Passive house in Nigerian context: *Barriers and Prospects of Sustainable Energy Efficiency in Office Buildings*

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Abstract— **Office buildings are substantial users of energy and materials in construction industries which give off greenhouse emissions (GHG). Energy efficiency is essential capstone of buildings to be consider as factor for improving the performance of a green building design that profound the occupants with a comfortable, safe, healthy and environment. The study tends to enlighten the potential of passivhaus concept as energy saving prospective in office buildings within the Nigerian context. Reviewed literatures were studied to identify the various concepts of passivhaus in public buildings with the view to develop an insight on energy efficient building. A questionnaire survey was administered within the construction industry: actors of major cities of building industry and academic institutions were involved. The results showed the major factors hindering passivhaus developments and practices in the Nigeria's built environment. Nonetheless, this will require the adoption of passivhaus pedagogy in recurrent academic literature and in practice. This study also concluded by highlighting the future prospects of Passivhaus development in Nigeria's building industries and academic institutions in other to improve energy efficiency in Nigeria building industry.**

Keywords. Energy, Efficiency; Green Building; Office buildings; Passivhaus; Sustainability.

I. Introduction.

Nowadays, office buildings are substantial users of energy and materials in construction industries, which give off greenhouse emissions (GHG). Energy efficiency is essential capstone of a building to be consider as factor for improving the performance of a green building design that profound the occupants with a comfortable, safe, and healthy environment. Energy efficiency has become the key driver of sustainable development in many economies in the world[1]. There are high tendency to design and construct buildings with light envelops and energy efficient envelope that will reduce the rate of energy consumption in the built environment.

Most developed countries in Europe and United stated have adopted the concept of passive house into their building industry as such they were able to cut down energy consumption, improved well-being of the occupants as well as reducing carbon foot print.

Residential and commercial buildings are thus significant consumers of energy and are one of the major producers of greenhouse gases (GHGs) globally. These brought the shift in building industry to embrace energy efficient buildings as way onward.

Passive housing (PH) is the implementation of certain technological innovations such as better insulation, air-tightness and heat recovery ventilation, which drastically lower the energy demand of a building. The utilization of the German 'Passivhaus Standard' has grown rapidly in recent years[2]. The concept and the technology is suitable for all climate types, however the specifics do need to match the climate in which it is implemented [3].

The word Passive house is sometime use as Passivhaus which literally means same. There is no difference between the definitions of "Passive House" and "Passivhaus", though the latter is the phrase commonly used in Germany which is closely associated with the Passivhaus Institut [4]. According to Schnieders [5]and Hermelink a passive house is "a building which assure(s) a comfortable indoor climate in summer and in winter without needing a conventional heat distribution system [6].

The study tends to enlighten the potential, awareness of passivhaus concept as energy saving prospective in office buildings within the Nigerian context: amongst actors, end-users, construction companies, and policy stakeholders. Nigerian climate suits the features of passive house to operate effectively within the region. The Building Energy Efficiency Guideline for Nigeria was commissioned by the Federal Ministry of Lands, Housing and Urban Development, Abuja Nigeria with support from Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH, UN Habitat and the European Union under the Nigerian Energy Support Programme (NESP). It aims to give practical advice to professionals in Nigeria on how to design, construct and operate more Energy Efficient Building [7].

Taking the advantage of tropical climate of Nigeria with the predicament of epileptic energy supply in public, residential and commercial buildings: The Passive house can reliable delivers up to approximately a 90% reduction in heating and cooling demand and up to a 75% reduction of the overall primary energy demand when compared to existing building stock [8]. The first passive house project in Nigeria was Chevron PIND office project is an Energy Efficient office complex designed by Yorkshire Consult and project managed by Sustainable Building Concept [9]. Substantial energy balance was achieved in this regards. The development of energy efficiency standards is likely to ensure that Nigeria has more access to electricity at lower cost[10].

An important factor of a Passivhaus is that they do not conform to any one design style; therefore Passivhaus can either be of traditional, or a more contemporary design[11]. The importance of Passive House and the equivalent standards of low energy building design should not be underestimated. Pitts,[4] added that the best low energy designs not only produce reductions in energy costs but also offer occupants the potential for higher quality environments and more stable and controlled levels of thermal comfort . One of the main goals of this study is to enlighten the potential of passivhaus concept as consideration to energy performance and sustainability to the earlier stages of building design process and to create awareness in academic literatures.

A. *Hypothesis.*

The hypothesis was formulated for this study was to ascertain the goals, using chi square statistical tool to test the hypothesis.

- Null hypothesis(Ho). There are no barriers/hindrances that deter the prospects of sustainable energy efficiency for office buildings in Nigeria using passive house Concept.
- Alternative hypothesis (HA). There are barriers/hindrances that deter the prospects of sustainable energy efficiency for office building in Nigeria using Passive house concept.

II.LITERATURE REVIEW.

Passive House is a design and performance standard initially devised in Europe in the 1980s by Wolfgang Feist from Germany and Bo Adamson from Sweden. A prototype exemplar was produced in 1991 and the Passivhaus Institut was established in 1996, both linked to the development of design guidance and an exacting standard for building performance. Buildings certified under the standard are assumed to have a strong likelihood of exhibiting very low energy demand evidenced by the evaluation against technical specifications and performance testing[4].

The success that followed the reduced energy and high comfort levels in the first projects encouraged the spread of the standard to different parts of Europe. The Cost Efficient Passive Houses as European Standards (CEPHEUS) [12] and Passive-On projects were carried out in different countries across Europe, including Italy, UK, Spain, Switzerland, Austria, Sweden, Portugal, Germany and France[13]. Buildings certified under the standard are assumed to have a strong likelihood of exhibiting very low energy demand evidenced by the evaluation against technical specifications and performance testing. Key parameters include energy use per unit floor area and air-tightness[4].

The standard requires adherence to specific criteria; most notably annual maximum space heating requirements of 150kWh/m2, maximum annual primary energy of 120kWh/m2, utilization of Mechanical Ventilation with Heat Recovery (MVHR) and an air tightness (n50) of less than 0.6h-1 [13].

A. Passivhaus Planning Package (PHPP)

The Passive House Planning Package (PHPP) is an Excel based energy calculation tool. It is based around the same core energy calculation methods used throughout Europe. It is produced by the Passivhaus Institut as a design tool to model the performance of a proposed Passivhaus building [11]. The Passivhaus Planning Package (PHPP) is the principle design tool for Passivhaus buildings. As a steady-state predictive model, it is unable to consider the full implications of thermal bypass mechanisms [13].The PHPP is intended for use by anyone involved in the design of a Passivhaus, and a Passivhaus must be modelled by using the PHPP to verify that the Passivhaus criteria have been met.

B.Why Passive House?

Passive House as compared to other Environmental Assessment systems has a narrow but rigorous method. It is simple, flexible and easily adaptable to the local environmental situation in Nigeria and elsewhere [9]. NY Passive house,[8] established the following reason for passive house:

a. It fundamentally addresses the climate imperative.
b. It is also a global building energy performance standard acceptable
c. It developed a global collaboration and produces a predictable product.
d. It is affordable for both construction and occupancy,
e. It is a catalyst for local manufacture of high performance product enable storm resilience,
f. It enables nearly zero energy building
g. It enables a more resilient power grid and it locks in energy saving for future generation.

III.Buildings and Energy Use in Nigeria.

The Intergovernmental Panel on Climate Change (IPCC) has frequently signaled in its reports the importance associated with reducing energy demand in buildings [14]. The energy consumption must be based on the assumption that the building operates within ASHRAE-thermal comfort zone, during the cooling and heating periods [15]. Most of the buildings incorporate energy efficient passive cooling, solar control,photovoltaics, lighting and day lighting, and integrated energy systems adopted in Europe and USA[16].

It has been established that fossil fuels accounts for 94% of exports from Nigeria in 2006 with only a small fraction of this available for domestic use and about 40% of households connected to the national electricity grid[17]. Office buildings consume 40% portion of total energy globally and in Nigeria[19]. Within the buildings, energy consumption of up to 36% is related to the type of materials making up the fabric[20]. Much more energy were used to meet up the comfort of the occupants/enduser of such buildings in Nigeria.

IV.GAP IN CURRENT APPROACH IN ARCHITECTURAL DESIGN OF ENERGY EFFICIENT BUILDING.

The performance gap between “as designed” and “as built” is increasingly well evidenced [21]. Recent research has identified unintended consequences of energy efficient dwellings for installed technology, building fabric an ultimately occupant health and wellbeing[22].

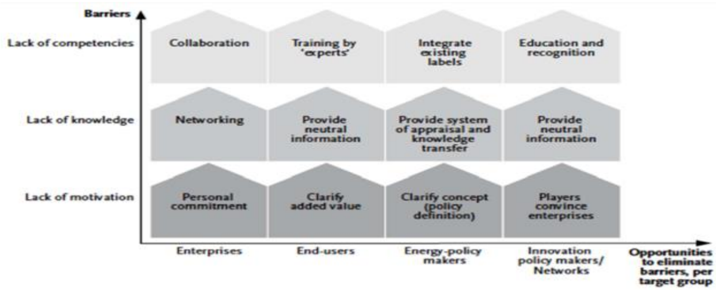
The design of energy efficient buildings is beyond the skills and expertise of only architects therefore, the integrated design process becomes an essential tool for the effective in corporation of expertise across different disciplines[15].In Nigeria, the cardinal predicament of getting High Performance Building into building industry is the designers hesitation into new innovative technology without the in depth knowledge of design and practices [23]. It is also a challenging task of architects and other building professionals today is to design and promote low energy buildings in a cost effective and environmentally responsive way[16] Integrated design process can be used to bridge the gap in conventional design [7].

V.SUSTAINABLE ENERGY EFFICIENT PRACTICES IN NIGERIA.

The issues of sustainability are often neglected in design or expected to be someone else’s responsibility [24]. The energy performance aspects are often not assessed before the detailed building design has been decided [25]. The neglect of sustainability issues during the early building design process is not only embedded within the application of building regulations and sustainable building codes[26]. Nonetheless, Nigeria recently embraced the Building Energy Efficiency guide line in 2016 and in 2017 National Building Energy Efficiency Code was put in place. Professional bodies in Nigerian building industry have taken a giant step towards ensuring energy efficient building were enlighten by series of conferences, workshops, colloquium and seminars.

Architects Registration Council of Nigeria (ARCON) describes activities involved in the design and construction process, from appraising the client’s requirements through to post construction for low energy buildings and measures were taken to ascertain energy efficiency [27].This would go a long way in reducing carbon footprint and improving living standard of occupants/end-users. Nigeria has the potential to assent passive house due to it peculiar challenges and prospects towards reduction of greenhouse gas emission.

Passive and low energy architecture has been proposed and investigated in different locations of the world design guides and handbooks were produced for promoting energy efficient buildings [27].Policy makers can provide a system of appraisal in order to stimulate the diffusion of passive house [29]. According to Mlecni [6] that it is difficult to indicate the right combination of policy instruments, since this will vary for different countries and region. He further develops an integrated approach to eliminate adopting barriers for high energy efficient building as showed in figured 2 below.



Source: Mlecnik’s Approach for eliminating adoption barrier,2013.

VI . METHODOLOGY.

This study involves the review of various literatures from secondary data such as journals, conference/seminar/workshop paper, and magazine and internet sources. However, a 5-point Likert scale questionnaire survey were administered to professionals in Nigerian building industry. Moreover, the mean item score and chi-square-test statistic were used for data analysis.

VI.DATA PRESENTATION, ANALYSIS AND RESULTS.

The table below shows the respondents by their various professional disciplines which were obtained through primary data of questionnaires distributed in Nigeria’s Built Environment. However, equal numbers of questionnaires were distributed to professional disciplines.

Table1. Questionnaires (Qns.) responses by the various Professionals.

S/N	Professional disciplines	Nr.of Qns Distributed	Nr. Of Qns returned	Percentage (%) Total returned Qns. per discipline
1	Architects	50	43	8.60
2	Civil Engineers	50	37	7.40
3	Building Engineers	50	31	6.20
4	Electrical Engineers	50	39	7.80
5	Mechanical Engineer	50	37	7.40
6	Quantity Surveyor	50	29	5.80
7	Estate Surveyor	50	23	4.60
8	Project Managers	50	42	8.40
9	Town planner	50	21	4.20
10	Land Surveyor	50	17	3.40
	Total	500	319	63.8

Sources: Researcher's Field work.

As beheld above, all the professionals were administered equal number of questionnaires (50nr) each. The total number of questionnaire distributed were 500 numbers while 319 questionnaires were returned. The response rate at 63.8% was worth acceptable for a progression. The Architects have the highest response rates with 8.60%, followed by Project managers with 8.40% while the land surveyor and town planner have the least of 4.2% and 3.4% respectively.

The perception of various professional in built environments was determine based on the structured Likert Scale provided (Strongly Agree (SA)=5, Agree(A)=4,Neutral(N)=3,Disagree(D)=2,Strongly Disagree=1) as showed in the table below.

The mean item score also known as the weighted average score is computed for each determining factor using the below formula:

$$\text{Mean Item Score (MIS)} = \frac{5(SA)+4(A)+3(N)+2(DA)+1(SDA)}{N} \quad (1)$$

Table 2. Assessments of determinant factors for Passive house: Barriers and Prospects in Nigeria.

S/N	Passive house: Barriers and Prospects	Strongly Agreed	Agreed	Neutral	Disagreed	Strongly Disagree	WEIGHTED AVERAGE OR MEAN ITEM SCORE	REMARK	Ranking
		5	4	3	2	1			
1	Lack of design expertise on passive house	186	142	64	120	29	3.67	Agreed	7th
2	Inadequate knowledge and technical Know how	175	183	103	45	35	3.84	Agreed	4th
3	lack of adoptable GB rating tools	145	168	84	110	34	3.58	Agreed	9th
4	Enduser purchasing power/spending will	182	177	63	88	31	3.78	Agreed	6th
5	Client Budget	203	147	97	77	17	3.85	Agreed	3rd
6	Accessibility of local materials	207	177	79	61	17	3.95	Agreed	2nd
7	Perception of novel technology in constructions.	157	183	47	98	56	3.63	Agreed	8th
8	Scio-economic,techno-economic and cultural barriers	176	184	73	87	21	3.79	Agreed	5th
9	Perception of novelty concept of PH	275	173	57	17	19	4.27	Agreed	1st
10	Lack of political will in government	121	141	89	179	11	3.36	Agreed	10th

Sources: Researcher Statistical Computation.

From table 2 above, observations and deductions were arranged: First, the novelty concept of Passive house has the major hindrance to development of energy efficient building in Nigerian context was raked 1st as determinant factor. Moreover, lack of accessibility of local materials was ranked 2nd as stumbling block to energy efficient building as well as Client budget is also a prevailing factor that was ranked 3rd. It was equally observed that inadequate knowledge and technical know-how was ranked 4th.This depict the major constraints in Nigerian built environments for sustainable energy efficient buildings. Nevertheless, Lack of adoptable GB rating tool and lack of political will in government was ranked 9th and 10th respectively thus, these were perpetuating malady in built environment.

A. Testing of hypotheses.

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 2 above were used as the data for the statistical computations with the result as shown in the table 3.

Level of Significance= 5%, df = degree of freedom.

f_o =Observed value, f_e= expected value,x^2=Chi-square.

$$\chi^2 = \sum \frac{(f_0 - f_e)^2}{f_e} \quad (2)$$

Table 3. Chi-Square Statistical Computation results.

		Level of Significance	df	x² Cal	x² tab 0.05,36
Number of row	10				
		5%	36	1047.9	50.998
Number of Column	5				

Based on the above computation of 36 degree of freedom (df) and 5% level of significance, the chi-square calculated ($x^2 Cal$=1047.9) which is greater than Chi-sequare tabulated ($x^2\ tab_{0.05,36}$=50.998).This ascertain the room for alternative hypothesis as accepted evidence: There are barriers/hindrances that deter the prospects of sustainable energy efficiency for office building in Nigeria using Passive house concept.

VIII. Conclusion.

This research provide an outlook to consider the suitability of Passive house buildings as the way forward for energy efficiency buildings in Nigeria. In Nigeria, the built Environment needed to embark on low energy efficient buildings. However, the study identify ten major factors that significantly determined the physibility of passive house standard in Nigeria's built environment. The results attested that there are barriers/hindrances that deter the prospects of sustainable energy efficiency for office building in Nigeria using Passive house concept. Furthermore, to enhance sustainable practice of energy efficient buildings, all hands must be on deck with stringent measures to subdue such guidelines into world of energy efficient buildings.

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