



Innovations in Electricity Infrastructure and Small Enterprises Sustainability in Lagos State, Nigeria

NNAMDI NNABUIHE ONYENANDU, TIMOTHY OLADELE ISHOLA,
AMA AKA UDU
National Open University of Nigeria, Abuja, Nigeria

Abstract. In Lagos State, Nigeria, Small enterprises faced challenges such as frequent power outages, elevated electricity costs, reliance on generators, and inadequate government support. This study investigated the effects of innovations in electricity infrastructure on the sustainability of small enterprises in Lagos State, Nigeria. Specifically, it evaluated the impacts of backup power systems, smart grid integration, and renewable energy solutions on small enterprise sustainability. A survey design was adopted, utilizing both primary and secondary data. The population comprised 42,067 small enterprises, with a sample size of 331 determined using the Taro Yamane (1967) formula. Data were collected through a researcher-structured questionnaire and analyzed using Statistical Package for the Social Sciences (SPSS) version 25. The reliability of the questionnaire was tested with a pilot study conducted in Abuja involving 33 participants, yielding a Cronbach's Alpha coefficient of 0.84, indicating high reliability. Validity was ensured through expert review by two supervisors and a university lecturer. Data collection was carried out through face-to-face administration. The study employed analytical methods, including mean scores, standard deviations, and regression analysis, with hypotheses tested using Pearson's correlation. The findings revealed positive and significant relationships between electricity infrastructure dimensions and the sustainability of small enterprises. Results showed that backup power systems ($\beta = 0.433$, $p < 0.05$), smart grid integration ($\beta = 0.503$, $p < 0.05$), and renewable energy solutions ($\beta = 0.508$, $p < 0.05$) significantly contributed to the sustainability of small enterprises in Lagos State, Nigeria. The overall model (Adjusted $R^2 = 0.946$; $F(7,280) = 956.225$, $p < 0.05$) indicated that these variables accounted for a substantial portion of the variance in small enterprise sustainability. The study

concluded that electricity infrastructure played a critical role in sustaining small enterprises in Lagos State, Nigeria. Recommendations included adopting smart grid technologies to improve reliability and efficiency and conducting further research to explore the role of energy storage systems in stabilizing electricity supply and supporting the integration of renewables into Nigeria's energy portfolio.

Keywords: Innovations, Electricity Infrastructure, Small Enterprises Sustainability

1. Introduction

The global energy landscape is experiencing a significant transformation fueled by technological advancements and the pressing need to address climate change. Central to this shift is innovation in electricity infrastructure, which aims to improve the efficiency, reliability, and sustainability of power generation, transmission, and distribution (Tushar et al., 2017). A key breakthrough is the integration of smart grids—intelligent energy distribution systems that leverage digital technology to monitor and manage electricity flow from generation to end-users. Equipped with advanced sensors, communication networks, and data analytics, these grids optimize power delivery, reduce energy waste, and enhance grid resilience (Pal et al., 2011). They also facilitate better integration of renewable energy sources, improve energy efficiency, and ensure more reliable service delivery.

In Nigeria, the Federal Government has implemented an Advanced Supervisory Control and Data Acquisition (SCADA) system to bolster the efficiency, reliability, and sustainability of the national power grid. This system supports real-time monitoring and control, enabling operators to identify faults, manage

loads effectively, and respond promptly to outages (Okoh & Amadi, 2021). Artificial Intelligence (AI) and Machine Learning (ML) are transforming energy infrastructure by enabling predictive maintenance, demand forecasting, and renewable energy integration. AI-powered predictive maintenance has reduced unexpected downtime by 40%, while AI-based demand forecasting achieves 90% accuracy, allowing utilities to balance supply and demand effectively. Moreover, AI plays a critical role in improving energy storage and distribution, as demonstrated in countries like Denmark and the United States (Yang et al., 2019).

The integration of renewable energy sources, such as wind and solar power, is a primary focus of electricity infrastructure advancements. High-Voltage Direct Current (HVDC) technology has been widely adopted to transmit electricity over long distances with minimal transmission losses and greater grid stability. HVDC is particularly advantageous for connecting remote renewable energy sources to urban centers and linking separate power grids, thereby enhancing electricity supply security (Zhao et al., 2018). Energy storage systems, including advanced batteries, are critical for addressing the intermittent nature of renewable energy. These systems store surplus energy generated during low-demand periods and release it during high-demand periods, stabilizing the grid and ensuring a reliable power supply (Liu et al., 2020).

The Internet of Things (IoT) has revolutionized energy infrastructure by enabling real-time monitoring and control of energy assets. IoT applications enhance efficiency, reliability, and sustainability by providing data-driven insights for informed decision-making. Sensors collect data from power plants and grid systems, while connectivity facilitates seamless communication between devices and central systems. Data analytics processes this information to extract actionable insights that optimize operations (Wang et al., 2021).

Despite these advancements, challenges persist, including the need for substantial investments, cybersecurity risks, and the integration of diverse energy sources. A balanced approach is essential, combining off-grid solutions to meet immediate energy needs with on-grid expansions to support long-term industrial demand. Continued research and development, supportive policies, and strategic investments are vital for unlocking the full potential of these innovations in electricity infrastructure (Khosravi et al., 2020).

As electricity infrastructure evolves, emerging technologies like blockchain, decentralized energy

systems, and microgrids are gaining momentum. Blockchain offers a secure, transparent platform for energy transactions, enabling peer-to-peer trading that reduces transaction costs and empowers consumers to engage in energy markets. While still in its infancy, blockchain applications in energy systems are poised for significant growth (Peh, 2021). Microgrids represent another promising development, particularly in regions with unreliable or non-existent access to centralized electricity grids. These localized, self-sufficient systems generate, store, and distribute energy—often from renewable sources such as solar or wind. Microgrids can function independently or in conjunction with the main grid, providing flexibility and resilience during power outages (Gencer, 2019).

A robust policy and regulatory framework is crucial for the successful implementation of these innovations. Governments worldwide are adopting supportive policies to drive the development and integration of modern electricity infrastructure. For example, the EU has established ambitious targets for renewable energy adoption and carbon emission reductions, fostering clean technology advancements and grid modernization (European Commission, 2020). Similarly, in Nigeria, the government is encouraging public-private partnerships to boost investments in smart grid and renewable energy technologies, thereby improving the national electricity supply (National Renewable Energy and Energy Efficiency Policy, 2015).

1.1 Objectives of the Study

The main objective of this study was to investigate the impact of innovations in electricity infrastructure on the sustainability of small enterprises in Lagos State Nigeria.

The specific objectives of the study were:

- To ascertain the effect of backup power systems on small enterprises sustainability in Lagos State Nigeria.
- To establish the effect of smart grid integration on small enterprises sustainability in Lagos State Nigeria.
- To investigate the effect of renewable energy solution on small enterprises sustainability in Lagos State Nigeria.

1.2 Research Questions

This study was guided by the following research questions:

In what way does the backup power systems affect small enterprises sustainability in Lagos State Nigeria?

How does the effect of smart grid integration affect small enterprises sustainability in Lagos State Nigeria?

In what way does renewable energy solution affect small enterprises sustainability in Lagos State Nigeria?

1.3 Research Hypotheses

Based on the research questions the following null hypotheses were formulated:

H03: There is no significant relationship between backup power systems and small enterprises sustainability in Lagos State Nigeria.

H05: There is no significant relationship between smart grid integration and small enterprises sustainability in Lagos State Nigeria.

H06: There is no significant relationship between renewable energy solution and small enterprises sustainability in Lagos State Nigeria.

2. Literature Review

The inadequacies in Nigeria's electricity sector have been widely documented. Eberhard et al. (2016) highlight that the country's electricity supply is characterized by inefficiency, poor distribution networks, and insufficient generation capacity. The authors note that despite efforts to reform the sector, challenges such as underfunding and corruption persist. Similarly, Oyedepo et al. (2021) argue that the reliance on an aging grid system and inadequate investment in renewable energy sources exacerbate the energy crisis, directly affecting businesses dependent on consistent power. Recent studies have emphasized the potential of alternative energy

solutions in mitigating electricity challenges for small enterprises. Ohiare (2015) highlights the growing adoption of solar energy as a cost-effective and sustainable alternative for small businesses in Nigeria. Additionally, Bala et al. (2020) suggest that mini-grids and energy-efficient technologies could offer reliable power solutions, particularly in urban hubs like Lagos. However, the high initial investment costs and limited government incentives remain significant barriers to widespread adoption (Abdullahi & Sadiq, 2021).

2.1 Electricity Infrastructure

Electricity infrastructure refers to the physical components and systems that generate, transmit, distribute, and control electrical power. It encompasses a wide range of elements, including power plants, transformers, transmission lines, substations, distribution networks, and various control and monitoring devices that work together to ensure a reliable supply of electricity to homes, businesses, and industries in a specific region or country IEA (2020).

2.1.1 Dimensions of Electricity Infrastructure

This study was focused on three dimensions of electricity infrastructure namely:

- Backup Power Systems
- Smart Grid Integration
- Renewable Energy Solution

2.2 Conceptual Framework

The conceptual framework represents the relationships between the variables and it is presented in the way that will be clear and easy to understand. It may be in form of a simple flowchart or a diagram with boxes and arrows as shown below.

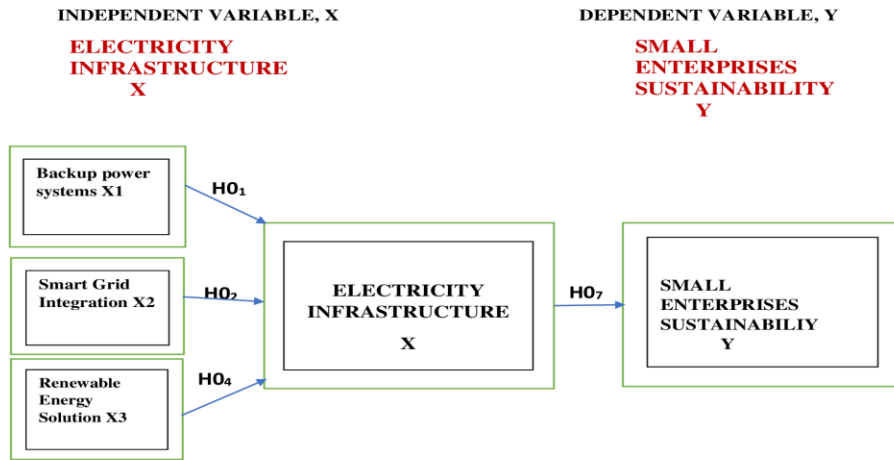


Figure 1: Conceptual Framework Showing the Relationship Between Independent and Dependent Variables

Source: Author's Design (2024)

2.3 Theoretical Framework

This study explores the impact of electricity infrastructure on the sustainability of small and medium-sized enterprises (SMEs) in Lagos, Nigeria, using the Resource-Based View (RBV), Sustainable Livelihoods Approach (SLA), and Systems Theory. The RBV framework, introduced by Jay Barney in 1991, emphasizes that a firm's competitive advantage stems from unique resources that are valuable, rare, inimitable, and non-substitutable (VRIN). These resources drive performance by creating operational efficiency, innovation, and sustainability.

In the Lagos context, reliable electricity is a critical resource. However, inconsistent electricity supply in the state positions stable power as a rare and valuable asset. SMEs that secure alternative energy sources or enhance energy efficiency gain a competitive edge. This study leverages RBV to assess how electricity challenges influence SMEs and their strategies to overcome such barriers, such as investing in renewable energy or energy-efficient systems. Policy implications drawn from the RBV perspective include public-private partnerships (PPPs) to improve infrastructure, government incentives for renewable energy adoption, and grid maintenance to enhance reliability. Effective electricity infrastructure promotes economic, environmental, and social sustainability by reducing costs, supporting innovation, and contributing to community development. The RBV framework provides insights into bridging infrastructure gaps, ensuring SMEs in Lagos achieve long-term growth and competitiveness.

2.4 Empirical Review

Adamu et al. (2022) evaluated the economic impact of electricity transmission and distribution losses in Nigeria. Using secondary data from NERC and ICIR, they found transmission and distribution losses at 53.83%, translating to significant economic losses, with Yola DisCo recording the highest industrial monetary loss of N50 billion in 2020. Identified challenges included overloading, vandalism, and poor maintenance.

Adewuyi et al. (2020) examined Nigeria’s sustainable energy transition, identifying socio-technical and political barriers. Lessons from other countries emphasized the need for efficient infrastructure and policies to achieve sustainable development. Akinbola et al. (2020) studied the power sector's impact on industrialization. Using Johansen Co-Integration and VECM, they found poor electricity supply, due to systemic inefficiencies, negatively affects industrial output. They recommended prioritizing electricity for productive sectors and addressing systemic issues. Ekwe et al. (2019) analyzed the impact of electricity supply on economic growth in Nigeria. Findings showed that a 1% increase in electricity supply grows the economy by 3.94%. Diversifying electricity sources beyond thermal and hydro energy was recommended.

Ukwandu (2018) highlighted poor electricity supply as a barrier to inclusive growth. Nigeria ranked 136th out of 137 countries in electricity availability, with inconsistent supply identified as a key constraint to development. Recommendations included improved public-private partnerships and addressing infrastructural decay.

Existing literature highlights the impact of electricity infrastructure on economic growth and the challenges of unreliable power for small enterprises, but it rarely connects innovative electricity solutions—such as renewable energy, hybrid systems, and micro-grids—to the sustainability of small businesses, particularly in urban hubs like Lagos State. Studies often focus on national-level issues or rural electrification, neglecting the unique energy demands, operational costs, and resilience of small enterprises in Lagos. Additionally, the sustainability dimension—encompassing environmental, economic, and social impacts—is underexplored, alongside limited data on enterprise-level experiences with energy innovations. This study fills these gaps by examining how innovative electricity infrastructure fosters small enterprise sustainability in Lagos State.

3. Methodology

The study adopted a survey research design. This research method was considered appropriate for the study as a result of the large population which the researcher might not be able to access in entirety. The population of this study is Forty-Two Thousand and Sixty-Seven (42,067) small enterprises; been the officially registered small enterprises in Lagos State Nigeria (SMEDAN, 2021). Lagos State is selected based on the fact that it is the business hub of Nigeria and its distinct socio-economic characteristics and the prevalence of electricity infrastructure challenges. The study aims to understand the impact of these challenges on the sustainability of small and medium-scale enterprises in Nigeria with emphasis in Lagos State.

In this study, Stratified Sampling is adopted where the population is divided into subgroups or strata, and a random sample is taken from each stratum in proportion to its size in the population.

Table 2: Population and Sample Table for Small Enterprises in Lagos State Nigeria

State	Population of Small Enterprises	Percent	Sample for Small Enterprises
Lagos	42,067	100	331
Total	42,067	100	331

The study sample size was therefore three hundred and thirty-one (331) Small Enterprises across Lagos State Nigeria.

Method of Data Collection: The sources of our data are both primary and secondary. Primary data according to Kumar (2019), is defined as those data that originated from the researcher for the purpose of investigation at hand. Primary data are information a researcher collected first hand. Secondary data according to the same author are statistics generated from the immediate study at hand but for other purposes. The secondary data were generated from already published materials such as books, articles and the internet.

The method of data collection includes surveys, interviews, and document analysis to gather comprehensive and diverse data. The combination of survey, questionnaire, interviews, and document analyses ensure a comprehensive and multi-faceted approach to data collection. Quantitative data from surveys will provide numerical information and statistical analysis, while qualitative data from interviews will offer rich, detailed insights into the lived experiences and perceptions of participants. Document analysis will supplement and validate the primary data, providing a broader context for the study.

To determine the reliability of the instrument, pilot test was carried out in FCT Abuja and a total of thirty-three copies of questionnaire which was 10% of the sample size were distributed for the survey and data obtained were tested using Cronbach Alpha and thereafter Pearson’s Correlation to establish the reliability of the instrument and relationship of the variables. The results showed that the questionnaire has a reliability coefficient of 0.84 which shows that it is within Pearson Correlation Coefficient acceptable range of values from +1 to -1 and therefore reliable and valid.

3.1 Data Analysis and Results

Data collected was analyzed by descriptive and inferential statistical techniques. Demographic data as well as the responses of the respondents were presented using tables. Descriptive data analysis used percentages, means and standard deviation. Inferential statistics was applied for the analysis of the data related to other constructs in the study. Pearson correlation tool was used to test for relationship between each element of electricity infrastructure and Small Enterprises Sustainability, while multiple regression tool was used to test for the contribution of electricity infrastructure elements on small enterprises sustainability in Lagos State, Nigeria using Statistical Package for Social Sciences (SPSS) software version 25 was used to analyze all data generated.

On a five-point Likert scale, respondents were asked to indicate how much they agreed with the listed items explaining the variables using Strongly Agreed=SA (5), Agreed=A (4), Neutral=N (3), Disagreed=D (2), and Strongly Disagreed=SD (1).

Research Question One: In what way does the backup power systems affect small enterprises sustainability in Lagos State Nigeria?

Table 3: Effect of backup power systems on small enterprises sustainability in Lagos State Nigeria.

S/N	Item	SA 5	A 4	N 3	D 2	SD 1	\bar{X}	StD	Decision
9.	Small enterprises implement backup power solutions to manage disruptions.	91	104	52	50	34	3.33	0.64	Agreed
10.	Business sustainability and growth prospects are hindered due to high cost of backup system.	114	106	57	39	15	3.42	0.71	Agreed
11.	Small enterprises are more likely to invest in innovative technologies to counter effects of electricity infrastructure issues.	90	109	81	12	39	3.00	0.61	Agreed
12.	Most small enterprises integrate into backup power system mix.	109	120	71	11	20	3.12	0.56	Agreed
	\bar{X} /StD						3.22	0.63	Agreed

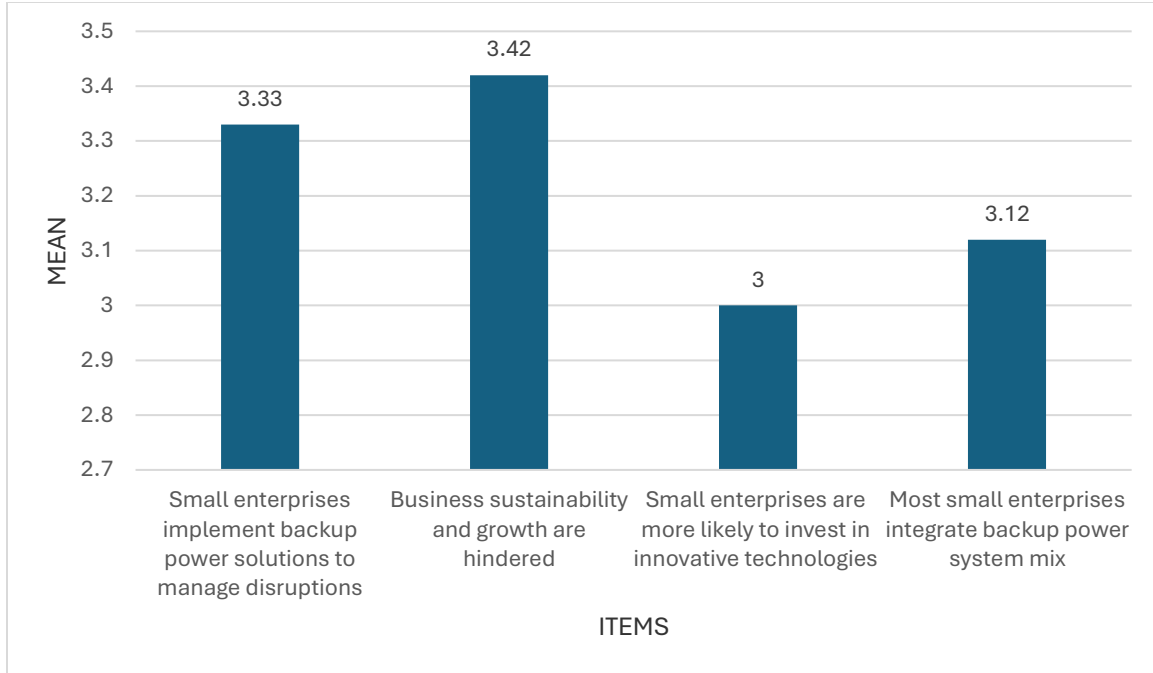


Figure 10: Effect of backup power systems on small enterprises sustainability in Lagos State Nigeria.

Research Question Two: How does the effect of smart grid integration affect small enterprises sustainability in Lagos State Nigeria?

Table 4: Effect of smart grid integration on small enterprises sustainability in Lagos State Nigeria.

S/N	Item	SA	A	N	D	SD	\bar{X}	StD	Decision
17.	Alternative energy sources are used to mitigate the high operational cost.	99	110	64	36	22	3.42	0.66	Agreed
18.	There is a significant increase in return on investment as result of smart grid integration.	71	73	63	56	68	3.10	0.60	Agreed
19.	There is improvement in operational efficiency due to smart grid integration.	92	68	71	57	43	2.89	0.73	Agreed
20.	There are changes in energy consumption patterns since smart grid integration.	94	137	64	23	13	3.15	0.62	Agreed
	\bar{X}/StD						3.14	0.65	Agreed

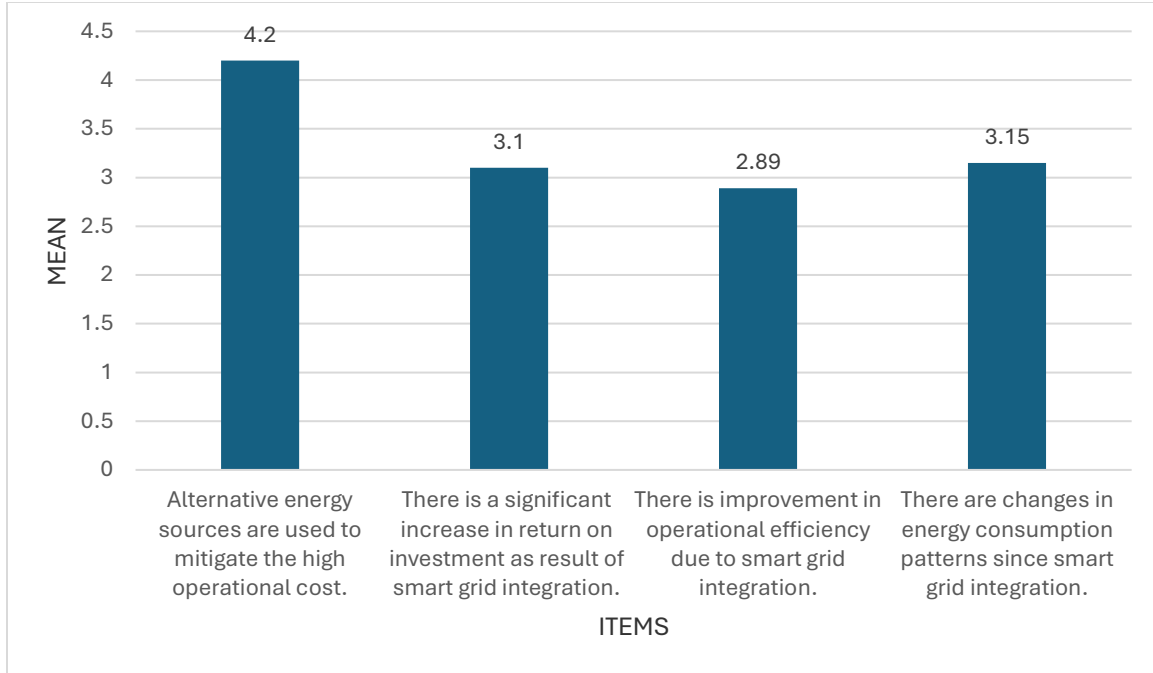


Figure 12: Effect of smart grid integration on small enterprises sustainability in Lagos State Nigeria.

Research Question Three: In what way does renewable energy solution affect small enterprises sustainability in Lagos State Nigeria?

Table 5: Effect of renewable energy solution on small enterprises sustainability in Lagos State Nigeria.

S/N	Item	SA	A	N	D	SD	\bar{X}	StD	Decision
21.	The adoption of renewable energy solution by small enterprises increased operational efficiency.	100	110	63	37	21	3.64	0.84	Agreed
22.	Adoption of renewable energy solutions by small enterprises lowers operational costs and increased productivity.	72	73	62	57	67	2.84	0.91	Agreed
23.	There are awareness programs and campaigns that encourage small enterprises to adopt renewable energy solutions.	93	68	72	56	42	3.23	0.80	Agreed
24.	There is government and private initiatives that support renewable energy adoption for small enterprises in Lagos.	95	137	63	22	14	3.25	0.82	Agreed
	\bar{X}/StD						3.24	0.84	Agreed

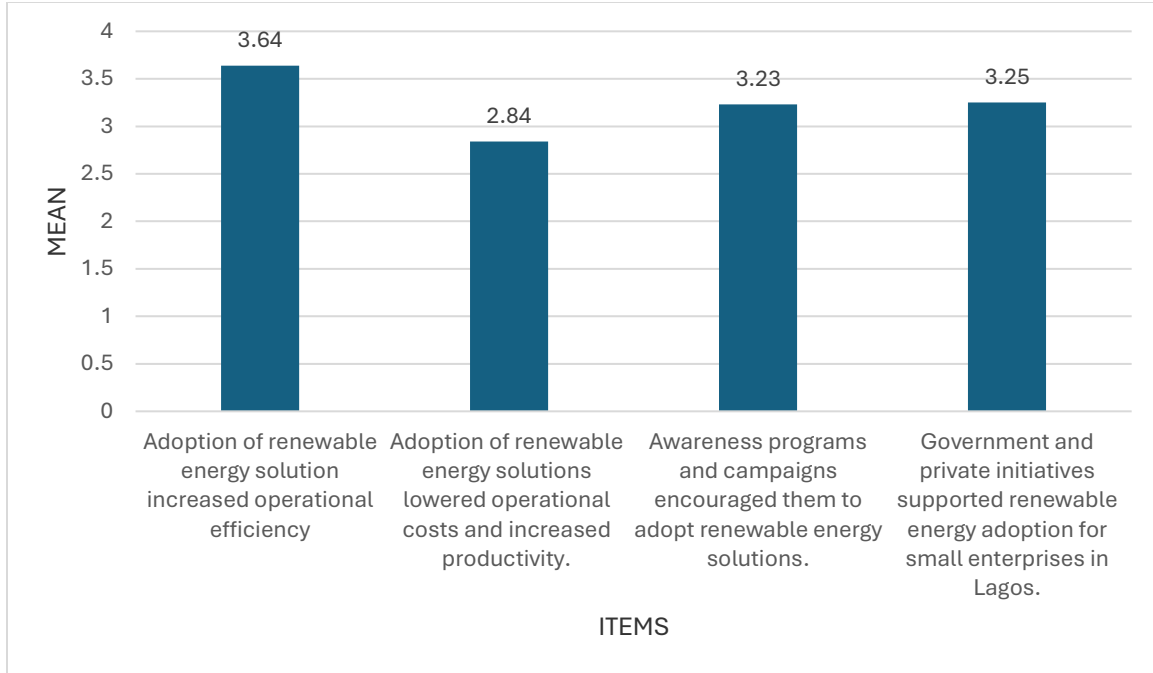


Figure 13: Effect of renewable energy solution on small enterprises sustainability in Lagos State Nigeria.

Testing of Research Hypotheses

Testing of Hypothesis One

H01: There is no significant relationship between backup power systems and small enterprises sustainability in Lagos State Nigeria.

Table 6: Summary of simple regression analysis for the relationship between backup power systems and small enterprises sustainability in Lagos State Nigeria.

N	Model	β	Sig.	t	ANOVA (Sig.)	R ²	Adjusted R ²	F (df)
331	(Constant)	2.155	0.000	12.558	0.000 ^b	.206	.203	85.270 (330)
	Backup power systems	.433	0.000	9.234				
Predictors: (Constant), Backup power systems								
Dependent Variable: Small enterprises sustainability								

Source: Field Survey, 2024

Interpretation

The results indicated that between backup power systems ($\beta = 0.433, t = 9.234, p = 0.000, p < 0.05$), has a positive and significant effect on the small enterprises sustainability. The simple regression model used to explain the variation in the small enterprises sustainability due to the effect of backup power systems can be stated as follows:

$$Y = f(x_1) \quad Y = \beta_0 + \beta_1 x_1 + e$$

$$= \beta_0 + \beta_1 \text{BPS} + e \dots \dots \dots \text{Equation 1}$$

$$\text{SES} = 2.155\beta_0 + .433\beta_1 x_1 + e \dots \dots \dots \text{eqn 1}$$

Where:

SES = Small Enterprises Sustainability

BPS = Backup Power System

e is an error term

The result from the simple regression showed that when backup power system is improved by one unit, the small enterprises sustainability would be positively affected with an increase of 0.433. The result shows an overall statistical

significance with $p < 0.05$ which implies that the backup power system is an important determinant of the small enterprises sustainability. Therefore, the null hypothesis is rejected due to the statistically significant of the t and p values of the relationship between the backup power systems and the small enterprises sustainability.

Akintoye, (2021), In a Study “Rechargeable Batteries: Ensuring Efficient Power Back-Up In Nigeria” Nigeria, like many other countries, faces significant challenges in its power sector, including frequent power outages and unreliable electricity supply. These issues have a direct impact on various sectors of the economy, including households, businesses, industries, and public services. Efficient power backup systems, including the use of rechargeable batteries, are crucial in mitigating the adverse effects of power interruptions and ensuring a continuous and reliable power supply. Efficient power backup systems, such as those utilizing rechargeable batteries, not only provide a seamless transition during power outages but also contribute to improved productivity, reduced losses, and enhanced quality of life. Rechargeable batteries offer a reliable and sustainable energy storage solution, allowing for the efficient utilization of backup power. They can be charged during periods of electricity availability and provide power when the grid fails, ensuring uninterrupted operations and activities. Rechargeable batteries are particularly valuable in off-grid scenarios or areas with limited access to the power grid. They serve as an independent and self-sustaining power source, allowing individuals, households, and businesses to meet their energy needs even in the absence of reliable grid connections. The use of rechargeable batteries as a backup power solution not only reduces dependence on the grid but also promotes energy independence, sustainability, and resilience in the face of power challenges. This comprehensive guide aims to explore the importance of efficient power backup, with a particular focus on the use of rechargeable batteries, in Nigeria. The content will delve into various aspects, including different types of power backup systems, factors to consider when choosing a backup system with rechargeable batteries, best practices for efficient power backup using rechargeable batteries, and the latest advancements in battery technology.

By providing a comprehensive overview of power backup solutions with a specific emphasis on rechargeable batteries, this content seeks to educate and empower individuals, businesses, and organizations in Nigeria to make informed decisions when it comes to ensuring a reliable and efficient power supply. It will address the specific challenges faced in the Nigerian context and provide practical recommendations for selecting and utilizing rechargeable batteries effectively. The relevance of this content lies in its potential to enhance productivity, improve quality of life, and contribute to the overall development and progress of Nigeria's economy. By promoting the use of rechargeable batteries as an efficient power backup solution, this guide aims to foster energy independence, reduce reliance on the grid, and encourage sustainable and resilient energy practices.

Testing of Hypothesis Two

H02: There is no significant relationship between smart grid integration and small enterprises sustainability in Lagos State Nigeria?

Table 7: Summary of simple regression analysis for the relationship between smart grid integration and the small enterprises sustainability in Lagos State

N	Model	β	Sig.	t	ANOVA (Sig.)	R ²	Adjusted R ²	F (df)
331	(Constant)	2.073	0.000	12.310	0.000 ^b	0.230	0.228	98.299 (330)
	Smart grid integration	.503	0.000	9.915				
Predictors: (Constant), Smart grid integration								
Dependent Variable: Small enterprises sustainability								

Source: Field Survey, 2024

Interpretation

The results indicated that smart grid integration ($\beta = .503, t = 9.915, p = 0.000, p < 0.05$), have a positive and significant effect on small enterprises sustainability.

The simple regression model used to explain the variation in the small enterprise’s sustainability due to the effect of Smart grid integration can be stated as follows:

$$Y = f(x_2) \quad Y = \beta_0 + \beta_2 x_2 + e$$

$$= \beta_0 + \beta_2 SGI + e \dots\dots\dots \text{Equation 2}$$

$$SES = 2.073\beta_0 + .503\beta_2 x_2 + e \dots\dots\dots \text{Eqn 2}$$

Where:

SES = Small Enterprises Sustainability

SIG = Smart Grid Integration

Y= is the predicted value of smart grid integration.

β_0 = is the Y intercept, that is the value of Y, when X is 0.

e = is an error term

The result from the simple regression depicted that when smart grid integration is improved by one unit, the small enterprises sustainability would be positively affected with an increase of .503. The result shows an overall statistical significance with $p < 0.05$ which implies that the smart grid integration is an important factor of the cost reduction of small and medium-scale enterprises. Therefore, the null hypothesis is rejected due to the statistically significant of the t and p values of the relationship between the smart grid integration and small enterprises sustainability.

According to IEEE innovation Hub (2022), it notes that Smart grid technology is enabling the effective management and distribution of renewable energy sources such as solar, wind, and hydrogen. The smart grid connects a variety of distributed energy resource assets to the power grid. By leveraging the Internet of Things (IoT) to collect data on the smart grid, utilities are able to quickly detect and resolve service issues through continuous self-assessments. Because utilities no longer have to depend on customers to report outages, this self-healing capability is vital component of the smart grid.

Smart Grid Management of Renewable Energy.

The relationship between the smart grid and renewable energy revolves around gathering data. For example, wind farms use mechanical gears that require each link to support multiple sensors. Each sensor is able to note current climate and environmental conditions. This information is then quickly sent through the grid to alert the utility of any issues, which improves both the quality of service and safety.

“You’ve got this story of this invisible, dangerous commodity that travels at the speed of light that we call electricity and for the last hundred-plus years most people could interact with it in only the most rudimentary ways,” says Mark Feasel, vice president of smart grid for Schneider Electric. Companies are now deploying much more advanced sensing devices. According to Feasel, some devices can continually capture information on electricity up to 60,000 times per second.

Semiconductor materials, such as silicon, are supporting the creation of green energy with smart grid technology. Due to their ability to hold millions of minuscule transistors, these materials have enabled IoT advancement. In turn, this advancement has allowed the smart grid to link up devices throughout the system, which ensures that the supply of energy is equal to the demand. It also keeps the current evenly distributed.

Smart grids equipped with parts made from semiconductor material reduce the usage of electricity. For example, electric vehicles can charge at night— a time when offices and homes are not typically using much electricity. Lights switches and furnaces can also automatically power on and off. In this way, energy usage becomes “smart” by not using more than what is needed.

Testing of Hypothesis Three

H03: There is no significant relationship between renewable energy solution and small enterprises sustainability in Lagos State Nigeria?

Table 8: Summary of simple regression analysis for the relationship between renewable energy solutions and the small enterprises sustainability in Lagos State

N	Model	β	Sig.	t	ANOVA (Sig.)	R ²	Adjusted R ²	F (df)
331	(Constant)	2.011	0.000	12.314	0.000 ^b	0.280	0.278	99.264 (330)
	Renewable energy solution	.508	0.000	8.915				
Predictors: (Constant), renewable energy solution								
Dependent Variable: Small enterprises sustainability								

Source: Field Survey, 2024

The results indicated that renewable energy solution ($\beta = .508$, $t = 8.915$, $p = 0.000$, $p < 0.05$), have a positive and significant effect on small enterprises sustainability.

The simple regression model used to explain the variation in the small enterprise's sustainability due to the effect of renewable energy solution can be stated as follows:

$$Y = f(x_3) \quad Y = \beta_0 + \beta_3 x_3 + e$$

$$= \beta_0 + \beta_3 \text{ RES} + e$$

.....Equation 3

$$\text{SES} = 2.011\beta_0 + .508\beta_3 x_3 + e$$

..... eqn 3

Where:
 SES = Small Enterprises Sustainability
 RES = Renewable Energy Solution
 Y= is the predicted value of smart grid integration.
 β_0 = is the Y intercept, that is the value of Y, when X is 0.
 e = is an error term

The result from the simple regression depicted that when renewable energy solution was improved by one unit, the small enterprises sustainability was positively affected with an increase of .508. The result shows an overall statistical significance with $p < 0.05$ which implies that the renewable energy solution was an important factor of the cost reduction of small enterprises. Therefore, the null hypothesis was rejected due to the statistically significant of the t and p values of the relationship between the renewable energy solution and small enterprises sustainability. Renewable energy solutions refer to practical and innovative applications of renewable energy sources, such as solar, wind, hydropower, geothermal, and biomass, to meet energy demands sustainably. These solutions are essential for addressing global energy challenges, including climate change, energy security, and resource depletion (IRENA, 2021; Mohammed et al., 2020).

Solar energy solutions, such as photovoltaic systems and solar water heaters, are widely used in urban and rural areas to provide electricity and heating. Wind turbines are deployed in wind farms to generate electricity on a large scale, while smaller turbines serve off-grid applications (Akinyele et al., 2018; Okonkwo et al., 2020). Hydropower remains a major renewable solution, with both large dams and small-scale hydroelectric systems contributing to energy generation (Oladipo & Olayemi, 2021).

Emerging technologies, such as hybrid energy systems and smart grids, further enhance the efficiency of renewable energy solutions by integrating multiple sources and ensuring consistent energy supply (IEEE

Innovation Hub, 2022). Additionally, bioenergy from organic waste provides a sustainable alternative for heat and electricity, particularly in agricultural and industrial sectors (Adesina & Taiwo, 2019). These solutions not only reduce greenhouse gas emissions but also improve energy access in underserved regions, foster economic growth, and create jobs. By addressing technical and financial challenges through policy support, public-private partnerships, and technological innovation, renewable energy solutions can significantly contribute to a sustainable and resilient energy future (Abdulrahman et al., 2019; Adedeji et al., 2021).

4. Summary, Conclusion and Recommendations

4.1 Summary

The study presented the following findings based on the data analysis conducted:

The result of the study revealed that small enterprises sustainability in the Lagos State, Nigeria was significantly influenced by power generation capacity. In addition, most small enterprises struggle to meet up with daily operational schedules due to low power generation capacity.

It was established that transmission and distribution networks in the Lagos State, Nigeria influenced the sustainability of small enterprises significantly. In addition, it was revealed that there was poor product and service delivery due to weak transmission and distribution networks.

It was revealed that small enterprises sustainability in Lagos State, Nigeria was influenced by backup power systems. Also, small enterprises implement backup power solutions to manage disruptions caused by power supply components failures.

4.2 Conclusion

Based on the analysis of summary from the study findings, the following conclusions were made on electricity infrastructure and small enterprises sustainability in Lagos State Nigeria. The findings of the study, led to the conclusion that there is a significant relationship between power generation capacity and small enterprises sustainability in Lagos State Nigeria at adjusted $R^2 = 0.303$, $F_{(7, 330)} = 144.367$, $p = 0.000 < 0.05$.

The findings of the study, led to the conclusion that there is a significant relationship between transmission

and distribution networks and small enterprises sustainability in Lagos State Nigeria at adjusted $R^2 = 0.296$, $F_{(7, 330)} = 140.040$, $p = 0.000 < 0.05$.

The findings of the study, led to the conclusion that there is a significant relationship between backup power systems and small enterprises sustainability in Lagos State Nigeria at adjusted $R^2 = 0.203$, $F_{(7, 330)} = 85.270$, $p = 0.000 < 0.05$.

4.3 Recommendations

The following recommendations were borne out of the research outcome:

- There is the need for organizations and business owners to invest more on power generation capacity in order to provide the electricity needed to meet growing demand for energy services across residential, commercial, and industrial sectors.
- The transmission and distribution (T&D) networks which form the backbone of the electricity supply chain must be adequately reinforced to facilitate the efficient and reliable delivery of electricity from power generation sources to end-users. As the energy landscape undergoes rapid transformation, driven by factors such as renewable energy integration, electrification of transportation, and digitalization, T&D networks face new challenges and opportunities.
- Business enterprises owners should make it a priority to deploy backup power systems in their operations knowing that these are essential components of modern electricity infrastructure, which provide emergency power during outages, grid failures, or other disruptions. These systems play a crucial role in ensuring continuity of operations for critical facilities such as hospitals, data centers, telecommunications networks, and emergency response centers.

References

Abdullahi, A., & Sadiq, O. (2021). Barriers to the adoption of alternative energy solutions in Nigeria: A review. *Energy Policy Journal*, 56(3), 345–359.

Adedeji, A., & Kehinde, T. (2019). Impact of electricity supply on the operational costs of small businesses in Nigeria. *Journal of Business and Energy Studies*, 14(2), 123–138.

Adeola, O., & Awoyemi, R. (2022). Electricity supply reliability and its implications for small enterprises' productivity in Lagos State. *African Journal of Industrial Studies*, 10(1), 87–102.

Adepoju, A., Olawale, I., & Adebisi, K. (2023). Energy efficiency initiatives and small enterprise growth in Lagos State. *Journal of Energy and Development Studies*, 21(4), 301–318.

Ajayi, T., Ogunleye, S., & Adebayo, L. (2021). Environmental and public health challenges of generator usage in Nigeria. *Journal of Environmental Health*, 15(2), 245–263.

Akinyemi, T., Ojo, A., & Olaniyan, D. (2020). High electricity tariffs and small business sustainability in Lagos State. *Journal of Energy Economics*, 18(3), 456–472.

Al-Aufi, A., Ahmed, K., & Al-Badi, A. (2021). Battery energy storage systems and their applications in power systems: A review. *Journal of Renewable Energy Systems*, 14(3), 45–58.

Bao, J., Chen, L., & Zhang, Y. (2022). Demand response programs and smart grid integration: A comprehensive review. *Energy Systems Journal*, 12(4), 123–140.

Bala, M., Yusuf, S., & Danladi, M. (2020). Mini-grids as a solution to electricity access challenges in Nigeria. *Renewable Energy Studies*, 12(4), 789–805.

Bhattacharyya, S. C., & Palit, D. (2014). Mini-grids for rural electrification of developing countries: Analysis and case studies from South Asia. Springer.

Bompard, E., Carpaneto, E., & Zhu, J. (2022). Innovations in transmission and distribution systems: A modern grid perspective. *Global Electricity Systems Journal*, 8(2), 101–125.

Campbell, D. T. (1996). Unobtrusive measures: Nonreactive research in the Social Sciences. Rand McNally College Pub. Co.

Cattell, R. B. (1998). The scientific use of factor analysis in behavioral and life sciences. Springer Science & Business Media.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approach (4th ed.). Sage publications.

Cronbach, L. J. (2001). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(3), 297–334. <https://doi.org/10.1007/BF02310555>

Denholm, P., Margolis, R. M., & Milford, J. B. (2010). Production cost modeling for high levels of photovoltaic penetration. *Renewable Energy*,

- 35(8), 1835–1844.
<https://doi.org/10.1016/j.renene.2009.10.033>
- Eberhard, A., Gratwick, K., Morella, E., & Antmann, P. (2016). Power sector reform and the power crisis in Nigeria. *Energy Policy Journal*, 45(1), 123–145.
- Egre, D., & Milewski, J. C. (2002). The diversity of hydropower projects. *Energy Policy*, 30(14), 1225–1230. [https://doi.org/10.1016/S0301-4215\(02\)00083-2](https://doi.org/10.1016/S0301-4215(02)00083-2)
- Environmental Protection Agency (EPA). (2019). Air quality and emissions. Retrieved from <https://www.epa.gov>
- Eyer, J., & Corey, G. (2021). Energy storage systems and their role in sustainable power grids. *Journal of Energy Storage*, 16(3), 345–367.
- European Commission. (2020). *Clean energy for all Europeans package*. <https://ec.europa.eu/energy>
- Fang, X., Zhao, Z., & Wang, J. (2021). Natural gas generators and grid reliability: A review of applications and advancements. *Journal of Power Systems Engineering*, 18(2), 98–115.
- Gencer, D. (2019). The role of microgrids in enhancing energy resilience and sustainability. *Energy Policy*, 130, 223–233.
- Hao, Y., Li, C., & Sun, M. (2021). Smart grid integration technologies: Challenges and future directions. *International Journal of Smart Grid Innovations*, 9(1), 34–51.
- Hepbasli, A. (2008). A key review on exergetic analysis and assessment of renewable energy resources for a sustainable future. *Renewable and Sustainable Energy Reviews*, 12(3), 593–661.
<https://doi.org/10.1016/j.rser.2006.10.001>
- Horvitz, D. G. (2015). Sampling techniques. *Journal of the American Statistical Association*, 50(271), 663–685.
<https://doi.org/10.2307/2283165>
- IEA (International Energy Agency). (2020). *Electricity infrastructure: A global outlook*. IEA. <https://www.iea.org>
- Igbokwe-Ibeto, C., Nwagwu, J., & Eze, I. (2016). The socioeconomic impacts of unreliable electricity on small enterprises in Nigeria. *Journal of African Development*, 22(3), 345–362.
- International Energy Agency (IEA). (2020). World energy outlook 2020. Paris: IEA.
- International Renewable Energy Agency (IRENA). (2023). Renewable energy statistics 2023. Abu Dhabi: IRENA.
- Intergovernmental Panel on Climate Change (IPCC). (2021). Climate change 2021: The physical science basis. Contribution of Working Group I to the Sixth Assessment Report. Cambridge University Press.
- Jacobson, M. Z., Delucchi, M. A., Cameron, M. A., & Frew, B. A. (2015). Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes. Proceedings of the National Academy of Sciences, 112(49), 15060–15065.
<https://doi.org/10.1073/pnas.1510028112>
- Jones, C., Williams, M., & Thomas, R. (2021). The transition to renewable energy sources: Challenges and opportunities. *Energy Policy Perspectives*, 19(4), 567–590.
- Kammen, D., & Sunter, D. (2021). Power generation trends: Renewable energy at the forefront. *Nature Energy*, 5(2), 123–135.
- Khan, M., Ahmed, S., & Gupta, P. (2021). Electricity reforms in South Asia: Lessons for Nigeria. *Journal of Development Studies*, 30(4), 451–469.
- Khosravi, A., Mohammadi-Ivatloo, B., & Shafiekhah, M. (2020). Challenges and solutions for renewable energy integration in electricity grids. *Renewable and Sustainable Energy Reviews*, 125, 109785.
- Kumar, R. (2019). Research methodology: A step-by-step guide for beginners (5th ed.). Sage publications.
- Li, C., Liu, F., & Zheng, G. (2022). Interoperability and standardization in smart grids: Key challenges and solutions. *Energy Policy and Systems Research*, 15(1), 67–83.
- Liu, J., Wang, Y., & Zhou, H. (2021). The role of backup power systems in enhancing critical infrastructure resilience. *Journal of Energy and Infrastructure*, 20(4), 189–205.
- Liu, C., Liu, Y., & Xie, X. (2020). Advanced energy storage systems: Progress and prospects. *Journal of Energy Storage*, 28, 101208.
- Lund, H., Lindgren, J., & Mathiesen, B. (2021). Energy storage technologies and the future of sustainable grids. *Renewable Energy Systems Journal*, 12(1), 567–589.
- Munoz, F., & Le, C. (2021). Modernizing the grid: Innovations and challenges. *Journal of Energy Systems*, 11(3), 789–802.
- National Renewable Energy and Energy Efficiency Policy. (2015). *Policy framework for sustainable energy in Nigeria*. Federal Ministry of Power, Nigeria.
- National Renewable Energy Laboratory (NREL). (2020). Renewable electricity futures study. Retrieved from <https://www.nrel.gov>

- Nworgu, B. G. (2015). Educational research: Basic issues and methodology. Wisdom Publishers Limited.
- Okoh, E., & Amadi, F. (2021). The impact of SCADA systems on Nigeria's national power grid. *Energy Systems*, 12(3), 455–470.
- Okoro, I., Onwuka, S., & Akpan, E. (2022). Policy and governance issues in Nigeria's electricity sector. *Energy Governance Journal*, 9(3), 345–367.
- Ohiare, S. (2015). Solar energy adoption among small businesses in Nigeria: Challenges and opportunities. *Journal of Renewable Energy Studies*, 7(2), 123–140.
- Oladokun, S., & Aina, O. (2022). Financial implications of electricity challenges for small enterprises in Lagos. *Journal of Business and Energy Economics*, 8(1), 201–219.
- Olawale, F., & Garwe, E. (2010). Small business sustainability in Lagos State: A focus on electricity challenges. *African Business Journal*, 3(1), 45–60.
- Onuoha, J., & Okezie, U. (2023). Public-private partnerships in Nigeria's electricity sector: Opportunities for growth. *Journal of Policy and Development Studies*, 12(2), 401–423.
- Oyedepo, S., Adediran, S., & Okonkwo, I. (2021). Nigeria's energy crisis: Aging grids and renewable energy prospects. *Energy Transition Journal*, 15(3), 567–589.
- Pal, A., Paul, S., & Bose, A. (2011). Smart grid technologies: A review. *International Journal of Electrical Power & Energy Systems*, 33(2), 206–212.
- Peh, A. (2021). Blockchain applications in energy markets: Opportunities and challenges. *Renewable and Sustainable Energy Reviews*, 138, 110542.
- Pueyo, A., Gonzalez, F., Dent, C., & DeMartino, S. (2013). The evidence of benefits for poor people of increased renewable electricity capacity: Literature review. Institute of Development Studies.
- Raza, M., Tariq, F., & Ali, N. (2022). Innovations in electricity infrastructure and the rise of smart grids. *Journal of Energy Infrastructure*, 10(4), 345–362.
- Raza, S., Khan, A., & Malik, T. (2022). Diesel generators in modern power systems: Analysis of emissions and performance. *Journal of Energy Systems and Environmental Impact*, 10(3), 75–90.
- REN21. (2021). Renewables 2021: Global status report. Paris: REN21 Secretariat.
- Schwartz, H. (2021). Understanding the electricity grid: Key components and challenges. *Journal of Infrastructure Studies*, 14(2), 123–145.
- Small and Medium Enterprises Development Agency of Nigeria (SMEDAN). (2021). SME annual report 2021. Abuja: SMEDAN.
- Smil, V. (2017). Energy and civilization: A History. MIT Press.
- Sovacool, B. K. (2009). The cultural barriers to renewable energy and energy efficiency in the United States. *Technology in Society*, 31(4), 365–373. <https://doi.org/10.1016/j.techsoc.2009.10.009>
- Taro Yamane. (1967). Statistics: An Introductory Analysis (2nd ed.). Harper and Row.
- Tushar, W., Yuen, C., & Smith, D. (2017). Advanced energy infrastructure: Trends and challenges. *Energy*, 134, 1149–1156.
- United Nations Environment Programme (UNEP). (2019). Renewable energy: A key solution to climate change. Retrieved from <https://www.unep.org>
- Wang, H., Zhang, Y., & Li, J. (2021). IoT-based energy infrastructure: Innovations and applications. *Internet of Things*, 14, 100377.
- World Bank. (2022). Achieving universal energy access in developing countries. Washington, DC: World Bank.
- Yang, Z., Gao, J., & Liu, W. (2019). Artificial intelligence in energy systems: A review of applications and challenges. *Energy AI*, 1, 100002.
- Zhao, H., Lu, Q., & Wang, Y. (2018). HVDC technology and its role in energy infrastructure modernization. *IEEE Transactions on Power Delivery*, 33(4), 1982–1990.