

Energy Reliability and Its Implications for Translational Research Capacity in Nigeria's Tertiary Institutions

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Abstract

This study investigated the implications of electricity reliability for translational research capacity in Nigerian tertiary institutions using a cross-sectional survey and quantitative laboratory energy assessment. Data were obtained from 90 respondents drawn from universities, polytechnics, and research institutes across Nigeria. Electricity reliability was estimated using an operational availability factor, while laboratory energy demand and backup energy adequacy were evaluated using standard engineering models. Findings revealed a highly unstable electricity supply, with 39% of respondents experiencing outages of 4–6 hours daily and 28% reporting interruptions exceeding 7 hours per day. Estimated electricity availability ranged from 0.75 to 0.83, while laboratory energy demand ranged from 10 to 50 kWh/day, depending on laboratory intensity and equipment usage. Although diesel generators (85%), solar photovoltaic systems (60%), and inverter systems (30%) were commonly used as backup energy sources, they were often inadequate for uninterrupted laboratory operations. Statistical analysis showed significant associations between electricity reliability and laboratory disruption ($\rho = -0.68$), project delays ($\rho = -0.61$), and research productivity ($\rho = 0.64$), all at $p < 0.01$. Linear regression further showed that electricity reliability was significantly associated with research productivity ($\beta = 0.59$, $R^2 = 0.41$, $p < 0.01$). Respondents also reported equipment downtime, disruption of sensitive laboratory procedures, loss of experimental samples, and delays in research timelines. The study concludes that electricity instability is an important infrastructural constraint on translational research capacity and recommends investment in hybrid renewable energy systems, dedicated research power infrastructure, and institutional energy planning to strengthen scientific productivity and innovation.

Keywords: Electricity reliability; translational research; Nigerian tertiary institutions; laboratory infrastructure; backup energy systems; research productivity.

I. INTRODUCTION

Electricity reliability is a fundamental requirement for scientific advancement, technological innovation, and sustainable research productivity in tertiary institutions. Modern translational research environments depend heavily on uninterrupted electricity supply to support laboratory instrumentation, refrigeration systems, molecular analysis equipment, computational facilities, environmental control systems, and digital data management platforms. In research-intensive disciplines such as microbiology, chemistry, biomedical science, physics, engineering, and environmental science, stable electricity supply is essential for maintaining experimental continuity, preserving sensitive samples, ensuring data integrity, and supporting precision-based analytical procedures. Consequently, electricity instability has emerged as an important infrastructural challenge that can undermine research efficiency, delay scientific discovery, and weaken innovation capacity within higher education institutions [1-2].

Globally, reliable electricity infrastructure is recognized as a strategic driver of research excellence and national technological competitiveness. Advanced economies maintain highly resilient research energy systems characterized by uninterrupted power supply (UPS) technologies, redundant grid infrastructure, automated backup systems, and integrated renewable energy solutions to ensure continuous laboratory operations and protection of critical scientific equipment [3-4]. In many research-intensive environments, high levels of electricity reliability are maintained through robust grid systems and institutional energy planning, while several African countries have also made progress through hybrid renewable energy integration and decentralized energy solutions [2], [6-7]. These developments highlight the close relationship between reliable electricity supply, scientific productivity, innovation performance, and institutional research competitiveness.

In contrast, electricity supply in many developing countries remains highly unstable, and Nigeria represents one of the most affected contexts within sub-Saharan Africa. The Nigerian electricity sector continues to experience persistent generation shortages, transmission inefficiencies, voltage fluctuations, and recurrent grid collapses that significantly affect institutional operations and socio-economic development [4], [8]. Public tertiary institutions are particularly vulnerable because laboratory-based research activities often depend on unreliable national grid supply supplemented by costly and inadequately sized backup systems. Although diesel generators, inverter technologies, and solar photovoltaic systems are increasingly adopted across Nigerian institutions, these alternatives frequently remain insufficient to sustain uninterrupted laboratory operations due to high operational costs, inadequate storage capacity, poor maintenance culture, and limited institutional funding [9-10]. Consequently, many laboratories operate under constrained

energy conditions that limit equipment utilization, reduce experimental continuity, and suppress overall research productivity.

Translational research, which involves the conversion of scientific discoveries into practical applications and technological innovations, is particularly sensitive to electricity instability because it depends on continuous experimental workflows, precision instrumentation, and reproducible laboratory conditions. Interruptions in electricity supply can result in loss of biological samples, disruption of molecular experiments, corruption of digital data, equipment malfunction, and delays in project completion timelines. These disruptions increase operational costs, reduce research efficiency, and weaken the reliability and reproducibility of scientific outcomes. Previous studies conducted in African research environments have shown that unstable electricity supply compromises laboratory integrity and significantly affects scientific productivity and innovation systems [11-12]. Similarly, studies in Nigerian universities have linked unreliable power supply with reduced academic performance, delayed project completion, and declining institutional efficiency [13].

Despite growing concern regarding energy insecurity in Nigeria, existing literature has focused predominantly on broader issues such as electricity access, funding constraints, and infrastructural deficits, with limited empirical attention devoted specifically to the relationship between electricity reliability and translational research capacity in tertiary institutions. Furthermore, most previous studies have relied largely on descriptive observations without integrating laboratory energy demand analysis, institutional reliability estimation, or inferential statistical evaluation of research outcomes. Consequently, there remains limited quantitative evidence on how electricity instability affects laboratory operations, research productivity, project continuity, and translational research capacity within Nigerian tertiary institutions.

Against this background, the present study investigates the implications of electricity reliability for translational research capacity in Nigerian tertiary institutions using survey-based empirical data and quantitative energy assessment methods. Specifically, the study evaluates electricity outage patterns, laboratory energy demand, backup energy system adequacy, and the relationship between electricity reliability and research performance indicators such as laboratory disruption, project delays, and research productivity. Electricity reliability was estimated using an operational availability factor suitable for institutional environments where detailed utility-level outage indices such as SAIDI, SAIFI, and CAIDI are not readily available. To strengthen analytical depth, the study further applied correlation and linear regression analyses to examine the association between electricity reliability and translational research outcomes. By integrating engineering-based energy assessment with empirical institutional data, the study provides evidence-based insights

into how electricity instability is associated with scientific productivity and translational research development within Nigeria's higher education system.

II. MATERIALS AND METHODS

This study adopted a cross-sectional survey design complemented by quantitative laboratory energy assessment to investigate the relationship between electricity reliability and translational research capacity in Nigerian tertiary institutions. The study population comprised lecturers, postgraduate students, laboratory technologists, research assistants, and administrative personnel drawn from public universities, private universities, polytechnics, and research institutes across Nigeria. A purposive sampling technique was employed to ensure that only respondents directly involved in laboratory operations and research activities were included in the study. Data were collected through a structured online questionnaire distributed via institutional and academic networks, resulting in 90 valid responses. The questionnaire captured demographic characteristics, electricity supply conditions, laboratory energy demand, backup energy infrastructure, and the effects of electricity instability on research productivity and continuity [14-15].

To improve methodological rigor, the questionnaire was reviewed by subject experts and pilot-tested before the main survey. The pilot study involved 15 respondents who were not included in the final analysis. The instrument comprised demographic items and Likert-scale measures coded from 1 (strongly disagree/very low) to 5 (strongly agree/very high), while categorical variables were coded numerically for statistical analysis. Internal consistency of the questionnaire items was assessed using Cronbach's alpha reliability analysis, yielding a coefficient of 0.82. This value exceeds the recommended threshold of 0.70 and indicates good reliability and satisfactory internal consistency of the measurement scales. The questionnaire items used for the correlation and regression analyses are provided in Appendix A.

Research productivity was assessed using a composite index derived from respondents' perceptions of four indicators: (i) completion rate of research projects, (ii) continuity of research activities and laboratory experiments, (iii) laboratory efficiency and utilization of research equipment, and (iv) research output/publication activities. These indicators were measured using four five-point Likert-scale items ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), as presented in Appendix A. The individual item scores were aggregated and averaged to generate a composite research productivity score, which served as the dependent variable in the correlation and linear regression analyses. Higher scores indicated greater perceived research productivity and continuity of research activities.

Electricity reliability was estimated using an operational availability factor because detailed utility-level reliability indices such as the System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency

Index (SAIFI) were unavailable for most participating institutions. The availability factor was calculated using (1).

$$AF = \frac{T_{available}}{T_{total}} \quad (1)$$

Where $T_{available}$ represents the duration of electricity availability and T_{total} represents the total operational period. The availability factor provides a simple operational estimate of service continuity based on respondents' reports rather than utility-recorded reliability indices. It does not capture outage frequency, voltage fluctuations, or power quality and should therefore be interpreted as a proxy indicator rather than a comprehensive engineering reliability metric. Estimated values ranged from 0.75 to 0.83.

To strengthen statistical transparency, confidence intervals associated with self-reported outage durations were computed using standard normal approximation methods at the 95% confidence level. The mean reported outage duration was 7.4 hours/day with a 95% confidence interval of 6.8–8.0 hours/day, indicating substantial variability in electricity supply conditions across institutions. The confidence interval estimation helped quantify uncertainty associated with self-reported outage measurements and improved the robustness of the reliability assessment methodology [16].

Laboratory energy demand was estimated using standard engineering relationships for electrical energy consumption given by (2).

$$E = P \times t \quad (2)$$

Where E denotes energy consumption (kWh), P represents equipment power rating (kW), and t is the duration of use (hours). For multiple devices, total energy demand was computed using (3).

$$E_{total} = \sum_{i=1}^n P_i \times t_i \quad (3)$$

This approach is widely applied in energy demand estimation and distributed energy system planning, particularly in environments with limited metering infrastructure [12]. Typical laboratory equipment, including refrigeration units, incubators, centrifuges, molecular analysis systems, and computing devices, was used to develop representative load profiles. Estimated daily laboratory energy requirements ranged from 10 to 50 kWh, depending on laboratory scale and research intensity.

The adequacy of alternative power systems, including generators, solar photovoltaic systems, and inverter-based storage systems, was evaluated by comparing effective backup supply capacity with estimated laboratory energy demand. Energy deficits during outage periods were calculated using (4), thereby identifying gaps between available backup capacity and operational energy needs. This approach aligns with recent studies emphasizing the importance of matching distributed energy systems to actual load requirements in resource-constrained settings [17]:

$$E_{deficit} = E_{demand} - E_{supply} \quad (4)$$

Quantitative data were analyzed using descriptive and inferential statistical methods. Frequencies, percentages,

means, and standard deviations were used to summarize respondent characteristics, electricity outage patterns, and laboratory energy conditions. Spearman’s rank-order correlation was used to assess associations between electricity reliability and research outcomes, including laboratory disruption, project delays, and research productivity. To strengthen the analytical depth of the study, linear regression analysis was conducted using the model, given by (5).

$$R = \beta_0 + \beta_1 E + \varepsilon \tag{5}$$

Where R represents research productivity, E denotes electricity reliability, β_0 is the intercept, β_1 is the regression coefficient, and ε represents the error term. In the regression model, research productivity served as the dependent variable, while electricity reliability served as the predictor variable. Statistical significance was evaluated at $p < 0.05$, while qualitative responses were analyzed thematically to identify recurring patterns related to energy insecurity, equipment vulnerability, and institutional mitigation strategies [18-19]. Ethical considerations were strictly observed, including voluntary participation, informed consent, anonymity, and confidentiality of all respondents.

III. RESULTS AND DISCUSSION

A. Demographic Characteristics of Respondents

A total of 90 valid responses were analyzed from lecturers, postgraduate students, laboratory personnel, research assistants, and administrative staff across Nigerian tertiary institutions. Most respondents were lecturers/researchers (60%), followed by postgraduate students (20%), while laboratory/research assistants and administrative staff accounted for 10% each. Institutionally, 65% of respondents were drawn from public universities, 20% from polytechnics, 10% from private universities, and 5% from research institutes.

The dominance of lecturers, researchers, and laboratory personnel indicates that the responses were largely obtained from individuals with direct operational experience in electricity usage, laboratory management, and research continuity. This strengthens the credibility of the findings because these categories of respondents are actively involved in laboratory experimentation, equipment utilization, sample preservation, and research project implementation. The high representation of respondents from public universities also reflects the structure of Nigeria’s research system, where public institutions account for a substantial proportion of laboratory-based scientific research and postgraduate training [19].

Table I presents the demographic characteristics of the respondents. The gender distribution showed higher male participation (75%) compared with females (25%), which is broadly consistent with patterns of gender representation in science, technology, engineering, and laboratory-intensive disciplines in many developing-country contexts. The inclusion of postgraduate students, technical personnel, and

administrators further improved the multidimensional nature of the dataset by incorporating academic, operational, and institutional management perspectives.

Table I. Demographic Characteristics of Respondents.

| Variable | Category | Frequency (n) | Percentage (%) |
|-------------|------------------------|---------------|----------------|
| Gender | Male | 68 | 75 |
| | Female | 22 | 25 |
| Role | Lecturer/Researcher | 54 | 60 |
| | Postgraduate Student | 18 | 20 |
| | Lab/Research Assistant | 9 | 10 |
| | Administrator | 9 | 10 |
| Institution | Public University | 59 | 65 |
| | Private University | 9 | 10 |
| | Polytechnic | 18 | 20 |
| | Research Institute | 4 | 5 |

B. Electricity Reliability and Outage Patterns

Findings revealed that electricity supply in Nigerian tertiary institutions is generally unstable, with frequent and prolonged outages affecting laboratory operations, experimental continuity, and research activities. As shown in Fig. 1, approximately 39% of respondents experienced electricity interruptions lasting between 4 and 6 hours daily, while 28% reported outages exceeding 7 hours per day. Only 20% of respondents indicated relatively stable electricity conditions with outages limited to 1–3 hours daily.

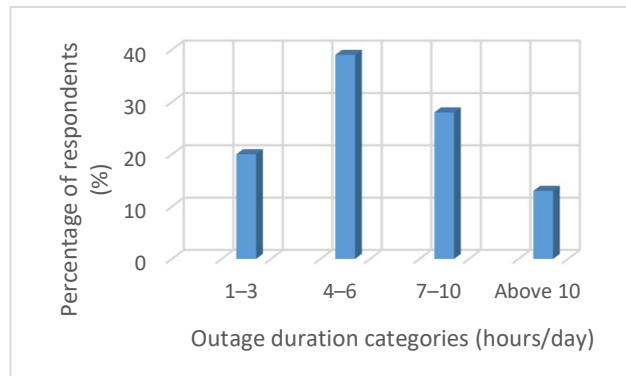


Fig. 1. Electricity Reliability Status in Nigerian Tertiary Institutions.

The operational availability factor used for estimating electricity reliability yielded values ranging from 0.75 to 0.83, indicating moderate-to-low levels of institutional power availability for research activities. These estimated availability values are considerably lower than electricity reliability levels commonly reported for research-intensive environments and indicate important limitations in institutional power availability for laboratory operations [3]. Although the availability factor used in this study is not directly equivalent to utility-level reliability indices such as SAIDI or SAIFI, the results nevertheless suggest substantial

limitations in institutional power availability for laboratory operations. Similar patterns of unstable electricity supply have been reported across Nigeria’s tertiary education sector, where recurrent grid failures, voltage fluctuations, and insufficient generation capacity continue to undermine institutional productivity [8]. The observed availability levels suggest that many research laboratories operate under conditions that may compromise experimental continuity, equipment utilization, and sample preservation. The findings therefore highlight an important infrastructural challenge that may constrain research efficiency and translational research capacity in Nigerian tertiary institutions.

C. Laboratory Energy Demand and Backup Energy Capacity

The study established that laboratory energy demand in Nigerian tertiary institutions ranges between 10 and 50 kWh/day depending on research intensity, laboratory size, and equipment usage patterns. Common laboratory equipment identified included refrigeration systems, incubators, PCR machines, centrifuges, analytical instruments, and computing systems. As summarized in Table II, laboratories involved in biomedical, molecular, chemical, and environmental research demonstrated relatively higher energy demand because of the continuous operation of refrigeration units, environmental control systems, and precision analytical equipment.

Table II. Estimated Laboratory Energy Consumption Profile

| Equipment Type | Typical Operational Pattern | Relative Energy Demand |
|----------------------|-----------------------------|------------------------|
| Refrigeration Units | Continuous | High |
| Incubators | Intermittent | Moderate–High |
| PCR Machines | Short Cycles | Moderate |
| Centrifuges | Short Bursts | Moderate |
| Computer Systems | Daily Use | Low–Moderate |
| Analytical Equipment | Variable | High |

The observed energy demand profile indicates that many research laboratories require relatively stable and uninterrupted electricity supply to maintain experimental continuity and equipment integrity. Refrigeration systems and analytical instruments were identified as the most energy-sensitive components because interruptions can lead to sample degradation, calibration instability, and experimental failure. These findings suggest that electricity instability may have particularly severe consequences in laboratory environments that depend on continuous temperature control, precision instrumentation, and time-sensitive experimental procedures.

Most institutions relied heavily on backup energy systems to sustain research operations during outages, with diesel generators representing the dominant alternative source of

electricity. As shown in Fig. 2, backup energy systems provided important temporary support for laboratory operations; however, their functional capacity varied considerably across institutions.

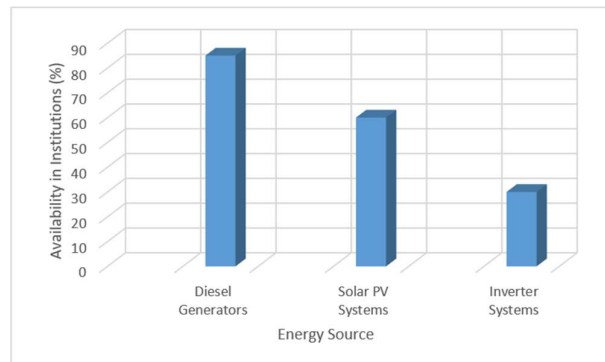


Fig. 2. Backup Energy Systems and Functional Capacity.

The survey findings indicate that although backup systems provide temporary mitigation, they are often inadequate to sustain uninterrupted laboratory operations, particularly in energy-intensive research environments [9]. Diesel generators, despite their relatively high functional capacity, are associated with rising fuel costs, greenhouse gas emissions, and maintenance challenges, which may limit their long-term sustainability for research operations. Solar photovoltaic systems and inverter technologies are increasingly being adopted in Nigerian institutions; however, their effectiveness appears constrained by inadequate battery storage, poor system sizing, and limited institutional investment. These findings highlight the need for more resilient backup energy strategies capable of matching laboratory load requirements and supporting continuity of research activities during prolonged power outages. In this regard, hybrid renewable energy systems that combine solar photovoltaic generation, battery storage, and improved load management may offer a more sustainable pathway for strengthening laboratory energy resilience and translational research capacity in Nigerian tertiary institutions.

D. Relationship Between Electricity Reliability and Research Outcomes

Statistical analysis indicated significant associations between electricity reliability and key indicators of translational research performance in Nigerian tertiary institutions. As presented in Table III, Spearman’s rank-order correlation analysis showed that electricity reliability had a strong negative association with laboratory disruption ($\rho = -0.68, p < 0.01$), indicating that improved electricity availability was associated with reduced interruption of laboratory activities and experimental procedures. Similarly, electricity reliability demonstrated a strong negative association with project delays ($\rho = -0.61, p < 0.01$), indicating that institutions reporting lower electricity reliability also tended to report greater project delays,

interruption of laboratory schedules, and reduced operational continuity. A strong positive association was also observed between electricity reliability and research productivity ($\rho = 0.64, p < 0.01$), indicating that higher electricity reliability was associated with improved research output, laboratory efficiency, and continuity of experimental activities.

Table III Correlation Between Electricity Reliability and Research Outcomes.

| Variables Compared | Spearman's ρ | p-value | Interpretation |
|---|-------------------|---------|-----------------------------|
| Electricity Reliability vs. Laboratory Disruption | -0.68 | <0.01 | Strong Negative Association |
| Electricity Reliability vs. Project Delay | -0.61 | <0.01 | Strong Negative Association |
| Electricity Reliability vs. Research Productivity | 0.64 | <0.01 | Strong Positive Association |

The findings are consistent with previous studies reporting that electricity instability negatively affects academic productivity, laboratory functionality, and institutional research performance in developing-country contexts [13], [18]. Frequent outages may disrupt sensitive laboratory procedures, compromise experimental reproducibility, and increase the risk of equipment failure and data loss. Such challenges are particularly important in research-intensive environments that depend on refrigeration systems, environmental controls, analytical equipment, and computational infrastructure for continuous operation.

Table IV. Linear Regression Analysis of Electricity Reliability and Research Productivity

| Variable | β Coefficient | Standard Error | t-value | p-value |
|-------------------------|---------------------|----------------|---------|---------|
| Electricity Reliability | 0.59 | 0.08 | 7.38 | <0.01 |

Table V. Model Fit Statistics

| Statistic | Value |
|----------------|---------------------------|
| R^2 | 0.41 |
| Adjusted R^2 | 0.39 |
| F-statistic | Significant at $p < 0.01$ |

As shown in Tables IV and V, the regression analysis indicated that approximately 41% of the observed variation in research productivity was statistically associated with electricity reliability conditions. Electricity reliability was a significant predictor of research productivity ($\beta = 0.59, t = 7.38, p < 0.01$), with an overall model fit of $R^2 = 0.41$ and

adjusted $R^2 = 0.39$. The positive regression coefficient suggests that higher electricity reliability was associated with higher reported levels of research productivity and laboratory operational efficiency. Although the cross-sectional design of the study does not permit causal inference, the observed relationship highlights the importance of reliable electricity supply for sustaining research continuity and laboratory functionality. Similar findings have been reported in studies conducted across African universities, where energy insecurity has been identified as a major infrastructural barrier to scientific productivity and institutional competitiveness [21-22]. The findings of this study therefore reinforce the importance of strategic investment in reliable hybrid energy systems and institutional energy planning to strengthen translational research capacity in Nigerian tertiary institutions.

E. Implications for Translational Research Processes

The study further showed that electricity instability adversely affects multiple stages of translational research activities within Nigerian tertiary institutions. As shown in Fig. 3, respondents reported frequent loss of experimental samples, disruption of molecular and laboratory experiments, interruption of refrigeration systems, and loss of digital research data during prolonged outages. These disruptions were particularly severe in laboratories involved in microbiology, molecular biology, chemistry, biomedical science, and environmental analysis, where experimental procedures depend heavily on continuous electricity supply for refrigeration, incubation, environmental control, and automated instrumentation. In addition, respondents indicated that repeated outages increased research costs through repeated experiments, damaged samples, equipment malfunction, and delayed project implementation. Such interruptions reduce the continuity and reproducibility of scientific investigations, thereby weakening the overall efficiency of translational research processes.

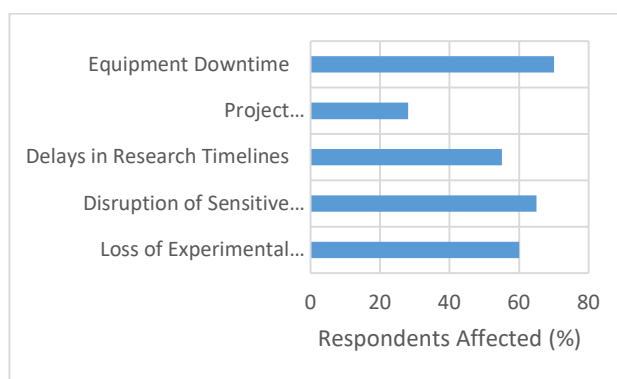


Fig. 3. Reported Effects of Electricity Instability on Research Activities.

The survey findings suggest that unreliable electricity supply is associated with reduced experimental continuity, reproducibility, and operational precision required for

translational research. Equipment downtime, reported by 70% of respondents, represents a major operational limitation because many scientific instruments, such as PCR systems, centrifuges, chromatography units, incubators, and refrigeration facilities, require uninterrupted electricity for stable operation. Similarly, the loss of experimental samples and digital research data reported by respondents highlights the vulnerability of laboratory systems to abrupt power interruptions and voltage fluctuations. Comparable findings have been reported in African laboratory environments where unstable electricity supply compromises research integrity, delays project completion, and increases operational costs [23-24]. The findings, therefore, suggest that electricity instability remains an important infrastructural constraint on scientific productivity and translational research capacity in Nigerian tertiary institutions.

F. International Benchmarking of Electricity Reliability

When benchmarked against electricity reliability levels commonly reported for research-intensive environments, Nigerian tertiary institutions exhibited comparatively lower levels of institutional power availability. The operational availability values observed in this study ranged from 0.75 to 0.83, suggesting that many research laboratories operate under conditions that may be inadequate for sustaining uninterrupted scientific experimentation, precision-based analysis, and long-duration laboratory procedures. Although the availability factor used in this study is not directly equivalent to utility-level reliability indices such as SAIDI or SAIFI, it provides a practical indication of institutional electricity availability under research operating conditions. The comparatively lower availability levels observed in this study reflect persistent structural challenges within Nigeria's electricity sector, including generation shortfalls, weak transmission infrastructure, unstable distribution networks, and limited institutional backup capacity [25–28]. Frequent outages and voltage instability may reduce laboratory operational efficiency and increase the vulnerability of sensitive research equipment and experimental samples.

As shown in Fig. 4, the electricity reliability conditions reported for Nigerian tertiary institutions remain lower than those commonly described for several other research environments. Research institutions in developed regions such as the United Kingdom and Europe generally maintain near-continuous electricity availability supported by redundant grid systems, uninterrupted power supply technologies, automated backup infrastructure, and advanced energy management systems [4], [28–32]. Similarly, South Africa and Ghana have made notable progress in strengthening institutional energy reliability through hybrid renewable energy integration, decentralized power systems, and improved infrastructure planning [32–35]. In contrast, the lower reliability levels observed in Nigerian tertiary institutions suggest an important infrastructural disadvantage that may constrain scientific productivity, innovation capacity, and research

competitiveness. These disparities highlight the importance of electricity reliability as a strategic component of translational research efficiency and laboratory resilience. Strengthening research capacity in Nigerian tertiary institutions will require deliberate investment in scalable hybrid renewable energy systems, institutional energy governance frameworks, smart monitoring technologies, and dedicated research power infrastructure capable of supporting uninterrupted laboratory operations.

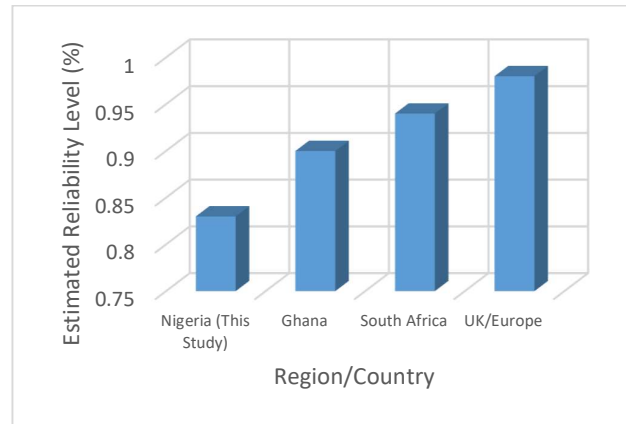


Fig. 4. International Comparison of Electricity Reliability in Research Environments.

IV. CONCLUSION

This study highlights the importance of electricity reliability as an infrastructural factor associated with translational research capacity in Nigerian tertiary institutions. The findings revealed that many institutions operate under moderate-to-low levels of electricity availability characterized by frequent and prolonged outages, limited backup energy capacity, and operational challenges within laboratory environments. Statistical analyses showed significant associations between electricity reliability and laboratory disruption, project delays, equipment downtime, loss of experimental samples, and research productivity. Compared with electricity reliability levels commonly reported in research-intensive environments, Nigerian tertiary institutions face important infrastructure-related constraints that may affect scientific efficiency, innovation capacity, and research competitiveness. Although diesel generators, solar photovoltaic systems, and inverter technologies provide important supplementary energy sources, their current deployment appears inadequate to support uninterrupted laboratory operations in many institutions consistently. The findings suggest that strengthening translational research capacity in Nigeria will require sustained investment in hybrid renewable energy systems, dedicated research power infrastructure, institutional energy planning, and effective energy governance frameworks that can improve the

reliability and resilience of electricity supply for research-intensive environments.

APPENDIX

Appendix A: Questionnaire Items Used for Analysis

The questionnaire items presented in this appendix correspond to the constructs used in the correlation and linear regression analyses reported in this study. All items were measured on a five-point Likert scale with the following response options:

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

Section D: Electricity Reliability

1. Electricity supply in my institution is reliable enough to support research activities.
2. Laboratory activities are frequently interrupted by power outages. (*reverse coded*)
3. Backup power systems adequately support laboratory operations during outages.
4. Power interruptions negatively affect the operation of laboratory equipment. (*reverse coded*)

Section E: Laboratory Disruption

1. Electricity outages disrupt ongoing laboratory experiments.
2. Sensitive laboratory procedures are frequently interrupted by power failures.
3. Power instability affects sample preservation and storage.

Section F: Project Delays

1. Electricity outages contribute to delays in research project completion.
2. Research schedules are often adjusted because of power interruptions.
3. Power instability increases the time required to complete laboratory investigations.

Section G: Research Productivity

1. Reliable electricity improves the completion rate of research projects.
2. Electricity availability enhances continuity of research activities.
3. Stable power supply improves laboratory efficiency and utilization of research equipment.
4. Reliable electricity contributes positively to research output and publication activities.

The composite score obtained from Section G (Research Productivity) was used as the dependent variable in the correlation and linear regression analyses.

Reference

- [1] UNESCO, Science Report: The Race Against Time for Smarter Development. Paris, France: UNESCO Publishing, 2024.

- [2] K. A. Adeyeye, "Decentralized energy transition in urban Nigeria: Institutional barriers and policy pathways for hybrid renewable energy systems," Oxford Open Energy, early access, 2025.
- [3] IEEE, IEEE Standard 1366-2012: IEEE Guide for Electric Power Distribution Reliability Indices. New York, NY, USA: IEEE, 2012.
- [4] UK Energy Research Centre (UKERC), Energy Use in Higher Education Laboratories: A Comparative Assessment. London, U.K.: UKERC Publications, 2022.
- [5] International Energy Agency (IEA), Africa Energy Outlook 2024. Paris, France: IEA, 2024.
- [6] O. A. Akinboade, S. Mokwena, and E. C. Kinfaak, "Electricity access in South Africa: Trends, impacts, and policy implications," Energy Policy, vol. 86, pp. 277–283, Nov. 2015, doi: 10.1016/j.enpol.2015.07.019.
- [7] J. V. Mensah and F. Kemausuor, "Solar hybrid systems for resilient energy supply in educational institutions," Renew. Sustain. Energy Rev., vol. 92, pp. 75–88, 2018, doi: 10.1016/j.rser.2018.04.088.
- [8] N. Edomah and G. Ndulue, "A review of stakeholders and interventions in Nigeria's electricity sector," Heliyon, vol. 7, no. 8, Art. no. e07842, 2021, doi: 10.1016/j.heliyon.2021.e07842.
- [9] A. Kuhe, A. A. Ndah, and M. A. Idris, "Enhancing energy security and cost efficiency in Nigerian higher institutions via hybrid renewable energy systems," Discover Environment, vol. 3, Art. no. 138, 2025, doi: 10.1007/s44274-025-00350-3.
- [10] International Renewable Energy Agency (IRENA), Renewable Energy and Electricity Access in Africa: Status and Prospects. Abu Dhabi, UAE: IRENA, 2023.
- [11] I. Churchill, "Impact of erratic power supply on research laboratories in Africa," African Journal of Science and Technology, vol. 11, no. 4, pp. 112–120, 2019.
- [12] S. Pelz, N. Chinichian, C. Neyrand, et al., "Electricity supply quality and use among rural and peri-urban households and small firms in Nigeria," Scientific Data, vol. 10, Art. no. 248, 2023, doi: 10.1038/s41597-023-02185-0.
- [13] T. O. S. Owolabi, A. O. Bello, A. J. Olatunji, and S. Jayeoba, "Influence of power supply reliability on academic performance and project completion rates of architectural students at Caleb University, Nigeria," African Journal of Humanities and Contemporary Education Research, vol. 4, no. 2, pp. 45–59, 2024, doi: 10.62154/ajhcer.2024.016.010391.
- [14] J. W. Creswell and J. D. Creswell, Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th ed. Thousand Oaks, CA, USA:

- Sage, 2018.
- [15] F. J. Fowler, *Survey Research Methods*, 5th ed. Thousand Oaks, CA, USA: Sage, 2014.
- [16] O. Osunmuyiwa *et al.*, “Electricity reliability measurement and energy transition dynamics in sub-Saharan Africa,” *Energy Research & Social Science*, 2025.
- [17] K. A. Adeyeye, “Decentralized energy transition in urban Nigeria: Institutional barriers and policy pathways for hybrid renewable energy systems,” *Oxford Open Energy*, early access, 2025.
- [18] C. Onwuchekwa, E. Ezeani, and C. Chukwu, “Power supply and research productivity among scientists in Nigeria,” *Int. J. Res. Eng. Technol.*, vol. 9, no. 5, pp. 207–215, 2020.
- [19] O. Nwafor and O. Okoye, “Academic research productivity in Nigerian universities: Trends and constraints,” *Higher Education Review*, vol. 50, no. 1, pp. 98–115, 2023.
- [20] O. A. Adewole, O. I. Dare-Adeniran, and O. O. Akinsooto, “Reliability analysis of a typical 33 kV distribution network using MATLAB: A case study of Ile-Oluji 33 kV distribution line,” *ABUAD Journal of Engineering Research and Development*, vol. 7, no. 1, 2024, doi: 10.53982/ajerd.2024.0701.09-j.
- [21] World Bank, *Electricity Access and Reliability in Sub-Saharan Africa: Diagnostic Report*. Washington, DC, USA: World Bank Group, 2023.
- [22] L. O. Adeyemi, T. Adefarati, G. S. Alabi, *et al.*, “Reliability assessment of transmission power system: A case study of Ajaokuta 132/33 kV substation feeders,” *Nigerian Research Journal of Engineering and Environmental Sciences*, vol. 9, no. 1, pp. 438–458, 2024, doi: 10.5281/zenodo.12600797.
- [23] F. O. Akpojedje and A. S. Orukele, “Optimal switch insertion for power loss reduction and reliability enhancement in the Nigerian conventional distribution networks: A case study,” *Int. J. Res. Innov. Appl. Sci.*, vol. 9, no. 4, pp. 368–375, 2024, doi: 10.51584/IJRIAS.2024.904026.
- [24] S. C. Bhattacharyya, *Energy Access and Sustainable Development*. Cham, Switzerland: Springer, 2021, doi: 10.1007/978-3-030-56580-7.
- [25] O. A. Ajeigbe and I. O. Abayomi, “Design and planning of a smart distribution network for power system reliability: Case study of Nigerian university campuses,” *Engineering and Technology Journal*, vol. 10, no. 3, 2025, doi: 10.47191/etj/v10i03.37.
- [26] B. K. Sovacool and M. H. Dworkin, “Energy justice: Conceptual insights and practical applications,” *Applied Energy*, vol. 262, Art. no. 114521, 2020, doi: 10.1016/j.apenergy.2020.114521.
- [27] M. I. Tabash, E. Oseni, A. Ahmed, Y. Elsantil, L. N. Daniel, and A. I. Lawal, “Pathway to a sustainable energy economy: Determinants of electricity infrastructure in Nigeria,” *Sustainability*, vol. 16, no. 7, Art. no. 2953, 2024, doi: 10.3390/su16072953.
- [28] United Nations Development Programme (UNDP), *Energy Access and Sustainable Development in Sub-Saharan Africa*. New York, NY, USA: UNDP, 2023.
- [29] African Development Bank (AfDB), *African Economic Outlook 2023: Mobilizing Private Sector Financing for Climate and Green Growth in Africa*. Abidjan, Côte d’Ivoire: AfDB Group, 2023.
- [30] J. O. Aibangbee and S. O. Ikheloa, “Reliability assessment of Ekpoma 33/11 kV injection substation distribution network,” *FUDMA Journal of Sciences*, vol. 9, no. 12, 2025, doi: 10.33003/fjs-2025-0912-4411.
- [31] European Commission, *Gendered Innovations 2: How Inclusive Analysis Contributes to Research and Innovation*. Luxembourg: Publications Office of the European Union, 2021.
- [32] International Energy Agency (IEA), *World Energy Outlook 2023*. Paris, France: IEA, 2023.
- [33] C. Okeke and P. Eze, “Institutional governance and resource planning in Nigerian higher education,” *Journal of Educational Management*, vol. 9, no. 4, pp. 55–71, 2022.
- [34] A. Oladimeji, O. Adeyemi, and O. Ige, “Hybrid solutions for academic energy reliability in West Africa,” *Energy for Development Journal*, vol. 8, no. 3, pp. 150–165, 2022.
- [35] Reuters, “Why Nigeria’s power grid is failing,” Reuters, Dec. 11, 2024.