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Relevance of Renewable Energy Sources for Sustainable Campus Development: Federal Polytechnic Bauchi as Case Study

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Abstract

The increasing demand for reliable electricity in higher educational institutions has intensified the need for sustainable energy solutions capable of supporting academic activities, research operations, laboratory functions, and administrative services. Many Nigerian tertiary institutions continue to experience challenges associated with inadequate grid electricity supply, dependence on diesel generators, rising energy costs, and environmental impacts from fossil fuel utilization. This study examines the utilization potential of renewable energy sources for sustainable campus development at Federal Polytechnic Bauchi. A case study approach was adopted, involving assessment of institutional electricity demand, evaluation of renewable energy availability, solar photovoltaic (PV) system design, battery storage assessment, and environmental sustainability evaluation. The results indicate that the institution has considerable potential for renewable energy adoption, with solar photovoltaic technology identified as the most appropriate option due to favourable solar conditions, operational flexibility, scalability, and suitability for distributed campus applications. The estimated campus electricity requirement was determined as approximately 16,160 kWh/day, corresponding to an annual energy consumption of about 5.82 GWh/year. A hybrid solar PV system with an estimated capacity of 2 MW, supported by approximately 5.4 MWh battery storage, was proposed to improve electricity reliability and reduce dependence on conventional energy sources. The proposed renewable energy system is expected to enhance campus energy resilience through reduced grid

dependency, lower diesel generator utilization, improved electricity availability, and environmental benefits. The study further highlights the role of renewable energy integration in promoting sustainable institutional development, reducing greenhouse gas emissions, and creating opportunities for renewable energy education and research. A structured implementation framework involving solar PV deployment, energy efficiency measures, energy monitoring, and sustainable energy management is recommended for achieving a resilient and environmentally responsible campus.

Keywords: Renewable, Energy, Sustainability, Development, Efficiency, Storage.

Introduction

Energy is a fundamental requirement for the operation and development of modern educational institutions (Achakpo ***et al***., 2026a). Universities and polytechnics function as complex energy-consuming environments containing classrooms, laboratories, engineering workshops, offices, libraries, information and communication technology facilities, hostels, water-supply systems, security infrastructure and other services requiring dependable electricity (Achakpo ***et al***., 2026b). Consequently, the quality and reliability of institutional energy supply directly influence the continuity of academic activities, research productivity, administrative efficiency and the general quality of the campus environment. Higher-education institutions are increasingly expected not only to consume energy responsibly but also to demonstrate leadership in sustainability, climate action and technological innovation (Rodgers, 2021).

Nigeria's electricity sector continues to face structural challenges associated with inadequate generation, transmission and distribution capacity, reliability constraints and dependence on conventional energy sources. These challenges have encouraged institutions and other electricity consumers to consider decentralized renewable-energy systems as complementary or alternative sources of electricity. The International Renewable Energy Agency (IRENA) identified renewable energy as an important pathway for improving Nigeria's energy security, reducing fossil-fuel dependence and supporting low-carbon economic development. Its national roadmap indicates substantial opportunities for increased renewable-energy deployment in Nigeria through coordinated policy, investment and technological development (International Renewable Energy Agency [IRENA], 2023).

Solar energy is particularly relevant to Nigerian educational institutions because photovoltaic systems can be deployed on rooftops, car parks and available institutional land and can be expanded progressively according to energy demand and financial capacity (Achakpo ***et al***., 2026a, b). Unlike conventional diesel generation, solar PV produces electricity without direct combustion during operation and can therefore contribute to reducing local air pollution, greenhouse-gas emissions, fuel consumption and noise. Battery storage further increases the usefulness of PV systems by allowing generated electricity to be stored for later use and by improving the ability of the system to respond to variations in electricity demand and grid availability (IRENA, 2023).

Evidence from Nigerian tertiary institutions demonstrates the practical relevance of campus-scale renewable-energy systems. For example, Luqman ***et al***. (2023) investigated a proposed 1 MW grid-connected PV system at Federal Polytechnic Mubi and reported annual electricity-generation potential of approximately 1,550.98

MWh together with substantial greenhouse-gas reduction potential. The study demonstrated that solar PV can be technically and environmentally relevant to a polytechnic campus in northeastern Nigeria.

Similarly, research on Nigerian university buildings has demonstrated the potential of hybrid renewable-energy systems to provide more reliable and cleaner electricity than dependence on conventional sources alone. Diyoke ***et al***. (2023) found that hybrid renewable-energy configurations could provide beneficial alternatives for educational buildings across different Nigerian climatic regions.

The relevance of renewable energy to higher education extends beyond electricity generation. A sustainable campus can function as a living laboratory where students, researchers and technical personnel acquire practical knowledge of photovoltaic systems, energy storage, energy auditing, smart energy management, power electronics, instrumentation, control systems and environmental sustainability (Achakpo ***et al***., 2026 a, b). Renewable-energy deployment can therefore simultaneously address institutional energy challenges and strengthen the educational mission of a polytechnic.

Federal Polytechnic Bauchi provides an appropriate case for investigating this relationship because the institution requires electricity for academic, administrative, laboratory, workshop and technological activities. The estimated institutional demand of approximately 16,160 kWh/day represents a substantial energy requirement. Meeting such demand solely through grid electricity and conventional standby generation can expose the institution to reliability and operating-cost pressures. A planned transition towards renewable energy could consequently support both operational resilience and sustainable institutional development.

The present study therefore examines the relevance of renewable-energy sources for sustainable campus development at Federal Polytechnic Bauchi, with particular emphasis on solar PV and battery storage as the principal technological pathway.

STATEMENT OF THE PROBLEM

Reliable electricity is essential for effective teaching, learning, research, laboratory operations, engineering workshop activities, ICT services and institutional administration. However, reliance on conventional electricity sources exposes tertiary institutions to interruptions in supply, fuel-price fluctuations, generator maintenance requirements and environmental impacts associated with fossil-fuel combustion.

The use of diesel generators as backup power also creates recurring expenditure on fuel, lubrication, servicing, repairs and replacement of components. In addition to financial implications, generator operation contributes to atmospheric emissions, noise and local environmental disturbance. Where electricity supply remains unreliable, academic activities and research operations can be interrupted, while sensitive laboratory and ICT equipment may be exposed to power-quality problems.

Although renewable energy provides an alternative pathway, institutional adoption requires systematic assessment of energy demand, resource availability, technology suitability, storage requirements, implementation costs, maintenance capability and long-term sustainability. A renewable-energy system that is inadequately sized may fail to satisfy critical loads, whereas excessive capacity may result in unnecessary capital expenditure.

The specific problem addressed by this study is therefore the absence of an integrated campus-level renewable-energy framework based on the estimated energy requirements and operational characteristics of Federal Polytechnic Bauchi. The study seeks to establish the relevance of renewable energy and develop a practical solar PV–battery configuration capable of supporting sustainable institutional development.

OBJECTIVES OF THE STUDY

The main objective of this study is to examine the relevance of renewable-energy sources for sustainable campus development at Federal Polytechnic Bauchi.

The specific objectives are to:

1. Estimate the electricity-energy requirement of Federal Polytechnic Bauchi;
2. Assess the suitability of renewable-energy sources for institutional electricity supply;
3. Develop an appropriate solar PV–battery configuration for improving campus energy reliability; and
4. Examine the potential contributions of renewable-energy integration to institutional sustainability, environmental protection, education and technological development.

RESEARCH QUESTIONS

The study was guided by the following research questions:

1. What is the estimated electricity-energy requirement of Federal Polytechnic Bauchi?
2. Which renewable-energy source is most appropriate for sustainable electricity supply at the institution?
3. What solar PV and battery-storage configuration can appropriately support the estimated campus energy requirement?
4. How can renewable-energy integration contribute to institutional sustainability, environmental protection, education and technological development?

RESEARCH HYPOTHESES

The following null hypotheses were formulated:

1. H_{01}: Renewable-energy integration has no significant relevance to sustainable electricity supply at Federal Polytechnic Bauchi.
2. H_{02}: Solar PV and battery storage do not provide a technically appropriate pathway for improving campus electricity reliability.
3. H_{03}: Renewable-energy integration does not contribute substantially to environmental sustainability, educational development and technological innovation at Federal Polytechnic Bauchi.

Because the study is primarily a technical case-study assessment rather than an inferential survey, the hypotheses are treated as conceptual propositions and are evaluated through the technical and sustainability evidence rather than through population-level statistical inference.

Renewable Energy and Sustainable Development

Renewable energy refers to energy obtained from naturally replenishing resources such as solar radiation, wind, hydropower, biomass and geothermal resources (Achakpo ***et al***., 2026a). Its increasing adoption is associated with energy security, environmental protection, climate-change mitigation and socioeconomic development (Achakpo ***et al***., 2026b). For Nigeria, renewable energy is particularly important because the country possesses substantial solar, biomass, hydro and other renewable-energy resources while simultaneously experiencing persistent energy-supply challenges (IRENA, 2023).

IRENA's Renewable Energy Roadmap for Nigeria indicates that renewable energy could provide a substantially larger share of Nigeria's future energy demand. The roadmap emphasizes that successful

deployment requires appropriate financing, policy coordination, infrastructure development, technology deployment and institutional capacity (IRENA, 2023).

The Nigerian policy environment has also increasingly recognized renewable energy and energy efficiency. The National Policy on Renewable Energy and Energy Efficiency provides a policy basis for increasing renewable-energy utilization and improving energy efficiency in Nigeria (Nigerian Electricity Regulatory Commission [NERC], 2017).

Renewable Energy in Higher-Education Institutions

Higher-education institutions have particular reasons for adopting renewable energy because they operate continuously and possess large concentrations of buildings, laboratories, equipment and other energy-consuming infrastructure. Rodgers (2021) argued that higher-education institutions can pursue renewable-energy investments through coordinated capacity planning and operational strategies aimed at reducing carbon emissions.

Renewable-energy adoption can also support the broader sustainability mission of higher-education institutions. Studies of higher-education campuses indicate that PV systems can contribute to environmental and social sustainability while providing opportunities for institutions to demonstrate sustainable development practices (Santos ***et al***., 2022).

Furthermore, renewable-energy systems can support educational objectives by providing real-world facilities for student training and research. A polytechnic equipped with PV systems, batteries, inverters, monitoring systems and energy-management infrastructure can transform its energy infrastructure into a practical learning platform for engineering, environmental technology and renewable-energy programmes.

Solar Photovoltaic Technology for Campus Applications

Solar PV technology converts incident solar radiation directly into electricity through semiconductor photovoltaic cells. Its modular characteristics make it suitable for applications ranging from small rooftop systems to large campus-scale installations. PV systems can be configured as grid-connected, off-grid or hybrid systems incorporating batteries and conventional backup generators (Achakpo ***et al***., 2026a).

For educational institutions, grid-connected PV can reduce electricity purchased from the grid during daylight hours, whereas battery-supported hybrid systems can provide greater resilience when the grid is unavailable. The appropriate configuration depends on the load profile, solar resource, available space, desired reliability and economic constraints.

The Federal Polytechnic Mubi study provides a particularly relevant precedent. Luqman ***et al***. (2023) assessed a proposed 1 MW grid-connected PV plant and estimated annual generation of 1,550.98 MWh, demonstrating the feasibility of large-scale solar PV deployment within a Nigerian polytechnic environment.

Battery Storage and Energy Resilience

Battery storage provides an important complement to solar PV because PV generation varies according to solar availability, while institutional electricity demand occurs throughout the day and night. Storage can absorb excess solar generation during periods of high solar availability and release stored electricity during periods of low solar production.

For campus applications, battery storage can provide peak-load support, improve renewable-energy utilization, reduce dependence on diesel generators and provide backup during grid interruptions.

However, battery capacity must be selected according to the critical-load requirement, desired backup duration, allowable depth of discharge, battery efficiency, lifecycle characteristics and economic considerations.

Renewable Energy and Environmental Sustainability

The environmental advantage of renewable electricity arises primarily from the displacement of fossil-fuel-based electricity generation. Reducing diesel-generator operation can decrease fuel consumption and emissions while also reducing generator-related noise and local air pollution.

At Federal Polytechnic Mubi, Luqman ***et al***. (2023) estimated that the proposed 1 MW PV system could reduce greenhouse-gas emissions by approximately 670.9 tonnes of CO_2 annually under the study assumptions. This provides evidence that solar PV deployment at Nigerian polytechnic campuses can have measurable environmental benefits.

Research Gap

Existing studies have examined renewable-energy feasibility at Nigerian universities and polytechnics, including Federal Polytechnic Mubi and the University of Abuja. However, the energy requirements and institutional conditions of Federal Polytechnic Bauchi require a distinct assessment. Previous studies have also frequently focused on individual technical or techno-economic dimensions. The present study extends the discussion by considering renewable energy as an integrated component of sustainable campus development, combining electricity demand, technology suitability, storage, environmental sustainability, education, research and institutional development.

Research Design

A case-study research design was adopted. The design was considered appropriate because the study focused specifically on Federal Polytechnic Bauchi and sought to evaluate the relevance of renewable-energy integration within the operational characteristics of a defined institutional environment.

The methodology consisted of four principal stages: assessment of institutional energy demand, evaluation of renewable-energy options, conceptual sizing of a solar PV–battery system, and assessment of sustainability implications.

Study Area

The study was conducted at Federal Polytechnic Bauchi, Bauchi State, Nigeria. The institution contains academic departments, engineering workshops, laboratories, administrative offices, ICT facilities and other supporting infrastructure that collectively create substantial electricity demand.

The institutional setting is particularly appropriate for renewable-energy research because engineering and technological programmes can utilize renewable-energy infrastructure as both an energy resource and an instructional facility.

Estimation of Energy Demand

The estimated campus electricity demand was established from the representative energy requirements of institutional buildings, equipment and services. The daily electricity requirement was taken as approximately:

Daily energy demand = 16,160 kWh/day

The annual energy requirement was calculated using Equation (1):

$E_{annual} = E_{daily} \times 365$ … (1)

Therefore:

$E_{annual} = 16,160 \times 365$

E_{annual}= 5,898,400 kWh/year

Hence, E_{annual} is approximately 5.90 GWh/year.

Table 1 presents an estimated energy requirement of Federal Polytechnic Bauchi, and the institutional demand may be sufficiently large to justify consideration of a campus-scale renewable-energy system rather than isolated small solar installations.

Table 1. Estimated Energy Requirement of Federal Polytechnic Bauchi

Parameter	Estimated value
Average daily electricity requirement	16,160 kWh/day
Approximate annual requirement	5.90 GWh/year
Proposed PV capacity	2 MW
Proposed battery storage	5.4 MWh
Principal renewable source	Solar PV
Proposed configuration	PV–battery hybrid

Source: Author's assessment.

Assessment of Renewable-Energy Options

Potential renewable-energy sources were evaluated based on resource availability, technical maturity, scalability, environmental performance, reliability, maintenance requirements and suitability for institutional application. Table 2 compares the assessment of renewable-energy option. Solar PV was selected as the principal renewable-energy technology because it offers high modularity, relatively simple operation, scalability and compatibility with rooftop and ground-mounted applications. The choice is also consistent with evidence from Nigerian polytechnic and university studies demonstrating the feasibility of solar-based systems (Diyoke ***et al***., 2023; Luqman ***et al***., 2023).

Table 2. Comparative Assessment of Renewable-Energy Options

Renewable source	Resource suitability	Scalability	Campus applicability	Major limitation
Solar PV	High	High	Very high	Intermittent generation
Wind	Moderate/ uncertain	Moderate	Site depended	Requires adequate wind resource
Small hydro	Low/ site dependent	Moderate	Limited	Requires suitable water resource
Biomass	Moderate	Moderate	Potentially applicable	Feedstock and emissions management
Geothermal	Low	Low	Limited	Resource availability
Solar thermal	High	Moderate	Specific applications	Mainly thermal than electrical

Source: Authors' assessment based on renewable-energy characteristics and Nigerian conditions.

Proposed Solar PV–Battery System

A conceptual 2 MW solar PV system supported by approximately 5.4 MWh battery storage was proposed. The configuration in ***Figure*** 1 consists of solar PV modules, DC combiner and protection equipment, maximum power-point tracking arrangements, grid-compatible inverters, battery energy-storage system, battery-management system, energy-management and monitoring system, AC and DC protection systems, earthing and lightning protection, campus distribution network, and grid/diesel-generator interface where required.

The proposed arrangement is intended to operate as a hybrid system rather than immediately eliminating all conventional electricity sources. The grid and existing standby generators can initially remain as supplementary sources while renewable-energy capacity is progressively increased.

Figure 1 illustrates the proposed energy architecture. The arrangement allows solar energy to serve campus loads during suitable solar periods, charge the battery when surplus energy is available, and support critical loads when solar generation or grid electricity is insufficient.

Solar PV Array → DC Protection/Combiner → Inverter → Campus Distribution Network → Institutional Loads

Solar PV Array → Battery Charger/Controller → 5.4 MWh Battery Storage → Bidirectional Inverter → Critical Loads

Grid/Diesel Generator → Automatic Transfer/Control System → Campus Distribution Network

Figure 1. Conceptual Solar PV–Battery Hybrid Energy Architecture for Federal Polytechnic Bauchi

Source: Authors' conceptual design.

Sustainability Assessment

The proposed system was assessed against five sustainability dimensions:

1. Energy sustainability: reduction of dependence on unreliable conventional electricity sources.
2. Economic sustainability: potential reduction in recurring expenditure on diesel fuel and generator operation.
3. Environmental sustainability: reduction in fossil-fuel consumption and associated emissions.
4. Educational sustainability: provision of practical renewable-energy infrastructure for teaching and research.
5. Institutional sustainability: improvement in energy resilience and support for long-term campus development.

The study therefore proposed 2 MW system that will serve as alternate energy source which may cater for about 50% of the campus load under certain operating conditions. However, a complete hourly load profile, measured solar-resource data, equipment specifications, battery degradation assumptions, power-quality assessment, land/roof-area assessment and detailed financial analysis will be required for sustainability.

Estimated Campus Electricity Requirement

The assessment established an estimated daily electricity requirement of approximately 16,160 kWh. This corresponds to an annual requirement of approximately 5.90 GWh depending on the annualization basis adopted.

The magnitude of the demand indicates that electricity is a major enabling resource for campus operations. Consequently, improving electricity reliability can have implications beyond energy management, extending to academic continuity, laboratory utilization, research productivity, ICT availability and administrative efficiency.

The result is consistent with the wider Nigerian higher-education context, where electricity reliability remains a significant concern and renewable-energy systems are increasingly being investigated as alternatives or complements to conventional supply. Diyoke ***et al***. (2023) demonstrated the potential of hybrid renewable systems for university buildings in different Nigerian climatic regions.

Suitability of Solar PV

Solar PV emerged as the most appropriate renewable-energy source for the case-study institution. Its advantages include modular deployment, relatively low operational complexity, scalability and the possibility of integrating generation with rooftops, car parks and suitable open spaces.

The suitability of solar PV is strengthened by regional evidence. Federal Polytechnic Mubi, also located in northeastern Nigeria, has been the subject of a detailed PV feasibility study. Luqman ***et al***. (2023) reported favourable solar-resource conditions and demonstrated the technical and environmental feasibility of a 1 MW PV installation at the institution.

The choice of solar PV is also consistent with Nigeria's broader renewable-energy transition pathway. IRENA (2023) identified distributed solar PV as one of the important technologies capable of supporting expanded electricity access and the country's transition towards a more sustainable energy system.

Proposed 2 MW PV Capacity

The proposed 2 MW PV capacity represents a campus-scale generation strategy designed to make a significant contribution to the institutional load. The system should not be interpreted as a final bankable design because the exact optimum capacity requires detailed hourly simulation and measured load and solar data.

The proposed capacity is nevertheless reasonable as a planning scenario because comparable Nigerian tertiary institutions have investigated or deployed large PV systems. Federal Polytechnic Mubi investigated a 1 MW system, while Nile University in Abuja has implemented progressively expanded solar installations for campus electricity supply.

The experience of Nile University is particularly relevant because it demonstrates that commercial-scale solar can be implemented within a Nigerian tertiary-education environment and can be expanded in phases. The reported system has progressed through multiple installation phases, illustrating the practicality of phased institutional renewable-energy deployment.

Battery Storage Requirement

The proposed 5.4 MWh battery system is intended primarily to improve energy resilience rather than simply to increase PV generation. Storage enables electricity generated during favourable solar periods to be retained and subsequently supplied to critical loads.

Battery storage can also reduce the frequency with which diesel generators are required to respond to short-duration grid interruptions. However, battery sizing should be refined using an hourly load profile and critical-load classification. The 5.4 MWh value should therefore be regarded as a planning configuration rather than a final procurement specification.

Table 3 shows that the proposed system is not simply a collection of solar modules and batteries. Effective campus energy transition requires generation, storage, power conversion, protection, monitoring and energy-management components to operate as an integrated system.

Table 3. Functional Role of the Proposed Renewable-Energy Components

Component	Primary function	Sustainability contribution
2 MW PV array	Electricity generation	Reduces conventional electricity dependence.
5.4 MWh battery	Energy storage	Improves resilience and renewable-energy utilization.
Inverter system	DC/AC conversion	Enables integration with campus loads.
Energy-management system	Monitoring and control	Supports efficient energy use.
Grid interface	Supplementary supply	Maintains operational flexibility.
Existing generators	Emergency/backup supply	Provides transitional resilience.
Protection/earthing	Electrical safety	Supports reliable operation.

Source: Authors' proposed system architecture.

IMPLICATIONS AND CONTRIBUTIONS TO KNOWLEDGE, PRACTICE AND INDUSTRY

Implication

i. Improved Energy Reliability

One of the major anticipated benefits of renewable-energy integration is improved electricity reliability. Grid interruptions can be partially mitigated by stored solar electricity, particularly for critical loads such as ICT facilities, laboratories, communication systems, security installations, selected administrative functions and essential academic equipment.

This approach is consistent with the findings of Nigerian studies demonstrating the potential of hybrid renewable-energy systems to provide cleaner and more reliable electricity to institutional buildings (Diyoke ***et al***., 2023).

ii. Environmental Implications

The environmental significance of the proposed system arises mainly from displacement of diesel and other fossil-fuel-based electricity generation. Reduced generator operation can decrease fuel consumption, greenhouse-gas emissions, particulate emissions and noise.

The Federal Polytechnic Mubi study provides empirical support for this potential, estimating substantial carbon-emission reductions from a proposed 1 MW PV system (Luqman ***et al***., 2023).

The environmental benefit of the Federal Polytechnic Bauchi system would depend on the quantity of conventional electricity actually displaced. Therefore, a future implementation study should quantify annual avoided diesel consumption, grid-electricity displacement and associated CO_2-equivalent emissions using measured operational data.

iii. Economic and Operational Implications

Although this study does not present a detailed bankable financial model, renewable-energy deployment can potentially reduce recurrent expenditure associated with diesel fuel, generator servicing and emergency power generation. Higher education institutions have increasingly investigated renewable generation and energy-efficiency investments as components of long-term carbon and cost-reduction strategies (Rodgers, 2021).

The economic case should, however, be evaluated using current Nigerian equipment prices, financing costs, battery replacement requirements, operation and maintenance costs, tariff

structures, generator fuel consumption and expected PV degradation. A phased implementation approach can reduce the initial financial burden.

iv. Educational and Research Implications

A renewable-energy campus can become a living laboratory for students and researchers. At Federal Polytechnic Bauchi, PV arrays, batteries, inverters, energy meters and monitoring platforms could support practical instruction in mechanical engineering, electrical/electronic engineering, renewable-energy technology, instrumentation, control and environmental management.

This is particularly important for a polytechnic whose mandate includes technical education and practical skills development. Renewable-energy infrastructure can therefore serve two functions simultaneously: supplying electricity and providing an educational platform.

v. Sustainability and Institutional Development

The integration of renewable energy can strengthen the institution's sustainability profile by linking energy management with environmental responsibility, education, innovation and community development. Higher-education institutions have a special opportunity to demonstrate sustainable technologies because they combine infrastructure, research capacity, technical expertise and large user populations.

Research on sustainability in higher education has shown that renewable energy can form part of broader institutional sustainability strategies rather than being treated solely as an energy-generation project (Rodgers, 2021; Santos ***et al***., 2022).

Contributions to Knowledge, Practice and Industry

i. Contribution to Knowledge

The study contributes to knowledge by presenting renewable-energy adoption as a component of sustainable campus development rather than as an isolated electricity-generation intervention. It establishes a conceptual relationship among institutional energy demand, solar PV generation, battery storage, energy resilience, environmental sustainability and technical education.

The case study also adds to the limited body of literature specifically concerned with renewable-energy planning for Nigerian polytechnic environments. The Federal Polytechnic Mubi study provides an important precedent, while this study extends the discussion to Federal Polytechnic Bauchi and emphasizes the wider institutional-development implications of renewable-energy integration.

ii. Contribution to Practice

In practice, the study provides a framework that institutional management can use for phased renewable-energy planning. The proposed approach supports campus energy auditing, prioritization of critical electrical loads; phased solar PV installation, battery-storage deployment, energy-efficiency improvement, real-time energy monitoring, reduction of diesel-generator dependence, preventive maintenance, and institutional renewable-energy management.

iii. Contribution to Industry

The proposed renewable-energy transition can create opportunities for collaboration among Federal Polytechnic Bauchi, solar-energy companies, engineering consultants, financial institutions and government agencies. Such collaboration can support installation,

maintenance, skills development, technology transfer, student industrial training and renewable-energy research.

The Electricity Act 2023 also created a broader enabling environment for electricity-sector participation and renewable-energy development in Nigeria, including expanded opportunities for electricity generation and investment (United Nations Conference on Trade and Development [UNCTAD], 2023).

CONCLUSIONS, AND RECOMMENDATIONS

i. Conclusions

The study examined the relevance of renewable-energy sources for sustainable campus development at Federal Polytechnic Bauchi. The estimated institutional electricity requirement was approximately 16,160 kWh/day, corresponding to approximately 5.90 GWh/year depending on the annualization basis used.

Solar photovoltaic technology was identified as the most suitable renewable-energy option because of its scalability, modularity, environmental advantages and compatibility with distributed campus applications. A planning configuration comprising approximately 2 MW of solar PV and 5.4 MWh of battery storage was proposed as a potential pathway for improving institutional energy resilience.

The study concludes that renewable-energy integration can contribute to sustainable campus development through improved electricity reliability, reduced dependence on diesel generation, lower fossil-fuel consumption, environmental protection, renewable-energy education and research opportunities. However, the proposed capacity should be subjected to detailed hourly load analysis, solar-resource assessment, electrical-system studies and techno-economic optimization before procurement or construction.

Federal Polytechnic Bauchi can therefore benefit from a gradual transition from predominantly conventional electricity supply towards a diversified energy system in which solar PV, battery storage, grid electricity, energy efficiency and limited conventional backup operate within an integrated energy-management framework.

ii. Recommendations

Based on the findings and conclusions, the following recommendations are made:

1. Conduct a comprehensive campus energy audit: The institution should undertake a detailed audit covering all academic, administrative, laboratory, workshop, hostel and service buildings.
2. Develop a measured hourly load profile: Smart meters should be installed at major energy-consuming facilities to provide reliable data for final PV and battery sizing.
3. Implement solar PV in phases: A phased approach should be adopted, beginning with critical facilities and progressively expanding towards a campus-scale system.
4. Provide battery energy storage: Battery storage should be integrated to improve resilience during grid interruptions and maximize utilization of solar electricity.

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