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TECHNOLOGY INNOVATION AND DEVELOPMENT OF SOLAR POWER IN OFF-GRID ENERGY SECTOR IN NIGERIA

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ABSTRACT

Amidst the very low per capita energy consumption in Nigeria, Solar power has the potential to effectively tackle the energy difficulties in Nigeria's off-grid sector, however its adoption is impeded by multiple obstacles. This study examines the correlation between technology innovation and development of solar power in Nigeria's off-grid energy industry. We utilized a cross-sectional survey approach, following a positivist philosophical paradigm. We obtained data from 13 off-grid energy enterprises in Nigeria that are officially recognized by the Rural Electrification Agency (REA). The data was collected using a standardized questionnaire. We deployed Structural Equation Modelling (SEM) using Analysis of Moment Structure (AMOS) version 23 to examine a total of 239 fully filled surveys. The study discovered a notable and favourable correlation between the many aspects of technology innovation (such as market, process and product) and the indicators of the development of solar power (such as consumer trust). The results indicate that the promotion of technological innovation is essential for the effective development of solar power in Nigeria's off-grid sector. Nonetheless, it is crucial to tackle the difficulties related to government incentives to guarantee the extensive acceptance of solar power and enhance energy accessibility in urban and rural regions. Off-grid energy companies ought to allocate resources towards research and knowledge initiatives aimed at cultivating the essential expertise required for the development, installation, and maintenance of solar power systems. The study contributed to knowledge, by deploying the advanced analytical tool -Analysis of Movement Structure to carry out in-depth analysis and empirical evidence of the relationship between technological innovation and the development of solar power.

Keywords: Technology innovation, Solar power development, Off-grid energy sector, Renewable energy in Nigeria, Energy accessibility.

1.0 INTRODUCTION

Nigeria's pursuit of a robust technology innovation ecosystem is hampered by a complex interplay of interconnected challenges. These obstacles span infrastructural limitations, access to finance, institutional barriers, and human capital constraints, collectively hindering the development and widespread adoption of new technologies, particularly within the crucial off-grid energy sector. This interconnectedness underscores the need for holistic solutions that address multiple facets simultaneously, as isolated interventions are unlikely to achieve substantial progress.

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Nigeria's energy landscape is undergoing a critical transition. Historically reliant on fossil fuels like oil and natural gas for power generation, transportation, and industry, the nation now faces the challenge of diversifying its energy mix towards more sustainable sources. While hydropower provides a foundational renewable energy base, its potential is limited. Solar energy, though experiencing growth, currently represents a small fraction of the overall energy mix. This contrasts sharply with global trends, where a shift towards diversified energy portfolios, featuring rapidly expanding renewable sources like hydro, wind, and solar, is increasingly evident. This global shift is particularly pronounced in developed economies, while developing nations like Nigeria continue to grapple with a heavy dependence on fossil fuels.

Nigeria's renewable energy status presents a complex duality. On the one hand, the penetration of renewables, excluding large-scale hydropower, remains low, contributing less than 16.4% to the total electricity capacity as of 2022. Of this, over 90% is derived from existing hydropower infrastructure. On the other hand, the nation has articulated ambitious policy objectives, targeting 30% renewable electricity generation by 2030 and striving for net-zero emissions by 2060. Achieving these targets is hampered by significant obstacles, including infrastructure deficits, financing constraints, and complexities related to grid integration. Despite these challenges, Nigeria has demonstrated a commitment to a low-carbon future through its net-zero pledge and various national climate change and decarbonization strategies. The recent passage of the Electricity Act 2023 further underscores this commitment, signaling a potential shift towards sustainable power sources and emphasizing technological advancements within the renewable energy domain.

Technological innovation is a primary driver of this necessary transition. It encompasses intricate systems of interconnected technologies operating towards specific objectives. Innovation plays a vital role in addressing societal needs, achieving goals, and resolving challenges, ultimately fueling corporate, industrial, economic, and social advancement. Within the context of solar energy, technological innovation can be categorized into product and process innovation. Product innovation concentrates on developing enhanced solar products with improved functionality or performance, thereby creating competitive advantages and expanding market opportunities. Process innovation involves implementing new or substantially improved production methods, techniques, equipment, or software to reduce costs, enhance quality, and improve efficiency while minimizing environmental impact.

While a considerable body of research has investigated various facets of solar energy development, including consumer attitudes and adoption factors across diverse regions, a critical gap persists in understanding the specific role of technological innovation in driving off-grid solar power development in developing economies, particularly in Nigeria. Existing studies in Africa have primarily focused on general barriers to solar energy adoption. This study addresses this gap by investigating the relationship between technological innovation (both product and process) and the development of off-grid solar power in Nigeria, employing a structural equation modeling (SEM) approach. This research aims to provide valuable insights for policymakers and stakeholders in promoting the adoption and effective implementation of solar energy solutions within Nigeria's off-grid sector.

1.1 Aim of the Study

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The aim of this study is to evaluate the relationship between technology innovation and development of solar power of off-grid Energy Sector in Nigeria.

1.2 Objectives of the Study

The specific objectives are to:

1. Ascertain the relationship between market and consumer trust of off-grid energy sector in Nigeria.
2. Investigate the relationship between process and consumer trust of off-grid energy sector in Nigeria.
3. Examine the relationship between product and consumer trust of off-grid energy sector in Nigeria.

1.3 Research Hypotheses

Based on the specific objectives and research questions, the following null hypotheses was formulated:

HO1: There is no significant relationship between market and consumer trust of off-grid energy sector in Nigeria.

HO2: Process does not significantly affect consumer trust of off-grid energy sector in Nigeria.

HO3: Product has no significant effect on consumer trust of off-grid energy sector in Nigeria.

2.0 LITERATURE REVIEW

2.1 Technology Innovation

Technological innovation plays an important role in society for satisfying needs, achieving goals, and solving problems of adopters directed to supporting corporate, industrial, economic, and social change for competitive advantage of firms and nations, and improving overall human progress (Arthur, 2009; Coccia, 2019a; Dosi, 1988; Sahal, 1981). Abernathy and Clark (1985) state that: innovation is not a unified phenomenon: some innovations disrupt, destroy and make obsolete established competence; others refine and improve. Further, different kinds of innovation require different kinds of organisational environments and different managerial skills. An innovation is the initial market introduction of a new product or process whose design departs radically from past practice. It is derived from advances in science, and its introduction makes existing knowledge in that application obsolete. It creates new markets, supports freshly articulated user needs in the new functions it offers, and in practice demands new channels of distribution and aftermarket support.

2.2 Market Innovation

Marketing is the mechanism of economics incorporated into society to satisfy human needs. Implementing a new marketing approach including significant product design or package changes, product placement, advertising, and price promotion. All are also called marketing breakthrough (Sarathy & Banalieva, 2014). Typically, in the era of World War 2, growth was

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described as a rapid and sustained increase in the per capita actual income and changes in technological, economic, and population characteristics. Furthermore, they stated that the company must build marketing strategies and the needs of goods and services to gain customer trust without any resources. Therefore, the companies need carefully place their product with a pursued customer.

Market innovativeness is highly connected to product innovativeness, and often studied as product market innovativeness (Schumpeter, 1939). In fact, Ali et al. (1995) consider innovativeness as a market-based construct and define innovativeness as the uniqueness or novelty of the product to the market. At a broader level, market innovativeness refers to innovation related to market research, advertising and promotion (Andrews and Smith, 1996), as well as identification of new market opportunities and entry into new markets (Ali et al., 1995).

2.3 Process Innovation

Process innovation is the implementation of a production method, or significant changes in specific techniques, equipment and / or software, in order to reduce production and distribution costs, improve the quality, production or distribution of new or improved products, to increase the efficiency or flexibility of a productive activity or supply activity and to reduce the risks to the environment (Maier, 2014b). Even if new products are the visible results of market innovation, process innovation plays an equally important strategic role. Process innovation can be defined as bringing new elements that are introduced into production in an organization. The road to achieving business performance requires a redefinition of the processes that underpin its operation and the increasing use of innovative technologies. In this context, process innovation involves a business process approaching the use of innovation in the key processes of an enterprise and helping to reduce costs or time to produce a good or service (Maier, 2014a).

2.4 Product Innovation

Product innovation is a strategic resource for modern businesses (Auh & Menguc, 2005; Vorhies & Morgan, 2005, Jelenic, 2011). Several scholars conclude that the success and survival or failure of modern organizations rely on how innovative they are (Quinn, 2000; Nonaka & Takeuchi, 1995). As opined by Ahmed (1998), many businesses emphasize the importance of improving their innovative ability, so many try to achieve it, but only a few could actually achieve it. Product innovation has been noted to facilitate the achievement of organization's objectives as it helps in the transformation of ideas into new, better quality products, and services through enhanced processes (Baregheh, et al., 2009). Product innovativeness helps in distinguishing a firm's product from that of its contemporaries. Notable scholars have pointed out that fact that for a firm that cannot control the market price of products in its sector, the succumb lies in the making of innovative products (Palas, Böckermann, Goetz & Tecklenburg, 2013; Baregheh, et al., 2009).

2.5 Development of Solar Power

Solar power is energy from the sun and it is seen as a good source of energy for many years because of the vast amounts of energy that are made freely available, and because the

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conventional sources of energy are finite in nature and pose severe threats to man's environment. Rochell (2010) sees solar energy as a more sustainable alternative for the supply of electricity if harnessed by modern technology. Sambo (2009) noted that environmental degradation due to energy use and exploitation is already prevalent in Nigeria hence solar energy is a promising renewable energy sources in view of its apparent limitless potential. Also, Sambo (2012) believed that the massive load shedding experienced all over the nation had made electricity supply only for a few hours a day, implying that the energy supply all over the nation is not adequate for the teaming number of consumers regardless of the enormous potentials presented by the earth's resource system.

2.6 Consumer Trust

Trust is an important component of social capital and where trust is low in society, social capital tends to be built among small and more isolated groups, rather than cooperating across a larger network of groups. To provide access to goods and services, intermediaries use connections to key actors beyond their small group boundary to span networks to enhance access. Fukuyama (2001) describes this as a "radius of trust" and argues that more traditional groups (based on kin and familial relations) have more narrow radii, which reduces cooperation with outsiders with potential impacts on resource allocation and political corruption. As described by Krishna (2002), the development of social capital is a mediated action, with agents or intermediaries critical to the construction of local social capital.

3.0 THEORETICAL FRAMEWORK

3.1 Diffusion of Innovation Theory

Introduced in 1962, the Innovation Diffusion Theory was fine-tuned by Rogers (1995). Innovation diffusion theory focuses on understanding how, why and at what rate innovative ideas and technologies spread in a social system (Rogers, 1962). In terms of the theories of change, Innovation Diffusion theory takes a contrary approach to study changes. Instead of focusing on persuading individuals to change, it sees change as being primarily about the evolution or "reinvention" of products and behaviours so they become better fits for the needs of individuals and groups. In diffusion of innovations, it is not people who change, but the innovations themselves (Les Robinson, 2009). On the other hand, diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003). Fichman (2000) defines diffusion as the process by which a technology spreads across a population of organizations. The concept of diffusion of innovations usually refers to the spread of ideas from one society to another or from a focus or institution within a society to other parts of that society (Rogers, 1962). The whole theory of Innovation Diffusion can be divided into four main elements (Ismail Sahin, 2006).

3.2 Technology Acceptance Model

TAM is an intention-based model developed specifically for explaining and/or predicting user acceptance of computer technology (Hu et al., 1999). It has been used as the theoretical basis for many empirical studies of user technology acceptance (Adams et al. 1992; Mathieson, 1991; Davis et al. 1989; Davis, 1989). Technology acceptance was defined as "an individual's

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psychological state with regard to his or her voluntary or intended use of a particular technology" (Hendrick et al., 1984).

The technology acceptance model (TAM) was first created by Davis (1989), based on the theory of reasoned action (TRA) (Fishbein & Ajzen, 1975) in psychology research. The TRA posits that individual behavior is driven by behavioral intention where behavioral intention is a function of an individual's attitude toward the behavior and subjective norms surrounding the performance of the behavior. In other words, it states that one's behaviour and the intent to behave is a function of one's attitude toward the behavior and their perceptions about the behavior. Therefore, behaviour is the function of both attitudes and beliefs.

Meanwhile, TAM proposes that perceived ease of use and perceived usefulness of technology are predictors of user attitude towards using the technology, subsequent behavioral intentions and actual usage. Perceived ease of use was also considered to influence perceived usefulness of technology (Davis, 1989).

3.3 Institutional Theory

Major institutional theorists were Meyer & Rowan, DiMaggio & Powell. They asserted that the environment in any institution highly influences the formal structure development even more than market pressures. Any innovation-based structure can be easily legitimized in that organization. Ultimately, "irrational and negligent" is the final perception of behavior when the organizational actors do not accept that innovation, which become legitimized or critical. Organizations acquire and promote a formal structural form that does not even increase efficiency just for the sake of legitimacy. Organizations introduce/adopt specific "vocabularies of structure" like designations, procedural names, and employees' roles because they also provide legitimacy. Organizations continuously exhibit a behavior that can be explained as "trappings of legitimacy" to show that its actions are based on "good faith." Legitimacy, in one sense, is the need of an organization to stay relevant and increase its life cycle. However, the legitimacy out of these formal structures can lead to efficiency-reduction and technical or market competitiveness.

3.4 Empirical Review

Kalko, Erena and Debele (2023) examined Technology management practices and innovation: Empirical evidence from medium-and large-scale manufacturing firms in Ethiopia. Using simple random sampling, a total of 200 firms were chosen for this study to obtain responses from respondents. Four hypotheses were proposed for testing. Structural equation modelling and cross-sectional design were used to analyze the data using the LISREL 8.80 SIMPLIS program software tool. This study finds technology transfer and technology acquisition have significant positive effects on process innovation, product innovation, and method innovation. Technology process has a significant positive effect on process and method innovation. Technology absorption has a significant positive effect on product innovation. The major implication of this study is that technology management, coupled with appropriate technology management policies and strategies, is an appropriate resource to be used in the organization to enhance firm performance, particularly innovation and creativity.

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Ajah (2023). Factors influencing managers-owners of Micro, Small, and Medium Enterprises (MSMEs) willingness to adopt Solar Technology in Anambra State, Nigeria. A survey questionnaire was administered to 450 respondents who are managers-owners of MSMEs in the state. AMOS-23 was used to analyse the data. The findings showed that managers'-owners' attitude towards behaviour and their perceived potential benefits of solar technology were positive and statistically significant factors influencing solar technology adoption intention. However, managers'-owners' disruptive innovation activities (DIA) and perceived cost were not statistically significant in predicting adoption intention.

Batool et al. (2022) Nexus between energy poverty and technological innovations: A pathway for addressing energy sustainability. Pakistan has experienced energy poverty, as most of the people live in rural areas. Poor people are stereotyped as collecting the firewood and using the unclean energy sources to meet their residential energy needs. As a result, respondents in the provinces with the highest rates of energy poverty set a high priority on this research. Structured interviews were used to conduct the research in rural parts of Punjab and Sindh provinces. Due to the apparent country's large population and rapid industrialization, conventional energy sources cannot meet the country's present energy needs. Results revealed that energy poverty in rural areas had exposed the residents to security problems such as health dangers, fire accidents, time poverty, financial poverty, illiteracy, and other issues at various levels of severity.

Solarin et al. (2022). The impact of technological innovation on renewable energy production: accounting for the roles of economic and environmental factors using a method of moments quantile regression. With the advent of the Fourth Industrial Revolution (4IR), the availability, access, and use of green technologies including renewable energy have significantly improved. Researches on the factors that influence renewable energy production are available. However, we are unaware of any previous research that examines the role of renewable energy innovation in the promotion of renewable energy production. As a result, this study evaluates the impact of technical innovation on green growth from 1993 to 2018, while accounting for real GDP, producer price index, and CO2 emissions. Due to their pivotal status among the developing countries, our study has focused on the BRICS countries. By using a new panel quantile regression augmented with the method of moments, the empirical findings suggest that the influence of renewable energy innovation on renewable energy production is significantly positive across all quantiles.

Lind, and Aman (2022). Diffusion and adoption of renewable energy products for enhanced societal wellbeing. This study aims to understand and assess the diffusion and adoption of RES for enhanced societal wellbeing in developing countries. Furthermore, the purpose is to contribute to a deeper understanding of the drivers and barriers (D&B) to the diffusion and adoption of RES among smallholders in rural Tanzania. The study only investigated solar energy lamps and not all products within the scope of RE. This was to draw a more accurate and relevant conclusion from the empirical study. The study took place in Handeni, Tanzania, from March to May 2022. The primary data for the study was collected through observations and twenty semi-structured interviews in four different villages in Handeni's Rural district. The data sets were analyzed through a thematic analysis to identify which D&B the smallholders were facing regarding the adoption of solar energy lamps. These D&B were later further analyzed with the help of the secondary data from literature studies, where the Diffusion of

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innovations theory and the Sustainable livelihoods approach were the main theories used. Barriers to adopting solar energy lamps were identified as; knowledge, trust, economy, and accessibility. Driving forces for wanting a solar energy lamp were; the reduced risk of health problems, reduced risk for accidents, portability, facilitating household activities, no variable costs, and the possibility to study and work at night.

4.0 METHODOLOGY

This study employed a correlational research design to examine the relationship between technology innovation and the development of solar power within a non-contrived setting. The study adopted a positivist social paradigm. Positivism emphasizes the objective nature of the social world, focusing on observation, understanding, and prediction of events and relationships (Patton, 2002; Creswell, 2013). The population of the study comprised the Nigerian off-grid energy sector, including thirteen (13) recognized renewable energy companies (as listed by the Rural Electrification Agency of Nigeria), their customers (households and SMEs), and regulatory bodies (NERC and the Ministry of Power). A total of 1,614 individuals across these three groups constituted the target population. The accessible population was defined by specific criteria: representation of the off-grid energy sector, geographical location within Nigeria, recognition by the REA, and, for the companies, their status as renewable energy firms with publicly available information. For customers, the criteria were adoption or consideration of off-grid solar solutions. For regulators, the criteria were direct involvement in renewable energy policy. Population figures were obtained from the REA website (https://rea.gov.ng/rea-signs-mou-five-renewable-energy-companies-scale-electricity-access-nigeria/), company websites, and estimated through personal communication and visits.

The sample size was determined using the Taro Yamane formula (Ali, 2006) with a 95% confidence level (0.05 error precision). This formula provided a statistically representative sample size of 321 individuals from the total population of 1,614.

Both primary and secondary data were utilized in this study. Primary data, collected firsthand, offers specificity and control but can be resource-intensive (Jackson & Carter, 1993; Midgley & Chrismas, 2014). Secondary data, drawn from existing sources like publications and databases, is cost-effective but may lack relevance (Taylor, 1985). This study employed a mixed-methods approach, combining data extracted from online energy databases with primary data gathered through a structured online questionnaire. This triangulation aimed to leverage the strengths of each method while mitigating their weaknesses (Creswell, 2009; Popper & Schilt, 2008).

The online questionnaire, consisting of 39 closed-ended, multiple-choice questions (13 for each group), was designed to gather data on the study constructs and socio-demographic variables. The questionnaire was divided into two sections: demographics and respondent opinions on the variables. A 5-point Likert scale (1-5, Strongly Disagree to Strongly Agree) was used to measure technology innovation dimensions (market, process, and product) and consumer trust.

The questionnaire's validity was assessed through content validity (face and sampling). Instrument reliability was assessed through a pilot test with 30 randomly selected employees (10.52% of the sample), excluding those participating in the main study (Cooper & Schindler,

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2006). Cronbach's alpha was used to determine internal consistency, with a threshold of 0.7 (Nunnally & Bernstein, 1994). The reliability coefficients for each construct were observed to be above 0.7. Data analysis involved demographic analysis and inferential statistics using Structural Equation Modeling (SEM).

5.0 RESULTS AND DISCUSSION

5.1 Results and Analysis

This chapter presents and discusses the results of the study's analysis to evaluate the relationship between Technology Innovation and Development of Solar Power in off-grid energy sector in Nigeria. Descriptive and inferential statistics were adopted in evaluating the underlying relationships between predictors and criterion variables. The study clearly outlines evidences and results in tables and charts. The hypothesis was tested and findings discussed.

5.2 Data Analysis

Table 1: Distribution and Retrieval Frequency of Questionnaire

	Frequency	Percentage
Copies of Questionnaire distributed	321	100%
Copies of Questionnaire retrieved	243	76%
Copies of Questionnaire not retrieved	42	13%
Copies completed but not useable	4	1%
Copies completed and usable	239	74%

Source: Author's Field Survey (2024)

The researcher made available the link for the respondents to fill. Out of the sample size of 321, only 243 respondents (76%) filled the questionnaire. Out of the 243 copies filled, only 239 (74%) responses filled were valid and were used for the analysis.

Table 2: Demographic Analysis

Respondents_Group	**Number**	**Percentage**
Company	100	41.8%
Customer	120	50.2%
Regulator	19	7.9%
Gender_Regulatory_Bodies		
Male	10	52.6%
Female	9	47.4%

Table 2 shows the distribution of respondent's group, based on the population of 100 companies, 120 customers, and 19 regulatory bodies. Findings from the surveyed companies (solar energy providers) suggest a strong emphasis on product innovation. These companies generally reported actively introducing new and improved solar products, coupled with significant investment in research and development to enhance product efficiency and performance. While process innovation, such as improving installation and maintenance processes, was acknowledged, the adoption of advanced technologies for operational

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optimization appeared less consistent. Regarding market innovation, companies demonstrated a proactive approach to exploring new markets but showed varying degrees of innovation in their marketing strategies and the provision of flexible financing options. Notably, there was a consistent emphasis across companies on the importance of building consumer trust through prioritizing customer satisfaction, providing excellent after-sales service, and maintaining transparency about product performance and warranties.

Customer responses revealed a moderate level of awareness regarding product innovation within the solar market. While customers generally recognized advancements in solar technology and the availability of diverse products, their understanding of the full extent of technological progress appeared limited. Perceptions of process innovation were generally positive, with customers finding the installation process reasonably efficient and maintenance services accessible. However, awareness of market innovation, particularly regarding financing options and the full range of available products, was less pronounced among customers. Despite these gaps in awareness, customer trust in solar energy as a reliable power source was growing, although some concerns remained about warranties and long-term system performance.

The regulatory bodies (NERC and Ministry of Power) presented a perspective that emphasized a supportive regulatory framework for product innovation, although they acknowledged potential areas for improvement, particularly in streamlining approval processes and establishing more robust standards and quality control measures. The regulators also prioritized process efficiency and safety, focusing on promoting safe installation practices and effective performance monitoring of solar systems. Their perspective on market innovation centered on fostering market competition and ensuring consumer protection within the off-grid solar market. Furthermore, the regulatory bodies expressed a positive view of existing government incentives designed to promote off-grid solar adoption, while also recognizing the need for increased support and a more stable and predictable policy environment to encourage further investment.

Comparing the responses across the three groups revealed some interesting contingencies. Companies tended to perceive themselves as more innovative than customers perceived them to be, suggesting a potential gap in communication or a need for companies to focus on innovations more readily apparent to consumers. A positive correlation was observed between customer trust in solar energy and both their awareness of new products and the transparency of company communications. Additionally, the study suggested a link between supportive regulations and greater company investment in R&D, as well as a connection between companies' market innovation efforts and increased customer awareness of solar products. These findings provide valuable insights into the interplay between different stakeholders and highlight areas where improved communication, policy adjustments, and targeted interventions could further enhance the development of the off-grid solar sector in Nigeria.

Table 2 shows that due to the small sample size of the regulatory bodies (19 total), conducting Chi-square tests may not be statistically robust. With such small numbers, the test is less reliable and may not accurately reflect true associations. It is often recommended to have at least 5 expected counts in each cell of the contingency table for the Chi-square test to be valid. In this case, it might be more appropriate to report descriptive statistics (percentages) and avoid

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drawing strong statistical conclusions. "Among regulatory representatives, 52.6% of males and 47.4% of females agreed that the current regulatory framework facilitates market competition. Due to the small sample size, no formal statistical test was conducted."

Table 3: RESPONDENTS_GROUP_COMPANY * GENDER_COMPANY * PIN1 Crosstabulation

Count

PIN1			GENDER_COMPANY MALE	GENDER_COMPANY FEMALE	Total
AGREE	RESPONDENTS_GROUP_COMPANY	COMPANY	18	22	40
	Total		18	22	40
STRONGLY AGREE	RESPONDENTS_GROUP_COMPANY	COMPANY	47	9	56
	Total		47	9	56
Total	RESPONDENTS_GROUP_COMPANY	COMPANY	67	33	100
	Total		67	33	100

Table 3 reveals a Chi-square test revealed a significant association between gender and responses to PIN1. Male company representatives were more likely to "Strongly Agree" (SA) that their company introduces new products (47% of males vs. 9% of females), while female representatives were more likely to "Agree" (A) (22% of females vs. 18% of males).

This suggests a potential difference in how male and female representatives perceive their company's product innovation efforts. Perhaps men are more involved in the initial stages of innovation, leading to stronger agreement about new product introductions.

Table 4: RESPONDENTS_GROUP_COMPANY * GENDER_COMPANY * MIN3 Crosstabulation

Count

MIN3			GENDER_COMPANY MALE	GENDER_COMPANY FEMALE	Total
AGREE	RESPONDENTS_GROUP_COMPANY	COMPANY	47	40	87
	Total		47	40	87
STRONGLY AGREE	RESPONDENTS_GROUP_COMPANY	COMPANY	7	6	13
	Total		7	6	13
Total	RESPONDENTS_GROUP_COMPANY	COMPANY	54	46	100
	Total		54	46	100

Table 4.4 shows that No statistically significant association was found between gender and responses to MIN3. This suggests that both male and female company representatives have similar perceptions regarding the availability of flexible financing options offered by their companies.

Table 5: RESPONDENTS_GROUP_CUSTOMERS * GENDER_CUSTOMERS * CTT1_C Crosstabulation

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Count

CTT1_C			GENDER_CUSTOMERS MALE	FEMALE	Total
NEUTRAL	RESPONDENTS_GROUP_CUSTOMERS	CUSTOMERS	20	35	67
	Total				67
AGREE	RESPONDENTS_GROUP_CUSTOMERS	CUSTOMERS	40	25	33
	Total				33
Total	RESPONDENTS_GROUP_CUSTOMERS	CUSTOMERS			120
	Total		60	60	120

Table 5 shows a Chi-square test showed a significant association between gender and trust in solar reliability. Female customers were more likely to respond "Neutral" (N) (35% of females vs. 20% of males), while male customers were more likely to respond "Agree" (A) (40% of males vs. 25% of females).

This suggests that female customers may have more reservations or uncertainties about the reliability of solar systems compared to male customers. This could be due to differences in information access, risk perception, or other factors.

Table 6: RESPONDENTS_GROUP_CUSTOMERS * GENDER_CUSTOMERS * PIN2_C Crosstabulation

Count

PIN2_C			GENDER_CUSTOMERS MALE	FEMALE	Total
AGREE	RESPONDENTS_GROUP_CUSTOMERS	CUSTOMERS	9	16	25
	Total		9	16	25
STRONGLY AGREE	RESPONDENTS_GROUP_CUSTOMERS	CUSTOMERS	53	42	95
	Total		53	42	95
Total	RESPONDENTS_GROUP_CUSTOMERS	CUSTOMERS	53	67	120
	Total		53	67	120

Table 6 reveals no significant association was found. Both male and female customers similarly acknowledge advancements in solar technology.

5.3 Test of Hypotheses

Analysis of Moment Structure – Structural Equation Modelling (AMOS-SEM) was utilized in the analysis, with the help of SPSS-AMOS 23.0. Path Coefficients (β values) of .10 to 0.29, .30 to .49 and .50 to 1.0 are weak, moderate, and strong Path Coefficients respectively. In addition, hypotheses with p-values less than 0.05 Level of Significance were accepted, whereas those above 0.05 were rejected. The coefficients of determination (R2 or predictive accuracy) were identified. R2 values for endogenous variable are assessed as 0.00 to 0.25 (Weak), 0.26 to 0.50 (Moderate), ≥ 0.75 (Substantial).

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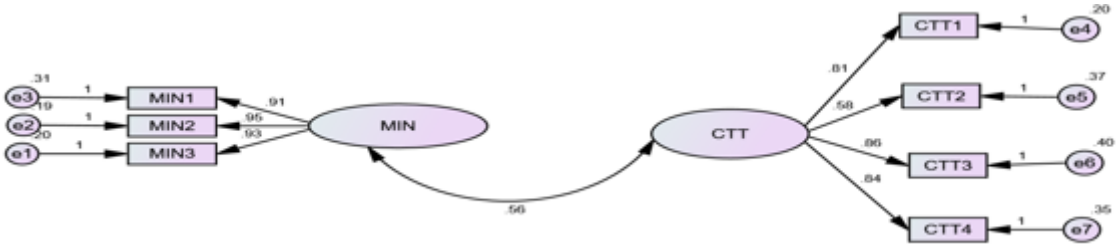
Test of Hypotheses 1

HO1: There is no significant relationship between Market Innovation and Consumer Trust.



Source: AMOS 23.0 output on Research Data, 2024

Figure 1: Hypothesis 1

Table 7: Test of Hypothesis 1

Hypotheses			*β*	*p*	R^2
MIN	<-->	CTT	0.566	0.001	0.320

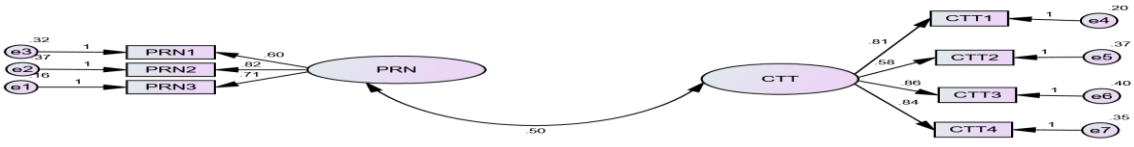
Source: SPSS-AMOS Version 23.0 Output, 2024

5.4 Hypothesis One (HO1) Testing

The path relationship analysis presented in Figure 1 and presentation in Table 7 indicate that there are positive and significant paths between market innovation and consumer trust (where β = 0.566, p = 0.001, R2 = 0.320). The covariance between market innovation and consumer trust is estimated to be 0.566. The covariance between market innovation and consumer trust is significantly different from zero (p=0.001) at the 0.05 level of significance (two-tailed). The coefficient of determination is 0.320, which implies that a unit change in market innovation will lead to a 32.0% change in consumer trust. In light of this, the study therefore rejects the null hypothesis and restate that there is a significant relationship between market innovation and consumer trust.

Test of Hypothesis 2

HO2: There is no significant relationship between Process Innovation and Consumer Trust.



Source: AMOS 23.0 output on Research Data, 2024

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Figure 2: Hypothesis 2

Table 8: Test of Hypothesis 2.

Hypotheses			*β*	*p*	R^2
PRN	<-->	CTT	0.508	0.000	0.258

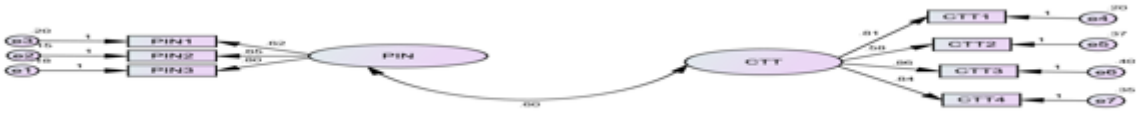
Source: SPSS-AMOS Version 23.0 Output, 2024

Hypothesis Two (HO2) Testing

The path relationship analysis presented in Figure 4.7 and presentation in Table 4.16 indicate that there are positive, and significant paths between process innovation and consumer trust (where β = 0.508, p = 0.000, R2 = 0.258). The covariance between process innovation and consumer trust is estimated to be 0.508. The covariance between process innovation and consumer trust is significantly different from zero (p=0.000) at the 0.05 level of significance (two-tailed). The coefficient of determination is 0.258, which implies that a unit change in process innovation will lead to a 25.8% change in consumer trust. In light of this, the study therefore rejects the null hypothesis and restate that there is a significant relationship between process innovation and consumer trust.

Test of Hypothesis 3

HO3: There is no significant relationship between Product Innovation and Consumer Trust.



Source: **AMOS 23.0 output**

Figure 3: Hypothesis 3

Table 9: Test of Hypothesis 3

Hypotheses			*β*	*p*	R^2
PIN	<-->	CTT	0.604	0.000	0.365

Source: SPSS-AMOS Version 23.0 Output, 2024

Hypothesis Three (HO3) Testing

The path relationship analysis presented in Figure 4.8 and presentation in Table 4.17 indicate that there are positive, strong and significant paths between product innovation and consumer trust (where β = 0.604, p = 0.000, R2 = 0.365). The covariance between product innovation and consumer trust is estimated to be 0.604. The covariance between product innovation and consumer trust is significantly different from zero (p=0.000) at the 0.05 level of significance (two-tailed). The coefficient of determination is 0.365, which implies that a unit change in product innovation will lead to a 36.5% change in consumer trust. In light of this, the study

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therefore rejects the null hypothesis and restate that there is a significant relationship between product innovation and consumer trust.

5.5 Serendipitous Findings

Several serendipitous findings have marked the development of solar power in off-grid Nigeria, significantly impacting the sector's development. These findings, often unexpected or unintended, have played a crucial role in driving innovation, reducing costs, and expanding access to clean energy.

a. Other researchers may discover through energy modelling that the projected growth in energy demand in Nigeria is significantly higher than anticipated, highlighting the urgent need for accelerated adoption of solar power and other renewable energy sources. This unexpected finding could lead to a renewed focus on policy interventions, investments, and technological advancements to ensure that Nigeria can meet its future energy needs in a sustainable and reliable manner.
b. Innovative solar power may find applications beyond their original intended use. For example, a solar-powered lighting device could also power agricultural equipment or medical devices. New technologies might lead to unforeseen cost savings, such as reducing maintenance costs or improving energy efficiency.
c. Research might uncover cultural or social factors that hinder the adoption of solar power, despite its perceived benefits. Researchers may identify unexpected regulatory challenges or bureaucratic red tape as significant barriers to the development of solar power.
d. The study reveals that NASENI's emphasis on local manufacturing of solar components has a more substantial impact on local economies than initially anticipated. This is manifest in greater-than-expected job creation within the communities hosting these manufacturing facilities, or the unforeseen development of supporting industries like component suppliers and logistics providers, creating a broader positive economic impact.
e. The research uncover that NASENI plays a vital role in developing a skilled workforce for the solar industry, exceeding the scope of their formal training programs. This involve employees gaining valuable on-the-job experience transferable to other ventures, or the attraction of skilled professionals to NASENI's research activities, leading to a wider diffusion of knowledge within the local community.
f. The study discovered that NERC's regulatory framework has a surprising influence on community engagement with off-grid solar projects. This involves clear regulations on community participation leading to stronger local support for these projects, or transparent regulatory processes minimizing conflicts related to land use and benefit distribution.

6.0 DISCUSSION OF FINDINGS

This study's first specific objective explored the relationship between market innovation and consumer trust. The results contradicted the null hypothesis (Ho:1), which posited no significant relationship. A positive and significant relationship was found between market innovation and consumer trust within Nigeria's off-grid energy sector. This suggests that increased market innovation is associated with increased consumer trust. When off-grid energy

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firms demonstrate a commitment to innovation and progress, they signal value and forward-thinking to consumers. This finding aligns with Moreira and Silva's (2014) research, which emphasized the crucial role of customer cooperation in driving marketing innovation. Companies that engage with customers are more likely to innovate in marketing. Innovation, as a marketing mix element, creates new advantages for companies (Harms et al., 2002; Chou, 2009; Cherchem, 2012).

The second specific objective investigated the relationship between process innovation and consumer trust. The null hypothesis (Ho:2), stating no significant relationship, was not supported by the data. A positive and significant relationship was found, indicating that increased process innovation is associated with increased consumer trust. When energy firms demonstrate a commitment to efficiency, quality, and customer satisfaction through innovative processes, they build consumer confidence. This finding relates to Xie et al.'s (2022) study on green process innovation and financial performance. Their research found a U-shaped relationship between green process innovation and financial performance, moderated by green social capital and customer needs. Firm innovativeness is perceived by consumers as an enduring firm capability (Kunz et al., 2011; Mahmoud et al., 2018). Since consumers determine innovation success, a consumer-centric perspective is crucial.

The third objective examined the relationship between product innovation and consumer trust. The null hypothesis (Ho:3), stating no significant relationship, was rejected. A strong and significant positive relationship was found between product innovation and consumer trust. Consistently delivering innovative products that meet or exceed consumer expectations builds trust and loyalty. Conversely, consumer trust is essential for new product adoption. This aligns with Henard and Dacin's (2010) findings, which showed that a high perceived reputation for product innovation leads to excitement and loyalty toward the firm. Successful new product development requires responsiveness to customer needs (Cooper & Sommer, 2016). Consumer perceptions should be considered early in the process (Siegrist, 2008; van Kleef et al., 2005).

7.0 CONCLUSION

The study examined the relationship between technology innovation and development of solar power in Nigeria's off-grid energy firms, with government incentives serving as a moderating variable. The findings support the following conclusions:

a. The areas of market, process and product innovation that affect technology innovation are strongly linked to the areas of consumer trust in off-grid energy companies in Nigeria. These are the measures of how quickly solar power spreads. Advancements in solar panel efficiency, battery storage, and inverter technology have significantly contributed to the growth and competitiveness of the industry.
b. Technology innovation play a crucial role in driving the development of solar power. Solar systems' improved performance, reduced costs, and increased reliability have made them more attractive to off-grid energy companies and consumers.

In conclusion, the research concludes that there exists a positive and significant relationship between technology innovation and development of solar power in the off-grid energy sector in Nigeria.

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7.1 Recommendations

Based on the study's findings and position on the relationship between technological innovation and development of solar power in Nigeria's off-grid energy sector, the following measures are recommended:

i. Off-grid energy companies should allocate funds for research and development of innovative solar technologies, with a focus on energy storage, efficiency improvements, and off-grid applications.
ii. Off-grid energy firms should implement streamlined approval processes for innovative solar products to reduce time-to-market.
iii. Off-grid energy firms should ensure that products align with the cultural preferences, needs, and practices of Nigerian consumers. Consider factors such as affordability, durability, and ease of use.
iv. The government should offer grants or subsidies to support the development and deployment of innovative off-grid energy solutions.
v. Off-grid energy firms should conduct regular reviews of the regulatory framework to assess its effectiveness and identify areas for improvement.

REFERENCES

Abernathy, W. J., & Clark, K. B. (1985). Innovation: Mapping the winds of creative destruction. Research Policy, 14(1), 3-22.

Adams, D. A., Nelson, R.R., & Todd, P.A. (1992). Perceived usefulness, ease of use, and usage of information technology: A replication. MIS Quarterly, 16(2), 227-247.

Ajah, S. N. (2023). Factors influencing managers-owners of Micro, Small, and Medium Enterprises (MSMEs) willingness to adopt Solar Technology in Anambra State, Nigeria. Thailand and The World Economy, 41(1), 61-86.

Arthur, B.W. (2009). The Nature of Technology: What It Is and How It Evolves, Allen Lane/Penguin, London.

Batool, K., Zhao, Z-Y., Atif, F., & Dilanchiev, A. (2022). Nexus between energy poverty and technological innovations: A pathway for addressing energy sustainability. Frontiers in Environmental Science, 10(1), 888080.

Cherchem, M. (2012). The Impact of the Imitation and Innovation Marketing in Services: the case of the Banks and Insurance. Technology and Investment, 3, 57-62. http://dx.doi.org/10.4236/ti.2012.32008

Chou, H. (2009). The effect of market orientation intention and superiority on new product performance. The Journal of American Academy of Business, 14(2), 93-97.

Coccia, M. (2019a). The theory of technological parasitism for the measurement of the evolution of technology and technological forecasting. Technological Forecasting and Social Change, 141, 289–304. doi: 10.1016/j.techfore.2018.12.012.

 Copyright © The Author, All rights reserved

Cooper, R. G., & Sommer, A. F. (2016). The agile-stagegate hybrid model: A promising new approach and a new research opportunity. Journal of Product Innovation Management, 33(5), 513–26.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. MIS Quarterly, 13(3), 319-339.

Davis, F.D., Bagozzi, R.P., & Warshaw, P.R. (1989). User acceptance of computer technology: a comparison of two theoretical models. Management Science, 35(8), 982-1003.

Dosi, G. (1988) Procedures, and microeconomic effects of innovation. Journal of Economic Literature, 26 (3), 1120–1171.

Fichman, R.G. (2000). The Diffusion and Assimilation of Information Technology Innovations," in: Framing the Domains of IT Management: Projecting the Future Through the Past, R.W. Zmud (ed.), Pinnaflex Educational Resources, Cincinnati, OH.

Fishbein, M., & Ajzen, I. (1975). Belief, attitude, intention and behavior: an introduction to theory and research. Reading, MA: Addison-Wesley.

Harms, F., Rohmann, S., Heinrich, M., Druener, M., & Trommsdorff, V. (2002). Innovative marketing. Pharmaceuticals Policy and Law, 5, 135-149.

Henard, D. H., & Dacin, P. A. (2010). Reputation for product innovation: Its impact on consumers. Journal of Product Innovation Management, 27(3), 321-335.

Hendrick, C., Hendrick, S., Foote, F. H., & Slapion-Foote, M. J. (1984). Do men and women love differently?. Journal of Social and Personal Relationships, 1(2), 177-195.

Hu, P.J., Chau, P.Y.K., Sheng, O.R.L., & Tam, K.Y. (1999). Examining the technology acceptance model using physical acceptance of telemedicine technology. Journal of Management Information Systems, 16(2), 91-112.

Kalko, M. M., Erena, O. T., & Debele, S. A. (2023). Technology management practices and innovation: Empirical evidence from medium-and large-scale manufacturing firms in Ethiopia. African Journal of Science, Technology, Innovation and Development, 15(1), 107-123.

Kunz, W., Schmitt, B., & Meyer, A. (2011). How does perceived firm innovativeness affect the consumer?. Journal of Business Research, 64(8), 816-822.

Les Robinson, (2009). A summary of Diffusion of Innovations, ChangeoLogy, the Book.

Lind, F., & Aman, B. (2022). Diffusion and adoption of renewable energy products for enhanced societal wellbeing. Minor field study in Handeni, Tanzania. Industrial engineering and management, Bachelor's Thesis.

 Copyright © The Author, All rights reserved

Mahmoud, M. A., Hinson, R. E., & Anim, P. A. (2018). Service innovation and customer satisfaction: the role of customer value creation. European Journal of Innovation Management, 21(3), 402-422.

Maier, A. (2014a), Cercetărișicontribuțiiprivinddezvoltareamodelelor de management al inovării, PhD thesis, Techical University of Cluj-Napoca, Romania.

Maier A., Keppler T., Maier D. (2014b), Innovation the new trend în today' s challenging economy, The 13th International Conference on Informatics în Economy, IE 2014, 15-18 May 2014, București

Mathieson, K. (1991). Predicting user intentions: comparing the technology acceptance model with theory of planned behaviour. Information Systems Research, 2(3), 173-191.

Moreira, J., & Silva, M. J. A. M. (2014). Cooperation between the consumer and firms as a determinant of marketing innovation: Empirical study of Portuguese firms. Contemporary Management Research, 10(3), 215-232.

Rogers, E. M. (2003). Diffusion of Innovations. Fifth Ed Free Press. New York. Rezvani, Z., Jansson. J. & Bodin.

Rogers, E. M. (1995). Diffusion of innovations. Fourth edition. New York. Free Press.

Rogers, E. M. (1962). Diffusion of innovations. First edition. New York. Free Press.

Sahal, D. (1981). Patterns of Technological Innovation, Addison-Wesley, Reading, MA.

Sarathy, R., & Banalieva, E. R. (2014). Economic Development and Marketing Strategies: a Comparative Lens. Organizations and Markets in Emerging Economies, 5(1), 49–73. https://doi.org/10.15388/omee.2014.5.1.14241

Schumpeter, J. A. (1939). Business cycles: A theoretical, historical and statistical analysis of the capitalist process.

Siegrist, M. (2008). Factors influencing public acceptance of innovative food technologies and products. Trends in Food Science & Technology, 19(11), 603–60.

Solarin, S. A., Bello, M. O., & Tiwari, A. K. (2022). The impact of technological innovation on renewable energy production: accounting for the roles of economic and environmental factors using a method of moments quantile regression. Heliyon, 8(1), e09913.

van Kleef, E., van Trijp, H. C. M., & Luning, P. (2005). Consumer research in the early stages of new product development: A critical review of methods and techniques. Food Quality and Preference, 16(3), 223–01.

Xie, X., Hoang, T. T., & Zhu, Q. (2022). Green process innovation and financial performance: The role of green social capital and customers' tacit green needs. Journal of Innovation & Knowledge, 7(1), 100165.

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