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Assessment of Compliance to Building Energy Efficiency Strategies in the Development of Housing Estates in FCC, Abuja Nigeria

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Abstract

Compliance to local energy efficiency strategies can significantly reduce energy consumption in buildings and promote sustainability. However, Nigeria Building Energy Efficiency Code (BEEC) seems to be just paper work without enforcement or compliance. Assessment of Compliance to Green Building Energy Efficiency Strategies in the Development of Housing Estates in FCC, Abuja Nigeria was carried out. The compliance of estate buildings to BEEC in the study area was assessed; and the aspects of the building energy efficiency strategies with more compliance were determined. Data were mainly from primary sources such as questionnaire survey, interview with key informants and observation. The study population included all estate developers and building construction professionals. Data were gathered from one hundred and fifty (150) building professionals through questionnaire administration. Data collected were analysed using Z score and ANOVA and presented in tables. Results show that only 18% of respondents agreed that building complied with BEEC, and the Z score for positive affirmation is below average score. There is a significant difference in the integration of different energy efficient management strategies in the estates' construction at 95% confidence level. The integration of measures such as window to wall ratio and window shading' were significantly higher than other BEEC strategies such as roof insulation and minimal air condition unit (≤EER/COP of 2.8). Thus, the development of estates in FCC Abuja did not achieve energy efficiency.

Keywords

Energy Efficiency, Estate, Green Building, Compliance, Housing

1. Introduction

The current practice is to design, construct and use buildings in an energy efficient manner. Though the practice of Green Building (GB) started way back in the 70s during the energy crisis in the United States, it slowed down at a point but the recent climate change and its associated challenges are promoting the concept recently. An energy efficient building is designed and implemented to minimise energy demand by taking advantage of nature Abugu *et al.* [1]. Energy efficiency of building can be achieved by some notable techniques such as proper building orientation, window-to-wall ratio, use of inverter air conditioning and local climate roofing and other building materials [2] [3] [4] [5]. Abugu, *et al.* [1] stated that energy efficient building has become a major interest of environmentalist and building professionals towards sustainable development.

Yüksek and Karadayi [6] stated that creating an energy efficient building starts with the right design approach, considering the specific microclimate conditions of the site, orientation and shaping the building form, a conscious selection of building materials and envelope systems aiming to minimise building heat gains. Oyebode [7] advised that when lighting a green house, the first consideration to be made is day lighting, this is done based on the design, position, siting, and angle of the house, this allows sunlight into the house during the day. Consequently, eliminate the need for artificial lights during the day, then at night solar powered energy saving bulbs can be used to ensure low energy consumption for lighting features Sangeetha *et al.* [8].

Another technique is the use of motion sensitive lights which automatically trip off in the absence of movement of people and trip on when someone walks in. The use of dimmers to reduce the intensity of light has also been recommended Save on Energy [8]. Energy saving also involves the use of light bulbs examples: Compact Fluorescent Lamps (CFLs), and Light-emitting Diodes (LEDs) Eartheasy [9]. According to Backer *et al.* [10], there are a lot of great translucent insulating building products which will allow you to let light into your home without letting heat in or out. You can maximize the light in a given room by choosing light colours and reflective materials for your walls, ceiling and floor. Backer *et al.* [10] recommended the following hierarchy of steps to achieve energy efficiency of building:

1) Minimise energy demand: Through climate adaptive design (passive design) taking into account local conditions and microclimates

2) Increase efficiency of systems: Improving mechanical systems, appliances and lighting efficiency

3) Cover remaining energy demand with renewable energy: Given the large renewable energy capacity of the country, use renewable energy sources to substitute fossil fuel energy whenever possible.

To Herie [11], the main strategies for achieving substantial energy demand reduction while maintaining and even increasing human comfort are based on the following: 1) Bioclimatic architectural design to reduce energy demand. Bioclimatic design refers to architectural building design that seeks to optimize its performance by adapting the design to the local climate and achieve a more resource efficient building. 2) Planning energy efficient mechanical systems based on low demand. Alongside bioclimatic measures, active systems such as air conditioning may be required to guarantee the comfort of occupants. In keeping with the objective to be resource-efficient, energy efficient systems and appliances should be adopted where required. 3) Covering the remaining energy demand (partly) by renewable energies. Once demand has been reduced by passive design and the necessary mechanical systems have been designed and selected to optimise their performance and efficiency, then renewable energy generation can add even more building performance.

Increasing energy demand and a decrease in available energy are leading to mandatory energy efficiency strategies in every sector globally (United Nations Industrial Development Organization (UNIDO) and Renewable Energy and Energy Efficiency Partnership (REEEP) [12]. Therefore, adopting appropriate energy efficiency strategies can significantly reduce energy consumption in buildings. This has led to numerous mechanisms and policies proposed and implemented, especially in developed countries towards an energy conscious building development Mclennan and Jason, 2004 [13]. To achieve energy efficiency in buildings and other sectors, appropriate decisions, strategies and efforts are necessary by all stakeholders. Nigeria currently does not have a legalized building code but promotes the adoption of Building Energy Efficiency Code (BEEC) published in 2017.

Unfortunately, it seems that the adoption is low and researchers have not paid adequate attention to compliance to energy efficiency strategies of estate buildings in FCC, Abuja. Thus, the purpose of this study was find out whether building professionals in FCC, Abuja Nigeria have complied to BEEC in estate housing construction in FCC, Abuja, Nigeria. Thus, this study in its objectives assessed compliance of estate buildings to BEEC in the study area; and then, determines which aspects of the building energy efficiency aspects were achieved. Thus, it answered the following research questions: what is the level of compliance of estate buildings to BEEC in the study area? And which among the different energy efficient management strategies complied most with the BEEC? A Null hypothesis (Ho): "there is no significant difference in compliance to different energy efficient management strategies in the estates' construction at 95% confidence level was tested.

2. Materials and Methods

2.1. The Study Area

The study area Federal Capital City (FCC) Abuja is located within the Federal capital territory (FCT), which itself covers an area of around 8000 km^2, the FCT is positioned between latitude 7˚25' and 9˚20'N of Equator and longitude 5˚45' and 7˚39'W of the Greenwich Meridian. The Federal Capital Territory Abuja is located at the centre of Nigeria. It is bounded on the north by Kaduna State, on the west by Niger State (**Figure 1**).

Abuja has witnessed a huge influx of people into the city; the growth has led to the emergence of satellite towns, such as Karu Urban Area, Suleja, Gwagwalada, Lugbe, Kuje and smaller settlements towards which the planned city is sprawling. The city has a large and growing immigrant community comprising mainly of nationals from the ECOWAS sub-region. This rapid population growth created demand for mass housing in the FCC. However, mass housing requires a lot of energy and need to comply with Building Energy Efficiency Code to adapt to climate change and be sustainable.

2.2. Methodology

This study adopted survey design for data collection. Both primary and secondary sources of data were used. Data were mainly from primary sources such as questionnaire survey, interview with key informants and observation. The study population included all estate developers and building construction professional/experts (engineers, architects, town planners, builders) in the FCC. These set of people were purposely selected based on their direct involvement on the estate construction. The sample frame is nineteen thousand eight hundred and sixty

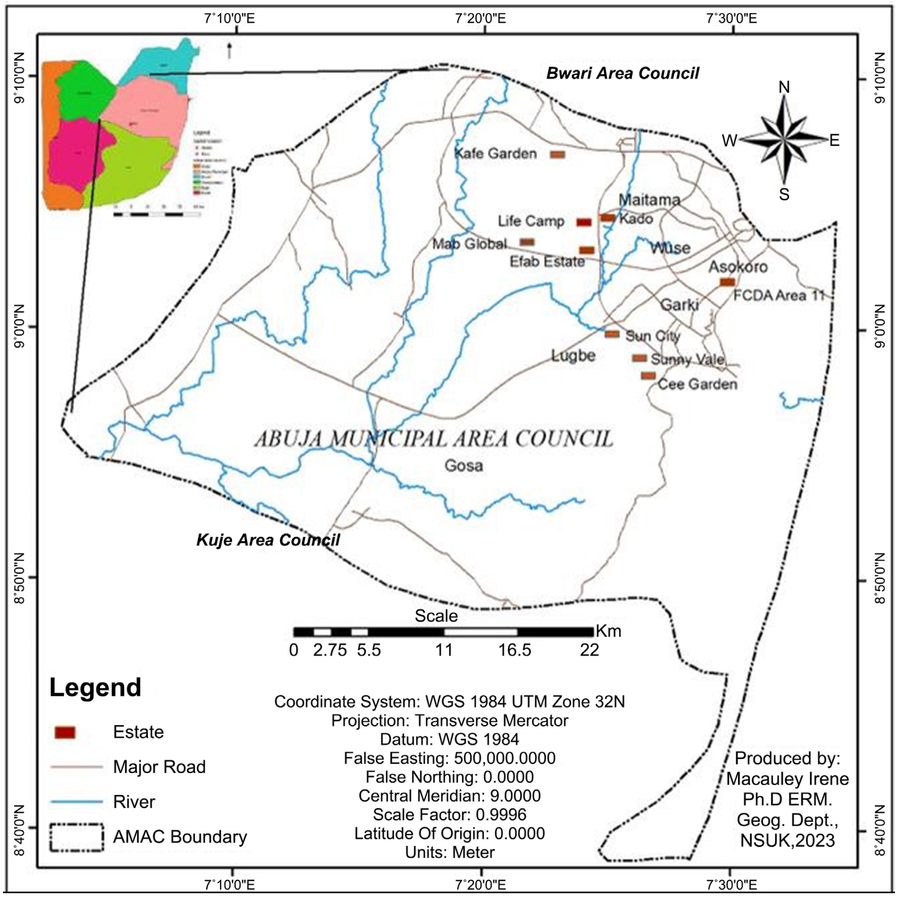

Figure 1. The study area.

(19,860) people. The estimate was based on number of registered persons in their various professional bodies in Abuja. Though, the target population is the building professionals and developers other stake holders like Government Agencies in charge of estate development and occupants of the estates were consulted for interview.

Sample size of one hundred and fifty (150) people was calculated using sample size calculator by Geopoll online at Easycalculation.com available at https://www.geopoll.com/blog/sample-size-research/ as follows: Confidence Interval 7.95 and Confidence Level 95% and population 19860. Thus, one hundred and fifty (150) building professional were contacted for questionnaire administration. The distribution of samples among the building professionals were based on number of people in each profession (Table 1).

Stratified and simple random sampling techniques were used to select samples. Firstly, samples were stratified into different professions (engineers, architects, builders, town planners and developers) to allow equal representations and reduce bias. Then, simple random technique was used to select respondents from the list of their professional body within the FCC. Data collected were analysed using Z score and ANOVA and presented in tables.

3. Results and Discussions.

The result for the energy efficiency strategies of buildings used in the construction of housing estates in the FCC, Abuja to Achieve Sustainability is presented in Table 2.

Table 2 shows the result for the energy efficiency strategies of buildings used in the construction of housing estates in the FCC, Abuja to achieve sustainability in line with BEEC as follows: In general, that 18% ± 9.57% agreed that energy efficiency strategies of buildings were used in construction of the housing estates in the FCC, Abuja to achieve sustainability, 43.45% ± 18.55% disagreed while 38.56%± 20.84% were unaware. Moreover, the Z-scores for those that agreed, disagreed and unaware of the integration of energy efficiency strategies are −4.12, 0.65 and 0.58 respectively. The Z-scores for those that agreed, disagreed and

Table 1. Sample size for questionnaire administration.

S/NO	Profession	Population Size	Sample size	%
1	Civil Engineer	2554	23	15.37
2	Electrical Engineer	2595	23	15.62
3	Mechanical Engineer	1275	12	7.67
4	Architects	4953	37	24.67
5	Builders	2245	17	11.33
6	Town Planners	3654	28	18.66
7	Developers	1360	10	6.67
Total		**19,860**	**150**	**100**

Table 2. Compliance to energy efficiency strategies in the development of housing estates in FCC Abuja.

BEEC Standard	Agreed	Disagreed	Unaware
	%	%	%
Window to wall ratio did not exceed 20%	32	26.67	41.33
Windows are adequately shaded where window to wall ratio of was not achieved 20%	26.67	67.33	6
Lighting power did not exceed 6 W/m^2	18	27.33	54.67
Air condition unit have minimum of EER/COP of 2.8	11.33	48	40.67
Roofs are insulated	12.67	62.67	24.66
All roof construction included a layer of insulation of thermal resistant not less 1.25 m^2/K/W(R-Value)	7.33	28.67	64
Mean (μ)	**18**	**43.45**	**38.56**
Standard Deviation (σ)	**9.57**	**18.55**	**20.84**
Z-score	**−4.12**	**0.65**	**0.58**

unaware of the compliance to energy efficiency strategies being −4.12, 0.65 and 0.58 respectively imply that those that agreed on the integration of energy efficiency strategies in the construction of the housing estates is below average score while those that disagreed or unaware scored above average.

This result suggests that the level of compliance to BEEC is low. Therefore, energy efficiency was not achieved in the mass construction of the housing estates. It also portrays low awareness of respondents on the compliance of energy efficiency strategies in the estates construction. This result agree with Geissler, *et al.* [14] which have pointed out poor energy efficiency of estates in Nigeria and blame it on some limitations of the BEEC. According to Geissler *et al.* [14], the code must put emphasis on climate adaptive design and must define requirements and procedures in a clear and simple way to allow for effective enforcement. Only then can energy-efficient mass housing be feasible in Nigeria. It also aligned with GamalEldine and Corvacho [15] who posited that building energy codes application and effectiveness are still limited in developing countries despite that it is considered to be an effective policy tool for energy reduction worldwide. The result also corroborate Abugu, *et al.* [1] which reported that scope and principles of Green Building Concept are well documented but compliance is still a contending issue in Nigeria.

However, the standard deviation for those that agreed, disagreed and unaware being ±9.57, ±18.55 and ±20.84 respectively suggest disparity on the various energy efficiency strategies (window to wall ratio, window shading, Lighting, Air Condition (AC) and roof insulation). The results also exhibit high variations on the affirmation of the various energy efficient management strategies by respondents. It shows for instance that 94.67% agreed on the utilization of high efficiency fixtures but 0% agreed on both the installation of water metre and collection of water data. Thus, ANOVA was used to test for the significant of the mean variations (Table 3). Table 3 presents the ANOVA result for the affirmations of the compliance to building energy efficient management strategies.

Decision:

Since the calculated F value of 2.78 is greater than the critical F value of 2.21, H_o "There is no significant difference in compliance to different energy efficient management strategies in the estates' construction at 95% confidence level is rejected. Thus, there is a significant difference in the integration of different energy efficient management strategies in the estates' construction at 95% confidence level. Therefore, integration of measures such as Window to wall ratio and window shading' were significantly higher than other Building Energy Efficiency Code (BEEC) strategies such as Roof insulation and minimal Air condition unit (≤EER/COP of 2.8).

3.1. Window to Wall Ratio (W to WR)

Result in table shows that only 32% agreed that "window to wall ratio did not exceed 20%", a good number (26.67%) disagreed and majority 41.33% were unaware. This indicated poor awareness and integration of BEEC in terms of W to WR. This result suggests that Energy efficiency was not achieved in the construction of housing estates in the FCC, Abuja in terms of W to WR despite that building's window-to-wall ratio (WWR) plays a significant role for predicting energy consumption in tropical climate. As huge amount of solar heat gain occurs through the exterior windows for having high solar radiation intensity and annual average temperature in tropical climatic regions Pathirana *et al.* [16].

The implication is that occupants will need artificial lighting and air condition to feel comfortable at home. This comes with environmental cost especially where the lighting energy source is not renewable. Marino *et al.* [17] have demonstrated that among the considered factors (window-to-floor ratio, shading transmittance, glazing type, space aspect ratio, etc.), window-to-wall ratio has a great influence on useful daylight illuminance and annual heating and cooling. The window-to-wall ratio of not more than 20% should be integrated in new building to offset the effect of poor indoor air quality to resident and promote a healthier and more sustainable living environment in the study area.

3.2. Window Shading

Result shows that only 26.67% of respondents agreed that "windows are adequately

Table 3. ANOVA result for compliance to energy efficient management strategies.

Source of Variation	Sum of Squares	Degree of Freedom	Mean SS	F Ratio
Between Group	152.12	5	20.53	
Within Group	201.34	5	7.38	2.78
Total	**353.46**	**10**		

Calculated F = 2.78, F-table at 0.05 = 2.21, Critical F = 2.21.

shaded where window to wall ratio of 20% was not achieved", 67.33% disagreed while the remaining 6% were unaware. This implies that majority of building professionals disagreed that "windows are adequately shaded where window to wall ratio of was not achieved 20%". Thus, window shading has not been fully adopted to achieve energy efficiency of estate buildings in the study area. There are still windows that are not shaded despite that different style of window glazing, coverings and external shading have been adopted to make windows more energy efficient. Shaded and non-shaded windows were also observed during the site visitation of estates in the study area (Plates 1-4).

Plate 1. Shaded window at Sunrise Estate. Source: Field Work, 2023.

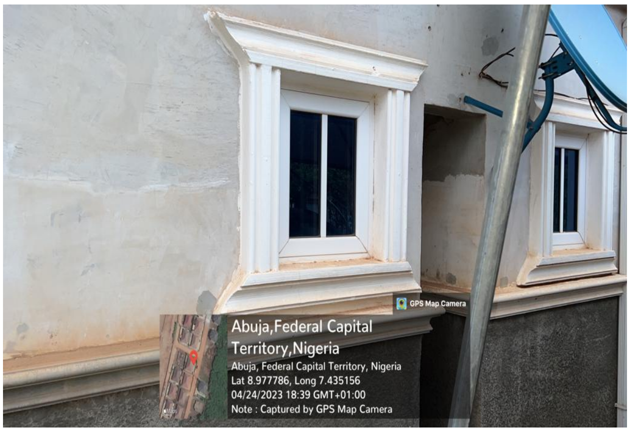

Plate 2. Shaded window at Pent Estate. Source: Field Work, 2023.

Plate 3. Non-shaded window at Sunrise Estate. Source: Field Work, 2021.

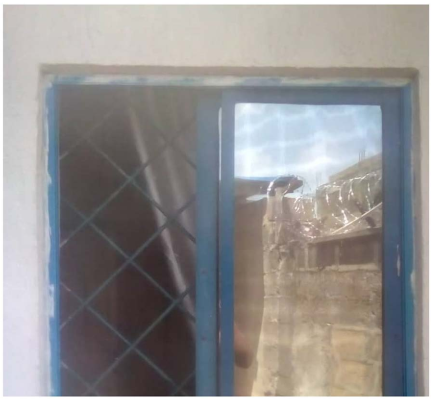

Plate 4. Non-shaded window at CEE Garden. Source: Field Work, 2021.

Lighting and Air Condition

Result in **Table 2** shows that only 18% of respondents agreed that "lighting power did not exceed 6 W/m^2", 27.33% disagreed while majority 54.67% were unaware. Moreover, interview with residents of estates in the study area shows that electricity serve as indoor day-lighting for majority, as 70% - 90% of respondents accepted that they put on electricity during the day. Respondents (estate occupants) where asked of their indoor day-lighting energy sources, an overwhelming number of the respondents interviewed held the strong position that fossil fuel energy sources like generator are used for indoor day-lighting in the study area. Minority of residents also uses solar panel.

All respondents (100%) also use electricity from hydro power but decline on the use of biofuel and nuclear energy for lighting. This indicates poor energy efficient building in the estates. It shows that energy efficiency sources such as biofuel, wind energy and nuclear energy are yet to be utilized in the study area. Direct solar energy and solar panel can be effectively used for day-lighting in the study area based on the tropical location of the study area. Previous studies showed that "day-lighting through side windows is the most common and the most effective method to bring daylight for illuminating the building interior in the tropics Tanachaikhan, [18].

Moreover, Biofuel can also be produced from the household waste for lighting if properly planned and implemented. Qureshi, [19] pointed that one of the most important renewable or clean energy that needs to be incorporated into Green Buildings is biogas. Respondents (estate occupants) were asked of the type of electric bulb they use at home. The responses portray ill fate for the achievement of energy efficient buildings in the study area. Though, majority use energy efficient bulb like LEDs and Compact Fluorescent Light (CFL) many stated that they use incandescent bulbs. The reason for the use of inefficient bulb at homes cannot be far from the fact that incandescent bulbs are currently being produced in Nigeria despite that energy efficient bulb like LEDs and CFL can be produced in Nigeria says Engr John a stakeholder consulted at the Depart of Development Control FCT Abuja. Switching to energy-efficient lighting is one of the fastest ways to achieve energy efficiency and cut energy bills.

3.3. Air Condition

Result in **Table 2** shows that only 11.33% of respondents agreed that "Air condition unit have minimum of EER/COP of 2.8", 48% disagreed while the remaining 40.67% were unaware. This suggests poor awareness and integration of GBC. Moreover, interview with residents of estates in the study area shows that very few are using inverter AC. This might be connected to the fact that it is only in recent years that inverter technology has become commonplace in many household appliances Real Living Team [20]. Real Living Team [20] have explained that inverter technology works like a car accelerator: it controls the speed of the compressor motor and in turn decreases or increases power consumption in response to the cooling demand (*i.e.* at night or if there are less people in the room), regulating the temperature and thus making it more energy-efficient. The switch to inverter-type ACs can save the residents of the estates energy in the long run.

However, it is not yet common in the study area, as majority (98%) still use non-inverter AC in their homes. Attempts to encourage residents to switch to inverter AC were fraught by economic reasons. Residents explained that until there is need for additional AC or damage of the available non-inverter. Some even argued that changing to non-inverter will lead to wastage. A resident of EFAB estate MR John Udom raised concerned on possible electronic waste generation that will follow such action. He explained that he can only switch, if his current non-inverter AC can be converted to inverter AC. Thus, this study agreed with [20], as it can be said that the adoption of inverter AC is low as the technology is new compare to the non-inverter AC.

3.4. Roof Insulation

Result in **Table 2** shows that only 12.67% of respondents agreed that roofs are insulated in the study area; majority (62.67%) disagreed while the remaining 24.66% were unaware. Moreover, only 7.33% agreed that "all roof construction included a layer of insulation of thermal resistant not less 1.25 $m^2/K/W$ (R-Value)"

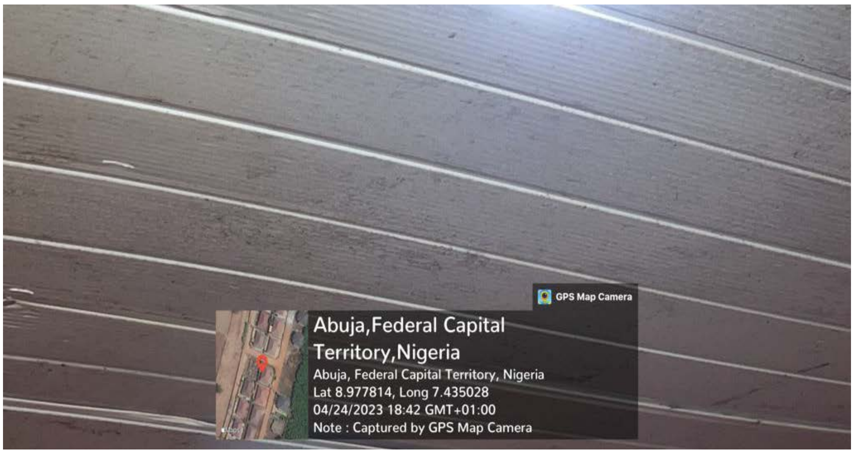

Plate 5. Polyvinyl chloride (PVC) ceiling used in Sunrise Estate. Source: Field Work, 2023.

Plate 6. Plaster of Paris (P.o.P) ceiling used in Efab Estate. Source: Field Work, 2023.

28.67% disagreed while majority (64%) were unaware. This suggests poor awareness and integration of roof insulation in the study area. Interview with occupants of the estates shows that ceiling in form of {Plaster of Paris (P.o.P), Plywood and Isorel (Masonite)} were the only form of thermal insulations used in the study area (Plate 5, Plate 6). The use of roof insulation is more effective in thermal reduction than a mere use of ceiling as practiced in the study area compared to the modern roof insulations. Interview with Development Control Department staff also indicated that roof insulation is not common in the study area and that roof vents are yet to circulate in the study area. Roof vent provide an unobstructed exit for the heat, hot air, odors and moisture trapped in your attic just as car exhaust does to the car.

4. Conclusion and Recommendations

The development of estates in FCC Abuja did not achieve energy efficiency. The Building Energy Efficiency Code (BEEC) which currently serves as Nigeria's energy efficiency guide wasn't complied with, as only 18% of respondents agreed that buildings in the estates in FCC complied with BEEEC. There is a significant difference in the integration of different energy efficient management strategies in the estates' construction at a 95% confidence level. The integration of measures such as window-to-wall ratio and window shading' were significantly higher than other BEEC strategies such as roof insulation and minimal air condition unit (≤EER/COP of 2.8).

The following recommendations were made based on the finding of the study:

- There is a need for urgent retrofitting of the FCC estates buildings. Developers should retrofit windows and improve solar energy while occupants should retrofit bulbs and AC. LED and CFL bulbs should replace incandescent bulbs while older AC should be replaced by inverter AC that requires less energy.
- Developers should ensure that new buildings comply with the Building Energy Efficiency Code.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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