

An Assessment of Residential Buildings to Identify Strategies Towards Building Sustainability

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Abstract: The aim of this study is to identify strategies for a sustainable residential building. Building sustainability can simply be described as the ease of using a building with little or no cost over a period of performance and efficiency. Sustainable Architecture is a path to elongating the dilapidating process of a structure. Architectural sustainability is still in its infancy in many countries. Therefore, there is a need to establish possible innovations and strategies in the collaborative design and construction of sustainable buildings. This research conducted a review of established sustainable strategies and recommended the most effective and efficient strategies for the tropics. Hence, this study evaluates the degree to which residential buildings adhere to sustainable design principles. Buildings were assessed based on their use of appliances, passive/bioclimate factors, and renewable energy technologies. This was accomplished using a quantitative analysis in addition to a descriptive approach to the data gathered. In order to assess differing measures on potential sustainable techniques and technologies that can be used in residential buildings, related literature was reviewed to identify strategies towards building sustainability. The study goes on to emphasize the significance of energy balance in buildings and concludes that developers and clients are not sufficiently informed about passive design strategies, consequently a higher reliance (of 50.4%) on appliances to compensate for the inefficient residential designs.

Keywords: Buildings, Efficiency, Performance, Sustainability, Tropics

1. Introduction

The need to block out the heat and cool off interior spaces is constant in the tropics. As a result, residents in residential structures employ a variety of measures to obtain the desired thermal comfort. Among these, there are sustainability issues as it relates to lighting, ventilation, etc. which can be attributed to poor sustainable design strategies. The utilisation of natural aspects of the environment to complement the constructed environment is necessary to make home designs and living arrangements sustainable. Ortiz et al. (2010) defined a sustainable project as one that uses resources economically and sustainably while being developed, constructed, restored, operated, or reused [15].

Humidity and air temperature are some of the most pressing issues facing most buildings especially residential complexes which are caused by insufficient insulation to attain the required thermal comfort within each respective season [7]. The majority of residential buildings in tropical regions

struggle with poor lighting, poor ventilation, high humidity, and excessive heating throughout the majority of the year. Appliances like air conditioners and lighting fixtures, which have a significantly low electrical demand, must be employed in order to make residential buildings sustainable. Owing to the fact that electricity is inadequate in most developing countries, there is the need to seek alternative sources of power supply for example, using generators whose emissions will raise the concentration of CO₂. Hence, there is a need to suggest sustainable design strategies for residential buildings.

2. Literature Review

Sustainability is a complex concept that has expanded to be the major issue of the built environment. Sustainability simply involves enhancing the quality of life by allowing people to live in an ideal environment with optimized social, economic, and environmental conditions [14].

According to Bodewig (2001), the most basic

understanding of sustainable architecture strives to optimize the usage of energy and resources for all stages of the life span of a building – from the conceptual stage through construction, usage, and finally to demolition [3]. In other words, the goal of Sustainable Architecture is to make the usability of structures, most especially buildings more efficient, effective, and affordable. Therefore, a building must benefit from a wide range of factors that need to be considered throughout the life cycle of the building. According to Lenzen and Treloar (2002), the precise quantity of energy used throughout the life cycle of a building material, from the manufacturing process to the use of building materials after their end of life, can have a variety of effects on the flow of greenhouse gases (GHGs) to the atmosphere throughout time [11].

Since the extraction and processing of resources use a significant amount of resources and energy and result in waste creation, there has been a great deal of interest in and debate about the notion of sustainability, focused mostly on the reduction of construction materials. Since fundamental environmental factors are not taken into account, using energy-efficient appliances and equipment alone is thought to be insufficient [4].

Uher (2003) established that buildings contribute significantly to environmental troubles, and Levin (1997) reported on the following distributions: use of raw materials (30%), energy (42%), water (25%) land (12%), and pollution emissions such as atmospheric emissions (40%), water effluents (20%), solid waste (25%) and other releases (13%) [17, 12]. Therefore, sustainably built buildings perform better than business-as-usual buildings. Fowler and Rauch (2008) carried out an investigation on Federal Buildings designed with an energy conservation approach and showed that they saved 25 to 30% more energy than similar commercial buildings [5].

Design decisions require a good sense of construction strategies in residential buildings, building materials, and building components which are usually accompanied by imperfections in investment through an inadequate economic control of decisions [6]. Therefore, it is necessary for every building project to have a sustainable design framework throughout the life span of the building.

It is predicted that by the year 2056, global economic activity will have increased five times; the global population will have increased by over 50%, while global energy consumption will increase almost thrice and global manufacturing activity may have increased at least thrice [13, 9]. Their consumption can be largely cut back through improving efficiency, which is an effective means to lessen greenhouse gas emissions and slow down the depletion of non-renewable energy resources [10]. Therefore, to achieve a sustainably built environment, Asif et al. (2007) suggested the adoption of multiple design strategies such as energy saving, best use of materials, material waste minimization, pollution and emissions control, etc. [2]. It is evident that the most effective strategy for building sustainability lies in the building orientation, configuration, and fabrics. Hill and Bowen (1997) stated that to reduce waste, building

sustainability starts with the design phase and continues through the building's life to its deconstruction and recycling [8].

3. Methodology

This research carried out a study on residential buildings in Ekpoma of Esan West Local Government, Edo state. This study assesses the level of residential building compliance with sustainable design strategies. Buildings were evaluated based on their adoption of renewable energy technologies, appliances, and passive/bioclimate considerations. This was done through a descriptive method of data analysis. Related literature was reviewed in order to obtain divergent approaches to possible sustainable strategies and technologies that can be adopted in residential buildings. The research went further to highlight the importance of energy balancing in buildings. Materials such as books, related literature and resources, journals, and articles were used to provide useful information.

An Assessment on the Level of Compliance With Sustainable Design Strategies

In order to ascertain the level of compliance of residential buildings to sustainable design strategies using Ekpoma - Esan West Local Government as a case study, an assessment was carried out in major districts. The assessment was done by selecting one major street in selected wards as shown in Table 1.

Table 1 shows a survey of the distribution of plot sizes of residential buildings in major streets of the various wards. It shows different neighbourhoods and their plot sizes which range from 30 m × 15 m to 30 m × 30 m. It can be observed that Ukpenu had the lowest number of plots (14) for residential buildings and Eguare had the highest number at 24 plots for residential development. Most residential buildings in the communities were not designed and built using sustainable design strategies.

For the purpose of this assessment, design strategies will be categorised under three major headings using the cost-benefit analysis pyramid.

The cost-benefit pyramid indicates the cost implications of three major categories of strategies that can be adopted in a building to improve building performance (Figure 1). Renewable Energy Technologies (RETs) involve the adoption of active strategies to enhance a building's performance, such as photovoltaic panels and technologically advanced, typically expensive equipment. The cost of low-energy appliances is moderate. The most effective and economical are passive/bioclimate strategies (PBC) such as building orientation/fabrics (Table 2).

Table 2 shows the compliance level of buildings to sustainable design strategies under the cost-benefit analysis grouping. One building was however discovered to have adopted some passive design strategies in its bioclimate considerations. This building was seen at the premises of The Cathedral of St. Andrew Esan Diocese, Eguare, Ekpoma, Edo state.

It can be seen from Figure 2 that the building has a lot of

shading devices around and wide eaves to shed off the sun and wind-driven rain. The building fabrics consist of pressurized clay for the walls, which are about 350 mm thick to reduce heat conductivity so the interior is relatively cool most of the time. There are a considerable number of openings and windows for natural ventilation and daylighting. The building's damp proof course (DPC) is significantly high and given a good treatment with a clay floor covered with a floor

finish. The roof is pitched high and ventilated to reduce solar heat gain into the building interior. The ground around the building is covered with grass and vegetation to absorb the heat from the sun and reduce solar reflection. These strategies put together increased the performance of the building and made the building more efficient and cost-effective for users as the occupants would not need to spend so much on cooling, ventilation and lighting.

Table 1. Distribution of plot size by neighbourhood.

Neighbourhood	Size and number of plots				Total
	Below 30m X 15m	30m X 15m	30m X 30m	Above 30m X 30m	
Ujoelen	6(26%)	12(52.2%)	3(13.0%)	2(8.7%)	23(100.0%)
Eguare	4(16.7%)	12(52.2%)	14(58.3%)	-	24(100.0%)
Ukpenu	-	9(64.3%)	3(21.0%)	2(14.3%)	14(100.0%)
Idumebo	6(40.0%)	9(60.0%)	-	-	15(100.0%)
Ihumudum	-	-	7(70.0%)	3(30.0%)	15(100.0%)
Emaudo	-	1(5.0%)	20(95.0%)	-	21(100.0%)
Ujemen	-	7(46.6%)	7(46.6%)	1(6.7%)	15(100.0%)
Total	16(12.6%)	50(39.4%)	54(42.5%)	16(12.6%)	127(100.0%)

Source: (Field survey, 2018).

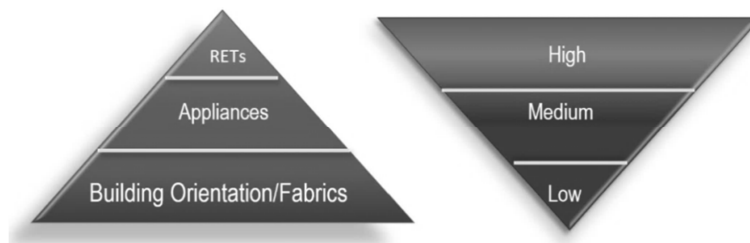


Figure 1. The cost-benefit pyramid.



Figure 2. Residential passive building in the compound of The Cathedral of St. Andrew Esan Diocese, Eguare, Ekpoma, Edo state (Source: Field survey, 2018).

Table 2. The compliance level of buildings to sustainable design strategies under the cost-benefit pyramid grouping.

Neighbourhood	RETs (Buildings)	Appliances (Buildings)	PBC (Buildings)
Ujoelen	3	15	5
Eguare	8	12	4
Ukpenu	7	5	2
Idumebo	6	6	3
Ihumudum	5	7	3
Emaudo	4	11	6
Ujemen	6	8	1
Total	39 (30.7%)	64 (50.4%)	24 (18.9%)

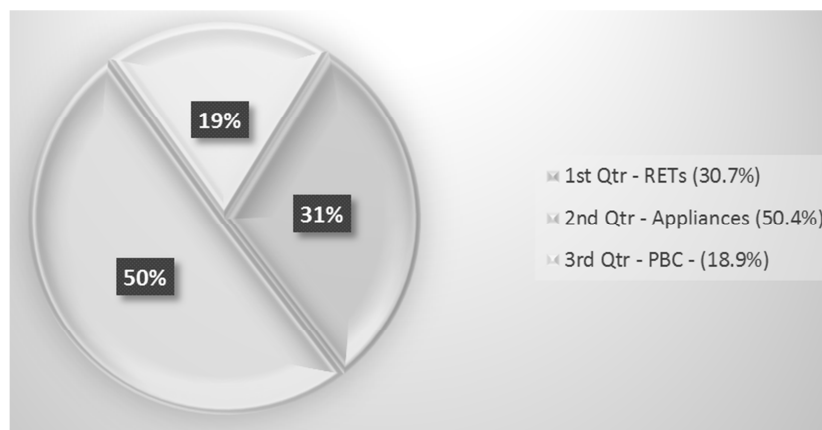


Figure 3. Pie chart showing the distribution of compliance with sustainable design strategies under the cost-benefit pyramid grouping.

From Table 2, it can be seen that the sampled households made use of appliances (50.4%) more than other strategies in an attempt to compensate for poor passive design strategies. A few employed the use of RETs (30.7%) such as solar panels and inverters etc. due to the high cost. On the other hand, very few adopted PBC (18.9%) strategies since many developers know little or nothing about bioclimatic considerations in the area (Figure 3).

4. Recommendations and Conclusion

In the design and execution of a residential building, it is very important that the well-being (health and comfort) of the occupants is taken into consideration. This is an important aspect in assessing the quality of life of the residents. In recent times most people spend more time indoors since it is built to be a resting place where individuals spend more than 90% of their time indoors and above 70% of their time at home - indoors [16, 1]. The prerogative of Architecture is to provide occupants with an efficient, effective, and safe place for good health, comfort, physiological satisfaction, and productivity.

This assessment conducted in the study area clearly showed that developers and clients are not sufficiently informed about passive design and, consequently a higher reliance (of 50.4%) on appliances to compensate for the inefficient design. Hence, there is a need to educate and create awareness of bio-climatic considerations. This concept is significant for the assessment of buildings in terms of building performance.

Esan West Local Government is in the tropics; consequently, energy balancing in buildings should be a major consideration which must balance human needs with the incorporation of the natural and built environments. Therefore, it is of great essence that sustainable design strategies are implemented during the construction of buildings. The materiality of building components needs to be considered during the design phase, such materials should be susceptible to circular economy principles. Buildings should be designed to foster the health and comfort of the occupants through their life cycle, supporting social activities and enhancing productivity.

Below are some sustainable design strategies that can possibly be adopted in tropical regions.

4.1. Bio-Climatic Considerations (Passive Design)

This approach is the most efficient and advised way to create a sustainable and energy-efficient home. This method bases all design decisions on the site's natural features in order to maximise building performance. A thorough survey of the area is done, and pertinent data on the site and its climatic conditions are gathered for analysis. Orientation, natural ventilation, building envelope, wind directions, humidity, solstice, daylighting, thermal mass, thermal comfort, building elevation, acoustic performance, building insulation, topography, functionality, thermal bridging, aesthetics, and building coloration, are a few examples of possible factors to consider. It is clear that all significant building characteristics are chosen during the design phase. As a result, the building should profit from a variety of passive housing techniques that are both affordable and effective.

4.2. Appliances

Another sustainable building strategy is the use of energy-saving equipment, albeit this is typically done to make up for poor passive design considerations. It involves using appliances, such as HVAC (Heating, Ventilating, and Air Conditioning) systems, to light, ventilate, dehumidify, cool, or heat an area. The majority of the appliances used in this situation typically have a low energy rating, such as expensive energy-saving lamps, inverted air conditioners, and air handling units.

4.3. Renewable Energy Technologies (RETs)

These are active systems towards sustainability, although they are typically highly expensive. They include utilising technology and systems like photovoltaic panels, wind turbines, hydropower turbines, etc. These measures are typically expensive ventures that may not be ideal on a modest scale.

As a result, it is essential that passive design principles be used from the beginning of a building design and construction. Thermal comfort in buildings is a crucial factor in occupant satisfaction and productivity. Another crucial factor to take into account when designing a home is the acoustics of the

structure. At the same time, it's imperative to maximise daylighting to cut down on lighting costs, which can also result in better ventilation. When a building's functionality is compromised, its performance may not be sustainable; in residential buildings, functionality is a crucial component of space usage that should be taken into account while keeping in mind the building's aesthetic features.

References

- [1] Adgate JL, Ramachandran G, Pratt GC, Waller LA, Sexton K (2002). Spatial and temporal variability in outdoor, indoor, and personal PM_{2.5} exposure. *Atmos. Environ.* 36: 3255–3265.
- [2] Asif M, Muneer T, Kelly R (2007). Life cycle assessment: A case study of a dwelling home in Scotland. *Build. Environ.* 42: 1391–1394.
- [3] Bodewig Kurt (2001). “Guideline for Sustainable Building”, *Federal Ministry of Transport, Building, and Housing*, January, pp. 01.
- [4] Boyle CA (2005). Sustainable buildings, *Proceedings of the Institution of Civil Engineers Engineering Sustainability*, 158 March, Issue ES1, pp. 41–48.
- [5] Fowler KM, Rauch EM (2008). Assessing green building performance: a post occupancy evaluation of 12 GSA Buildings, Pacific Northwest National Laboratory Report number PNNL-17393.
- [6] Giudice F, La Rosa G, Risitano A (2005) Materials selection in the Life-Cycle Design process: A method to integrate mechanical and environmental performances in optimal choice. *Mater. Des.* 26: 9–20.
- [7] Hariwan N, Zebari Rojhat K, Ibrahim (2016) Methods & Strategies for Sustainable Architecture in Kurdistan Region, Iraq, *Procedia Environmental Sciences*. 34: 202–211.
- [8] Hill RC, Bowen PA (1997). Sustainable construction: Principles and a framework for attainment. *Construct. Manag. Econ.* 15: 223–239.
- [9] Ilha MSO, Oliveira LH, Gonçalves OM (2009). Environmental assessment of residential buildings with an emphasis on water conservation. *Build. Serv. Eng. Res. Technol.* 30: 15–26.
- [10] Lee WL, Chen H (2008) Benchmarking Hong Kong and China energy codes for residential buildings, *Energy Build.* 40: 1628–1636.
- [11] Lenzen M, Treloar GJ (2002). Embodied energy in buildings: Wood *versus* concrete-reply to Borjesson and Gustavsson. *Energy Policy*. 30: 249–244.
- [12] Levin H (1997). Systematic evaluation and assessment of building environmental performance (ASEABEP). *Proceedings of the 2nd International Conference on Buildings and the Environment, CSTB and CIB*, 2, Paris, pp. 3–10.
- [13] Matthews E, Amann C, Fischer-Kowalski M, Huttler W, Kleijn R, Moriguchi Y, Ottke C, Rodenburg E, Rogich D, Schandl H, Schutz H, van der Voet E, Weisz H (2009). *The Weight of Nations: Material Outflows from Industrial Economies*; World Resources Institute: Washington, DC, USA, 2000; Available online: http://pdf.wri.org/weight_of_nations.
- [14] Ortiz O, Castells F, Sonnemann G (2009). Sustainability in the construction industry: A review of recent developments based on LCA *Constr. Build. Mater.* 23: 28–39.
- [15] Ortiz O, Pasqualino JC, Castells F (2010). Environmental performance of construction waste: Comparing three scenarios from a case study in Catalonia, Spain. *Waste Manag.* 30: 646–654.
- [16] Sev A (2009). How can the construction industry contribute to sustainable development? A conceptual framework. *Sustain. Dev.* 17: 161–173.
- [17] Uher TE (2003). Absolute Indicators of Sustainable Construction. RICS Research Foundation, Royal Institution of Chartered Surveyors, London, available at <http://www.rics.org.uk/>