Barriers and Drivers Facing Architects in Adopting Energy Efficiency and the use of Zero-carbon Technologies in Nigerian Built Environment.

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Abstract. The study presents the driving factors of energy efficiency with barriers that persuade against the progressive development of affordable and clean energy. With the benefit of the use of zero-carbon technology to reduce carbon related emission in the built environment, these might pave the road in saving 2.9 Gt CO₂ through the combined effort of design, models, stringent policies and management initiatives to enhance energy efficiency. However, these will bridge the gap by setting the rudiment steps for future energy-efficient in an urban environment. To ascertain a clear picture of the barriers and drivers facing the architects embracing energy efficiency and zero-carbon technologies for affordable and clean energy in the country. The study outline the positive correlations based on the Architects’ perspectives. The sources of the data were via questionnaire survey studies which were selected randomly, amongst various architects and professional architects in Nigeria’s built environment. The knowledge ranking of drivers and barriers where revealed based on the adopting energy efficiency technologies. Nonetheless, to save energy, funds, the environments and improve health being of end-users, were considered as greater achievement despite the resilience effects of Nigerian communities. The study concluded by pinpointing the future prospects of energy efficiency by identifying the driving factors, strategies, and approaches taken to reinforce energy efficiency with the use of zero-carbon technologies and renewable energy.

Keywords: Built Environment, Energy Efficiency, Emission, Zero-carbon Technologies.

1. Introduction.
In the last two decades, a red flag was unveiled regarding Climate change that has become an undoubted environmental predicament in the world. These were as resultant effects of Carbon footprint and increase in temperature of the atmosphere by burning of fossil fuel and other related activities. The values were becoming more alarming and important in environmental policies with the fight against climate change and Global warming. The Intergovernmental Panel on Climate Change (IPCC)[1] predicted that greenhouse gas emissions would grow by 25%-90% from 2000 to 2030, which will have an immeasurable influence on our living environment. The United Nations delivered a verdict on the action needed to reverse the effects of climate change [2]. The 4th Assessment Report of IPCC [3], indicates that the climate for the Middle East and North Africa Region (MENA) region is likely to experience temperature increases of up to 2 degrees centigrade (2°C) within the next 15–20 years, and over 4 °C by the end of this century[4].
Moreover, building construction is also one of the major sources of greenhouse gas emissions, with an estimated 36% of greenhouse gases being emitted by building construction related activities [5]. Without transferal and significant action in the next decade, the 2050 goals won’t be achievable [6]. One of the ways to reduce carbon emission in the buildings is by adopting energy efficiency and the use of Zero-carbon Technologies to meet up with the global challenge. In study of Omar,[7]the strategies adopted to reduce carbon emissions during operation include: reducing energy consumption, switching to renewable energy and implementing new technology sources in design. Nigeria is a fast growing economy but grieves from serious setbacks due to deficiency of power supply and the prevalent use of ecologically and economically questionable private diesel and petrol generators accounting for over 50% of the active generation capacity[8]. Several developed countries have made headways in achieving the sustainable built environment by ensuring energy efficient stringent policies and implementation are put into practice.

The Royal Institute of British Architects (RIBA) and the British government had set their target for energy efficiency and reduction of Co emission by 2030, which were put into practice. In 2002, Germany passed additional energy saving regulations known as EnEV, which set new minimum and mandatory standards for all new residential and almost all new non-residential buildings [9]. Whilst the America Institutes of Architects (AIA) created an initiative commitments at its conferences [2], with the resolution: “declaring an urgent climate imperative for carbon reduction: transforming day to day practices of architects to achieve a zero-carbon, equitable, resilient and healthy built environment: and leveraging the support of architecture’s peers, client policymakers and the public at large”. According to Intended Nationally Determined Contribution (INDC)[10], Nigeria pledged to unreservedly reduce GHG emissions by 20% by 2030, compared to business as usual (BAU) emission levels. It aims to achieve this goal by improving energy efficiency by 20%, providing 13 GW of renewable electricity to rural communities that are currently not connected to the electric power grid, and by ending the flaring of gas[11].

Nigerian professional bodies had embarked on initiatives to tackles problems of sustainable energy efficiency in the built environment. Due to different national realities, socio-economic development, different countries have different approaches to developing green buildings [12]. The Architect Registration Council of Nigeria (ARCON) hold its annually forum: Architects colloquium (2010;2011; 2012; 2013; 2014;2015;2016;2017 and 2018) with her sister institutes: Nigerian Institutes of Architects on sustainable built environment to extenuate energy efficiency in the country with the perspective of ameliorating occupant productivity and protecting the environment[13].

The Federal Ministry of Power, Works and Housing (FMPWH) established Building Energy Efficiency guidelines for Nigeria to adopt into practices since 2016, but the lukewarm behavioural practices couple with shortage of reliable data on energy consumption in buildings: thus, this is recognised as a major barrier to energy efficiency[14]. With adequate and diversified energy supply options in the country exist, the problem of unreliability of supply due to insufficient and inefficient power generating capacities constitutes a huge drain on the national economy. This leads to energy insecurity and has constituted a major characteristic of the energy crisis experienced by the country over the last decade, especially with regards to the supply of electricity. Furthermore, additional impetus from transformational Energy Efficiency in building development is generated by entrepreneurship, the spirit to grab opportunities, confront challenges, and take risks even in an uncertain environment[12] . The Study presents the driving factors of energy efficiency with barriers that persuade against the progressive development of affordable and clean energy. It also clearly pinpoints the key barriers to sustainable development by ranking the most critical part in Nigerian contexts.
1.1 Research Hypotheses.
Chi-square statistical tool was used for testing the hypotheses of research study to ascertain the correlations.
i. Null hypothesis (H₀); there are no uniform barriers and drivers facing architects in adopting affordable and clean Energy Efficiency and the use of Zero-carbon Technologies in Nigeria’s built environment.
ii. The alternative hypothesis (Hₐ); there are drivers with barriers that restricted the architect espousal of affordable and clean energy efficiency, with the use of Zero-carbon Technologies in Nigeria’s built environment.

2. The Barrier to Energy and Zero-carbon Technology (ZCT) implementation.
Sustainable development initiates the implementation of energy efficiency with ZCT, which yield affordable and clean energy in our built environment. Nonetheless, novel technologies competing with conventional technologies[15] however, they were slowly embraced in Nigeria. Major barriers to energy efficiency improvements in developing countries include lack of awareness of the importance of, and the potential for, inadequate financing mechanism, absence of expertise [5]. Moreover, socio-political and techno-economic factors were the epic challenges for the implementation of Energy Efficiency and ZCT, It takes ages to achieve a goal of the short-term plan. This is probably due to inconsistencies in government policies[16] couple with the change of government regime and an acute understanding of the effective tools of managing the environment for sustainable development goals.

2.1 Techno-economic factors.
Techno-economic factors are the hubs that yield the economic and technological development of Nigeria. The study of Hekkert M P et al., [15] stated that innovation system theories, with sustainable development and diffusion of novel technologies, require the participation of key stakeholders within the environ. These strategies are classified into technological producers and technological regulators which need to work concurrently to achieve the goals of sustainable development. Energy efficiency and the use of Zero-Carbon Technologies have proven to be a cost-effective strategy for building economies without necessarily increasing energy production and moderate damages to our ecosystem. Techno-economic factors increase energy productivity or the ratio of output and quality of goods and services per unit of energy input.

In the study of Eleri et al., [17] that barriers to techno-economic development could be due to inadequate local manufacturing capacity and obstacles to a simple funding mechanism that would boost the sector into full capacity. Moreover, the bereft of hope for educational sector in Nigeria predominantly posts primary and tertiary institutions that have prevented the development of inventive technologies. The educational sector is the hub that trained professionals, skilled labour to keep the system running on the track.

Furthermore, the techno-economic factors serve as a barrier to affordable energy in Nigeria due the presence of subsidies in petroleum energy production in the country. Hence, these prevent spring up of industries with competing technologies that would effectively drive into energy markets. Finally, Nigeria government can resolve the issue of subsidy by phasing it out and investing the funds into the educational sector and industries.

2.2 Socio-political factors.
Many previous studies [18],[19],[16] upshot that Nigerian built environment professionals are fully aware of energy-efficient /green building applicable to construction. For some reason, it appears to be a moderate interest in the practice in which professional bodies posit the poor government commitment with the unsupportive regulatory framework, have stifled sustainable development despite all efforts from the professional bodies. The socio-political factors impeding energy efficiency and the use of ZCT development and diffusion in Nigeria are basically cantered on enactment, execution and monitoring and week institutional framework policy. The inconsistencies in political climate in the
country have drastically affected the sustainable development and diffusion of economic growth, which speculate an unsupportive framework.

To limit the socio-political challenges, the Federal Government of Nigeria (FGN) must synchronize energy efficiency building laws, policies, design, rating, construction guidelines and redirecting national effort towards energy efficiency by focusing on potential sources such local materials and involving all stakeholders. Moreover, the policy implementation must be prioritized and monitored by all ministries, government agencies such as professional bodies charged with energy efficient buildings in Nigeria. The re-structural approach required drastic awareness of ministries, government agencies, and media to expatiate on the values of affordable and clean energy in Nigeria.

3. Drivers of changes in Energy Efficiency and Zero-carbon Technologies

3.1 Financial incentive from Federal Government of Nigeria (FGN)

Financial incentive is the phenomena that driving the growth of every sector for substantial development, previous study of Zhang X [20], revealed that financial incentives provide both efficient and effective tools for improving the building energy consumption and environmental protection situation. The FGN makes provision of the monetary budget for energy production and supply for over a decade, but the implementation has become the greatest challenge in the country due to corruption in the system. According to the Minister of Works and Power of Nigeria stated “that the problem of unreliability of power supply were due to insufficient and inefficient power generating capacities which constitutes a huge drain on the national economy despite the financial support”[14].

3.2 Policies incentive of FGN with related Professional Bodies

Energy Efficiency policies have been successfully driving the recent growth of Zero-carbon Technologies in developed countries. Policymakers can provide a system of appraisal in order to stimulate the diffusion of Energy efficiency [21]. Helena Chum et al., [12] assessment report on energy that additional enabling policies are needed to address issues associated with the Zero-carbon Technology into future energy systems. The Nigerian Energy Support Programme [8] supported in developing an energy efficiency policy with an energy efficiency action plan as the implementation mechanism. The policy outlines target activities such as developing building energy codes and guidelines. According to Mlecnik E [22], “that it is difficult to indicate the right combination of policy instruments since this will vary for different countries and regions”. The policy are targeted at underlining the trajectory dynamics between clean energy efficiency and socio-economic growth with sustainable development goals in Nigeria.

Federal Government of Nigeria (FGN) has enacted a number of key energy efficiency policies to guide and direct the development of energy efficiency in the country. The umbrella policy for energy development in Nigeria is the National Energy Policy (NEP) enacted in 2003 [23] while the policy is aimed at highlighting the relationship dynamics between energy and socio-economic growth and sustainable development in Nigeria. The professional bodies need to streamlined their policies with FGN policies to work in harmony and achieved common goals. The Environmental Policy, Energy Building code and power distribution in Nigeria remain dismally low despite the FGN commitment: enactment, execution, and monitoring and week institutional framework policy. Most recently, the Senate passed a bill to most professional bodies to relate to contemporary issues of sustainable development goals in their practices and global challenges. Several polices regarding sustainable built environments were tabled out into ACTs of each professional body to ensure desirable goals in the country.

3.3 Population growth.

In 2019, the estimated population of Nigeria is over 200.96 million, ranking 7th in the world[24]. The previous statistic carried out in 2012 by the Nigeria National Bureau of Statistics, the total population of citizens in Nigeria was around 166.2 million people. The population growth is not in harmony with the techno-economic values as socio-economic factors to ensemble in sustainable development. Moreover, the population growth adds pressure to these drivers, having increased 85%
from 1990 to 2014. The INDC also describes Nigeria’s target to reduce GHG emissions by 45% by 2030, conditioned upon receipt of international support[10]. The crucial measures to accomplish this higher target would be increased energy efficiency and knowingly reducing the use of generators[25] while providing access to energy for all Nigerians. According to Batagarawa A[26], fewer than half of Nigeria’s population has access to national grid-connected electricity. The electric power supply is grossly inefficient and has limited industrial development that led to decline techno-economic factors.

4. Research Milieu.
The major practices of Nigerian professional architects’ praxis within the notable fast developing states in Nigeria, which include Abuja, Lagos, Port Harcourt, Kano, Kaduna and Cross River states. These states posit the contemporary challenges in their cities by ensuring stringent policies were followed to certain degrees, to meet up with sustainable development goals and objectives. To explore the extent of practices, the need to determine the number of registered architects in the country. According to Nigeria institutes of architects [27] there are 12,860 registered architects all over the country with a few practicing in the above-mentioned states. By adopting krejcie R.V & Morgan D.W [28], sample techniques to determining the appropriate sample for the study. The Internet questionnaires were adopted and dispatch via various flat forms of professional bodies, social network and e-mails. A few respondents of 437 questionnaires were retrieved both from the internet and hand-to-hand dispatched for the study.

5. Research Methodology.
The main sources of data were the secondary method such as journals, conference/seminar/workshop papers, textbooks, magazines and the internet were used to review literature for energy efficiency and use of Zero-Carbon Technologies within Nigeria’s context. A formulation of the 5-point Likert scale questionnaire survey (as the primary source of data) was administered to professional and practicing Architects randomly in the country. The Mean item score and Chi square-test statistics was use for data analyses.

6. Results and Discussion.

6.1 Respondents Profile.

| Questionnaire | Frequency | %   |
|---------------|-----------|-----|
| Returned      | 437       | 87.4|
| Non-returned  | 63        | 12.6|
| In-complete   | 0         |     |
| Total         | 500       |     |

Source: Researcher’s field of Study 2019

From the above table 1, it clearly indicates that the overall response from the large population is acceptable with 87.4% of positive response and 12.6% of non-returned.
Table 2. Business categories of respondents.

| Categories of Respondents based on Practice | Frequency | %  |
|--------------------------------------------|-----------|----|
| Academic/Researcher's Architects            | 137       | 31 |
| Architects in Governments agencies/parastatals/ministries | 61       | 13 |
| Consultants Architects                      | 108       | 27 |
| Contractor's Architects                     | 96        | 21 |
| Freelancing Architects                      | 35        | 8  |

Source: Researcher’s field of Study 2019

Table 3. Respondent’s Years of Experience.

| Years of Experiences | Frequency | %  |
|----------------------|-----------|----|
| Less than 5 years    | 27        | 6.2|
| 10-15 years          | 216       | 49.4|
| 15-20 years          | 119       | 27.2|
| 20 years above       | 75        | 17.2|

Source: Research’s field of study 2019.

The highest participants of the survey were 31% of Architects in academic/researchers, with marginal difference of 4% to Consultant’s Architects. This depicted that the key main respondents were more acquainted with the subject of study in their practices. It was recorded that the contractor’s architects level of conversant is 21%. There was a shot fall with architects in government agency/ministries of 13%. Hence, 8% was recorded for freelancing architects from the above study which is the lowest. The level of experiences of respondents in practices have a significant role of acquaintance with subject of study, 10-15 years and 15-20 years understood the significant of energy efficiency in our built environment with 49.4% and 27.2% respectively. The graduates with less than 5 years experiences recorded 6.2% as least of the subject of study, while 17.2% was next thereof, through architects with above 20 years of experience.

Nonetheless, the respondents with highest years of experiences tally with the major key states of practices where remarkable infrastructural developments were observed in the built environment. From the table 4 below, Abuja with Lagos recorded 33.63% and 26.32% respectively as the foremost key states of practices. However, Kano and Port Harcourt have relatively same percentages with the fractional difference of 0.47%, which signifies the level of development with knowledge of the subject of study. Kaduna state was rate the third with 13% while Cross River was recorded 2% with the least of practice.
Table 4. Respondent’s Key States of Practice

| Key States of Practices | Frequency | %  |
|-------------------------|-----------|----|
| Abuja                   | 147       | 33.63 |
| Kano                    | 39        | 8.93  |
| Kaduna                  | 57        | 13.05 |
| Cross River             | 9         | 2.05  |
| Lagos                   | 115       | 26.32 |
| Port Harcourt           | 37        | 8.46  |
| others                  | 33        | 7.56  |

Source: Researcher’s field of study 2019

Table 5. Barriers and Drivers of Energy Efficiency.

| s/n | Barriers and Drivers of Energy Efficiency | Strongly Agreed | Agreed | Neutral | Disagreed | Strongly Disagree | Weighted Average Or Mean Item Score | Remark | Ranking |
|-----|------------------------------------------|-----------------|--------|---------|-----------|-------------------|-------------------------------------|--------|---------|
| 1   | Lack of simple funding mechanism to boost Energy Efficiency | 212             | 126    | 57      | 23        | 19                | 4.16                                | Agreed | 3rd     |
| 2   | Lack of specialized skill in building industry | 175             | 183    | 20      | 47        | 12                | 4.08                                | Agreed | 4th     |
| 3   | Inadequate policies for Energy Efficiency | 91              | 198    | 78      | 57        | 13                | 3.71                                | Agreed | 8th     |
| 4   | Lack of Political will in government | 219             | 187    | 7       | 15        | 9                 | 4.38                                | Agreed | 2nd     |
| 5   | Lack of requisite knowledge of Energy Efficiency | 203             | 106    | 8       | 103       | 17                | 3.90                                | Agreed | 6th     |
| 6   | Absence of Energy Efficiency Building Code | 89              | 103    | 98      | 68        | 79                | 3.31                                | Neutral | 9th     |
| 7   | Perception of novel technology in constructions | 183             | 132    | 12      | 73        | 37                | 3.89                                | Agreed | 7th     |
| 8   | Socio-economic, techno-economic and cultural barriers | 296             | 108    | 17      | 9         | 7                 | 4.57                                | S. Agreed | 1st     |
| 9   | Difficulty in measuring environment performance in an objective ways | 145             | 187    | 57      | 35        | 13                | 3.98                                | Agreed | 5th     |
| 10  | Inadequate supply of materials for energy Efficiency and ZET | 67              | 103    | 87      | 169       | 11                | 3.13                                | Neutral | 10th    |

Source: Researcher’s field of study 2019.

The hypotheses formulated for this research work was tested using chi-square Statistics, the formula is shown below. The values of the item scores in table 5 above were used as the data for the statistical computations with the result as shown in the table 6.
Level of Significance= 5%, df = degree of freedom. $f_o = \text{Observed value, } f_e= \text{expected value, } \chi^2 = \text{Chi-square}$

\[
df = (c-1) (r-1) \tag{1}
\]

\[
\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e} \tag{2}
\]

**Table 6. Chi-Square Cal and Chi-square tab.**

| Number of row | Level of Significance | df | $\chi^2$ Cal | $\chi^2$ tab$_{0.05, 36}$ |
|---------------|-----------------------|----|--------------|---------------------------|
| 10            | 5%                    | 36 | 3694.9       | 50.998                    |

From the table above, with 36 degrees of freedom (df) and 5% level of significance, the Chi-square tabulated ($\chi^2_{\text{tab}, 0.05, 36} = 50.99$) is lower than the Chi-square calculated ($\chi^2_{\text{cal}} = 3694.9$). Therefore, the Null hypothesis is rejected: which put forward that there are drivers with barriers that restricted the architects espousal of affordable and clean energy efficiency, and the use of Zero-carbon Technologies in Nigeria’s built environment.

### 7. Conclusion

Further attestation of Chi-square statistic established the alternative hypothesis of the research: that there were drivers with barriers which restricted the architects’ espousal of affordable and clean energy efficiency, and the use of Zero-carbon Technologies in Nigeria’s built environment. However, to subdue the predicaments of adopting clean energy efficient built environment in Nigeria from the study: The perceived barriers which were socio-economic, techno-economic and cultural impediments rate ranked first, whereas lack of political will in government became the second challenge. Although lack of simple funding mechanism to boost energy efficiency in Nigeria was the third raking which tight down the first ranking as a driver to affordable energy. Lack of knowledge among architects and system providers to incorporate energy efficiency is another major barrier. Moreover, energy efficiency in buildings is not taught as a part of the curriculum in most schools of architecture [29]. These are the major issues that hinder successful implantation of affordable and clean energy in Nigeria. With the aid of design strategies for new buildings to have the greatest impact on building energy efficiency [2] and use of Zero-Carbo Technologies, substantial saving of 2.9-30 Gt Co2 shall reduce carbon footprint in Nigerian built environment.

Energy efficiency for a sustainable built environment in Nigeria is possible by engaging the right stakeholders in all ramifications to ensure adoption of energy efficiency concepts. In addition, the successful implementation of energy efficiency concept and the use ZCT will stimulate the knowledge development, information diffusion networks such as technological hubs, clusters, and centres to promote future investments in the technological base of the country. Hence, these will reduce the nation’s dependence on fossil fuels thereby decreasing the high rate of oil spills and environmental degradation. However, these are the future prospects of implementing energy efficient built environment in the country, with the adoption of these prospects; Nigeria shall meet up with sustainable development goals agenda.
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