIS RESULTS (SURFACE WATER SAMPLES) continuation……

15	SALINITY	ppt	APHA 2320 B	NS	0.076	0.209
			IONS			
16	CARBONATE	mg/l	APHA 2320 B	NS	0.06	0.15
17	BICARBONATE	mg/l	APHA 2320 B	NS	99.93	219.85
18	CHLORIDE	mg/l	APHA 4500-Cl^- B	250.00	42.115	115.815
19	NITRITE	mg/l	APHA 4500-NO_2^- B	0.20	0.96	0.26
20	NITRATE	mg/l	APHA 4500-NO_3^- B	50	7.563	1
21	PHOSPHATE	mg/l	APHA 4500-P E	≤ 5	0.9	3.987
22	AMMONIUM	mg/l	APHA 4500-NH_4^+ B	≤ 0.5	0.974	2.015
23	SULPHATE	mg/l	APHA 4500-SO_4^{2-} E	250.00	7.08	0.46
			METALS			
24	CALCIUM	mg/l	APHA 3500-Ca B	75.00	78.21	97.76
25	MAGNESIUM	mg/l	APHA 3500-Mg B	NS	41.51	47.43
26	SODIUM	mg/l	APHA 3500-Na B	120.00	0.43	1.44
27	POTASSIUM	mg/l	APHA 3500-K B	NS	9.22	21.29
28	LEAD	mg/l	APHA 3113 B	0.010	0.008	0.046
29	IRON	mg/l	APHA 3113 B	0.300	1.667	0.305
30	CHROMIUM	mg/l	APHA 3113 B	0.500	0.000	0.000
31	COPPER	mg/l	APHA 3113 B	1.000	0.034	0.015
32	MANGANESE	mg/l	APHA 3113 B	0.200	0.002	0.000
33	ZINC	mg/l	APHA 3113 B	3.000	0.042	0.052
34	ARSENIC	mg/l	APHA 3113 B	0.010	0.005	0.005
			MICROBIAL PARAMETERS			
35	TOTAL BACTERIAL COUNT	cfu/ml	APHA 9215B	0	6.0×10^3	1.07×10^5
36	TOTAL FUNGI	cfu/ml	APHA 9222D	0	7.0×10^2	1.5×10^1

LABORATORY ANALYSIS RESULTS (SURFACE WATER SAMPLES) continuation……

37	TOTAL COLIFORM	cfu/ml	APHA 9222B	100	3.0×10^1	7.0×10^2
38	FEACAL COLIFORM	cfu/ml	APHA 9222E	0	ND	3.5×10^2

STANDARD : NATIONAL ENVIRONMENTAL (SURFACE AND GROUND WATER QUALITY CONTROL) REGULATIONS, 2011.

NOTE:

µS/cm= microsimensper millitilitre

mg/L = miligram per litre

cfu/ml = colony forming unit per milliliter.

NS = Not stated

ND = Not Detected

TNTC = Too numerous to count

FUNMI SUNDAY

ANALYST

CHECKED AND APPROVED BY

DR. EUNICE AJAYI

MD

APPENDIX IV: LABORATORY ANALYSIS RESULTS (SOIL SAMPLES)

BIO-METRICS GEO CONSULT

ADDRESS: ADDRESS; Plot 12, Radical 7, Owolabi Street Gudduwa Abuja.
EMAIL: biometricsgeo@gmail.com, TEL: 09164480089, +2348083153472.

CERTIFICATE OF ANALYSIS

CLIENT: BOLBEN ENERGY& ENVIRONMENTAL SERVICES NIGERIA LIMITED.

SAMPLE LOCATION: JABI FCT ABUJA

SAMPLE TYPE : SURFACE WATER

DATE SAMPLED: 6TH JULY, 2026

DATE ANALYZED: 7TH - 13TH JULY, 2026

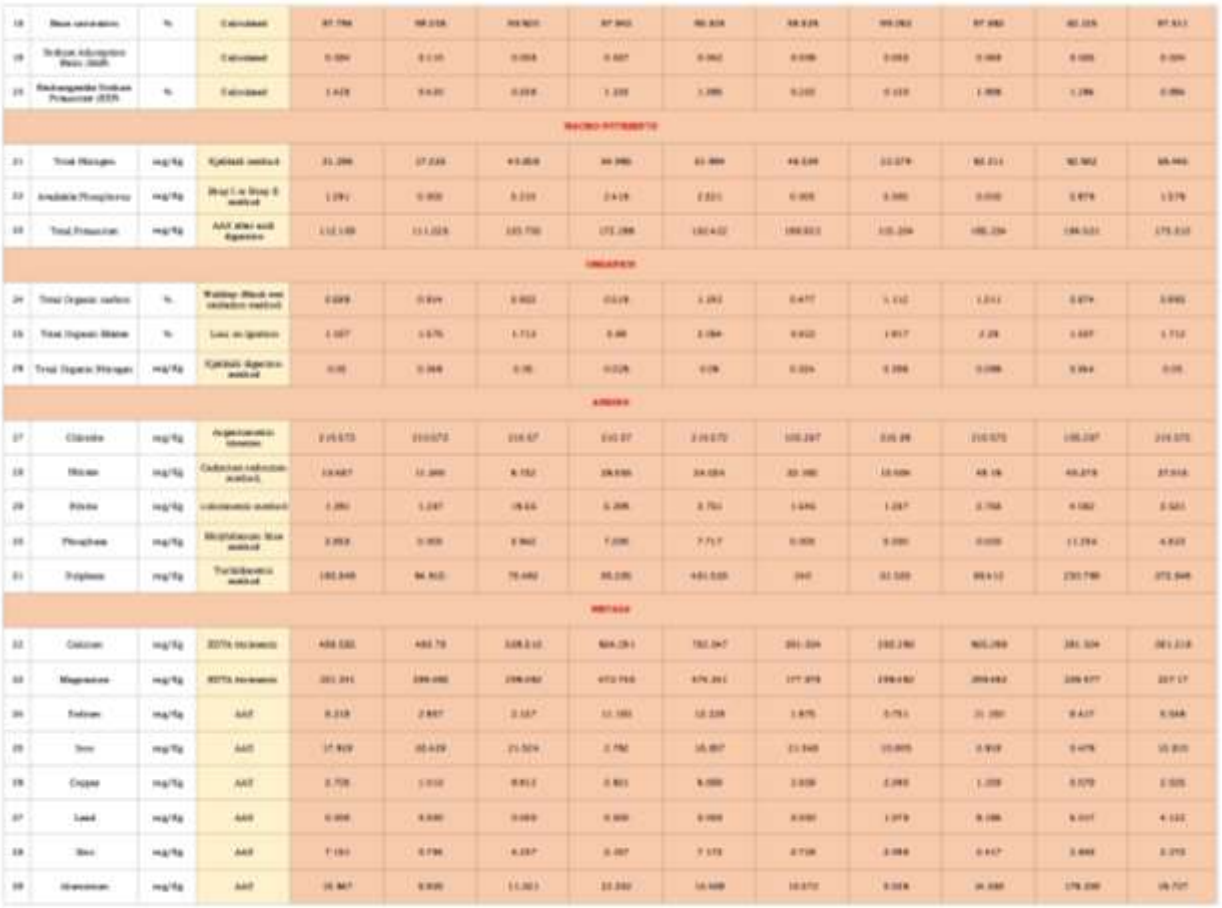
LAB NUMBER:BMGCL/E&S/26/07/04 L-052

PROJECT: REA OF NIGERIA ELECTRIFICATION PROJECT (NEP) UNDER RURAL ELECTRIFICATION AGENCY FOR 2MW POWERED PROJECT UNDER HEADQUARTERS ABUJA.

I hereby certify that the above identified samples were analyzed in the same condition received by us and stated here under, are our findings.

S/N	PARAMETERS	UNIT	TEST METHODS	L1 TOP	L1 BASE	L2 TOP	L2 BASE	L3 TOP	L3 BASE	L4 TOP	L4 BASE	CONTROL TOP	CONTROL BASE
				PHYSICO- CHEMICAL PARAMETERS									
1	Electrical Conductivity	µS/cm	ASTM D1125	280.000	190.000	200.000	180.000	290.000	190.000	540.000	820.000	440.000	510.000
2	pH	6.000	ASTM D4972	6.860	6.930	6.873	6.410	6.410	6.510	6.423	6.480	6.840	6.870
3	Moisture Content	%	ASTM D2216	11.335	12.488	9.200	11.578	8.501	8.680	14.580	15.596	11.331	12.380
4	Porosity	%	ASTM D7263	57.860	57.867	58.123	60.254	58.900	62.121	57.860	68.788	62.337	49.372
5	Soil Texture		ASTM D422	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Silty Sand	Sandy Clay
6	Bulk Density		ASTM D7263	1.124	1.117	1.063	1.060	1.343	0.977	1.121	1.345	0.994	1.226
7	Total Alkalinity	mg/Kg	Acid titration	200.000	200.000	200.000	200.000	200.000	200.000	400.000	400.000	400.000	400.000
8	Total Dissolved Solid	mg/Kg	ASTM D1125	0.822	0.822	0.822	0.822	0.822	0.218	0.942	0.822	0.218	0.822
9	Ammonium	mg/Kg	Distillation / Nesslerization method	11.52	14.827	17.324	12.080	14.149	12.277	10.522	10.198	14.178	15.05
10	Ammonia	mg/Kg	Distillation + titration or colorimetric method	10.878	12.841	16.567	12.058	12.381	12.500	9.945	9.82	12.058	14.211
11	Exchangeable sodium	Cmol/Kg	Ammonium acetate extraction + AAS	0.038	0.012	0.008	0.048	0.050	0.007	0.000	0.048	0.041	0.024
12	Exchangeable potassium	Cmol/Kg	Ammonium acetate extraction + AAS	0.287	0.288	0.309	0.442	0.406	0.435	0.288	0.424	0.409	0.427
13	Exchangeable Calcium	Cmol/Kg	Ammonium acetate extraction + EDTA titration	1.248	1.222	1.488	1.480	1.711	1.958	0.870	0.720	1.712	0.978
14	Exchangeable Magnesium	Cmol/Kg	Ammonium acetate extraction + EDTA titration	0.864	1.226	1.224	1.974	1.978	0.791	1.226	1.226	0.865	0.868
15	Exchangeable Acidity	Cmol/Kg	KCl extraction + titration with NaOH	0.050	0.022	0.042	0.042	0.06	0.027	0.018	0.050	0.062	0.042
16	Exchangeable Bases	Cmol/Kg	summation method extraction + calculation of	2.884	2.750	2.52	2.930	4.212	2.128	2.512	2.441	2.229	2.437
17	Cation Exchange Capacity (CEC)	Cmol/Kg	Ammonium acetate (1N NH4Oac, pH 7) method	3.981	3.718	3.992	4.016	4.262	3.177	2.93	3.434	3.991	3.480

LABORATORY ANALYSIS RESULTS (SOIL SAMPLES) continuation……





NOTE:

cfu/g = colony forming unit per gramme

Cmol/kg = centimole per kilogram

ND = Not stated

NC = Not Detected

TNTC = Too numerous to count

FUNMI SUNDAY

ANALYST

CHECKED AND APPROVED BY

DR. EUNICE AJAYI

MD

APPENDIX V: PICTORIAL EVIDENCE OF ATTENDANCE SHEETS



FEDERAL MINISTRY OF ENVIRONMENT
ENVIRONMENTAL IMPACT ASSESSMENT DEPARTMENT
SITE VERIFICATION EXERCISE

PROJECT PROPONENT:
PROJECT TITLE:
LOCATION:
DATE:

S/N	Names of Participants	Organization	Phone Numbers	E-Mail Address	Signature
1	Engr. Sadiq O. Shuaibu	NOUN	08060005178		
2					
3					
4					
5					
6					
7					

BOLBEN ENERGY

ENVIRONEMENTAL AND SOCIAL IMPACT ASSESSMENT SITE VERIFICATION AND BASELINE DATA GATHERING EXERCISES FOR THE PROPOSED REA-NEP (DtP PHASE II) POWER PROJECT, NOUN, ABUJA, FCT.

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: National Open University of Nigeria, Jabi, Abuja, Nigeria.

STATE: Fct, Abuja

DATE: Monday, 6th July 2026.

S/N	NAME	DESIGNATION/POSITION	PHONE NO.	SIGN
1	Prof. Uduma Oji Uduma	Vice Chancellor NOUN	08036661007	
2	Arc. Aisha N. Alfa	NOUN Principal Architect	08065232264	
3	Ms Nkiruka Nkwocha M.	Bolben Ltd	08100262826	
4	Engr. Dr. Ahmed O. Ahmed	Bolben Ltd	08030041815	
5	Fadiu Isiah	Bolben Ltd		
6				

BOLBEN ENERGY

ENVIRONEMENTAL AND SOCIAL IMPACT ASSESSMENT RECONNAISANCE VISIT FOR THE PROPOSED REA-NEP (DtP PHASE II) POWER PROJECT, NOUN, ABUJA, FCT.

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: National Open University of Nigeria, Jabi, Abuja, Nigeria.

STATE: Fct, Abuja

DATE: Friday, 3rd July 2026.

S/N	NAME	DESIGNATION/POSITION	PHONE NO.	SIGN
1	Arc. Aisha Alfa	Principal Architect	08065232264	
2	Engr. Sadiq O. Shuaibu	Director DPPRD	08060005178	
3	Ms. Nkiruka Nkwocha M.	Bolben Ltd.	08100262826	
4	Dr. Ahmed O. Ahmed	Bolben Ltd	08030041815	
5				

APPENDIX VI: PICTORIAL EVIDENCE OF STAKEHOLDER ENGAGEMENT











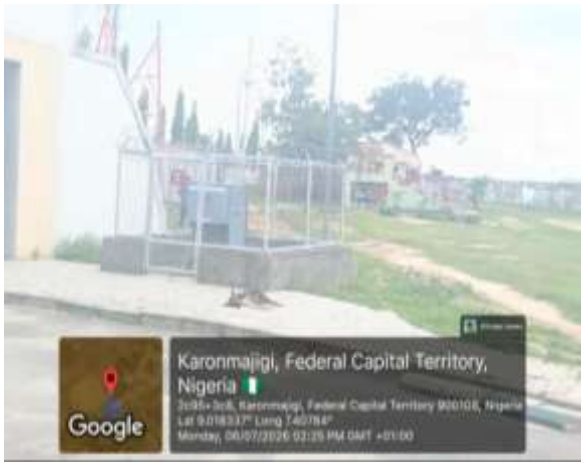

APPENDIX VII: PICTORIAL EVIDENCE OF OBSERVED INFRASTRUCTURE



ACETEL Building



Block of shops



Transformer (Close to Main Gate)



View of the Substation/Powerhouse



View of the University Clinic



Inside the University Clinic

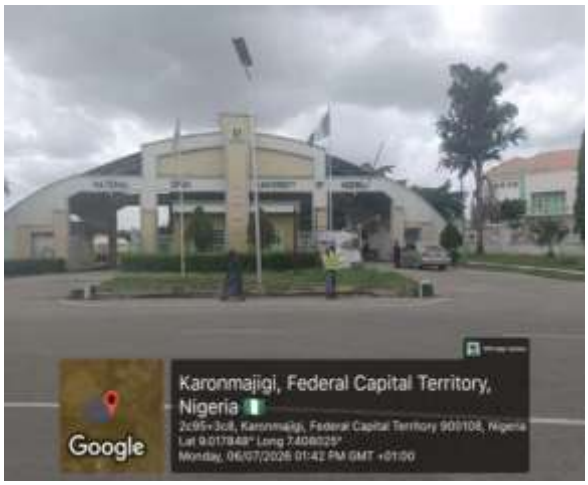
PICTORIAL EVIDENCE OF OBSERVED INFRASTRUCTURE continuation……..



Raked point sitting area for ceremonial activities (Matriculation, Convocation)



Open Dumping of Wastes within the Study Area



University Front gate



University Back gate



A Supermarket in the host Community

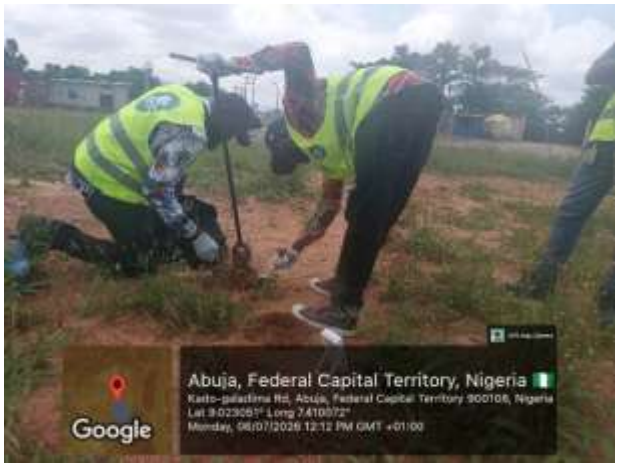


Trading activity within the host Community

APPENDIX VII: PICTORIAL EVIDENCE OF SOIL COLLECTION





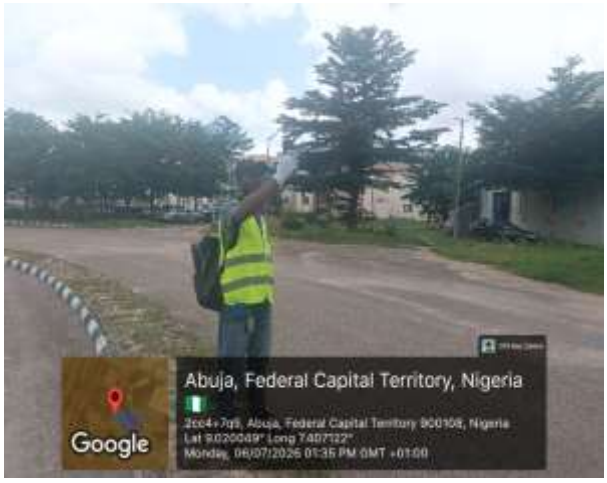








APPENDIX VIII: PICTORIAL EVIDENCE OF AMBIENT AIR QUALITY AND NOISE LEVEL SAMPLING













APPENDIX IX: PICTORIAL EVIDENCE OF WATER SAMPLING









APPENDIX X: 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*

APPENDIX XII: DETECTION LIMITS OF 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)