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Retrofitting and Greening Existing Buildings: Strategies for Energy Conservation, Resource Management and Sustainability of the Built Environment in Nigeria

Retrofitting and Greening Existing Buildings: Strategies for Energy Conservation, Resource Management and Sustainability of the Built Environment in Nigeria

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Energy consumption in residential buildings is one of the increasing phenomenal in the built environment. It has become imperative to react to the state of rapidly dwindling natural resources, environmental pressures and climate change posing fundamental threat to economic systems and human survival in Nigeria and globally. Until fairly recently, green considerations for existing residential buildings have received less attention. In Nigeria, thousands of households of low income buildings spends large sums of their earnings on energy bills, while getting less energy-driven services for their appliances and utilities to meet their needs. This paper explores possible alternatives for less dependence on national energy supply with more environmental benefits through sustainable retrofit and resource-efficiency interventions for low-income houses. The objective is to address issues relating to energy generation, conservation and other associated resource management with a view to achieving the development of a low carbon and more eco-friendly built environment. It is expected that the outcome of this paper will make an important contribution in the form of recommendations for future policies and programmes regarding retrofitting of existing residential houses and the construction of new ones in Nigeria. It concludes that if policies and regulatory mechanism are put in place for greening low-income housing in Nigeria, this could deliver a pathway to improving energy efficiency of the existing building sector.

KEYWORDS: Energy conservation, Low income houses, Retrofitting, Greening, Sustainability.

Introduction

Globally, it is acknowledged that there is need to devote much attention to how buildings are designed and constructed to reduce their energy consumption. A major issue arising from the concern about climate change is the reduction of energy use in residential buildings. Presently, it is estimated that nearly half of million tonnes of CO_2 emissions each year is attributed to energy use by residential buildings. Given that globally by 2050, the number of households is projected to increase by 67 percent, this make the residential sector a significant area that requires more attention. However, while the reductions in greenhouse gas emissions from residential sector is considered critically important; efforts geared towards achieving this is still inadequate to meet the required level of reductions predicted by climate change experts to prevent catastrophic cli-

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mate change. This brings to fore the need for greater attention to be accorded to existing building stock most especially residential buildings.

In the 2030 challenge, the American Institute of Architects (AIA) along with U.S. Green Building Council advocated that new construction of residential and commercial buildings should use half the fossil fuel of average existing buildings and a gradual increase in performance of the existing buildings so that by 2030 new buildings are carbon-neutral. Meanwhile, achieving the gradual increase in energy performance of existing residential buildings would require leading-edge energy retrofits. Presently, in Nigeria several thousands of housing units for the low income group are designed and constructed with little or no regard for low energy use and other 'green' design considerations. Thus, high levels of additional energy are required to keep the houses cool in the hot season months.

In Nigeria, the energy inefficiency of the existing housing stock result to the demand for more energy to reach comfortable temperatures. Most times, the required indoor comfort levels cannot be reached without considerable expenditure on energy. Hence, Nigeria is faced with the reality that requires retrofitting and greening strategies for vast majority of existing houses that provides less adequate internal comfort to reduce their environment burden.

Aim and Objectives

This paper aims is to explore the avenues for potential retrofit in Nigeria existing residential buildings. The specific objectives include; (i) to identify areas where retrofits measures can be applied to low income houses with a view to reducing their energy consumption through major renovations; (2) to identity the green features that can be retrofitted into existing residential buildings for efficient energy utilization and conservation; and (3) to highlight the challenges several dividends accruable from green buildings.

Methodological Approach

The methodology is based on secondary data collection approach which includes a comprehensive assessment and analysis of scientific literature from Google Scholar, Science direct Scopus and Web of Science. Relevant materials were consulted from refereed journal articles, government reports, books, theses and research reports to achieve the purpose of the paper. Other methods include literature search with the aid of the use of keywords altered according to the database searched. In general, the major keywords searched revolved around: (1) some policy instruments on greening of low income housing; (2) analytical framework towards selecting, evaluating and examining best practice case studies of greening low income housing projects; and (3) examining different promising areas.

In addition, some bibliographies were reviewed using Scopus, Web of Science, and Google Scholar for possible additional materials relevant to the topic. Consequently, the paper is organized as follows: Concept of green retrofits are presented along with examples of global efforts in retrofits of existing buildings. This is followed by energy conservation and management strategies suitable to promote greening existing buildings. Implementation challenges associated to retrofitting for energy savings in existing low income houses are evaluated. Finally, recommendations and suggestions are proffered for possible realisations of energy conservation and management for sustainability of low-Income houses.

Theoretical Framework

The Concept of Green retrofits and Global efforts on existing buildings

Green retrofits involve the upgrade of an existing building either wholly or partially occupied to improve energy and environmental performance, reduce water use, and improve the comfort and quality of the space in terms of natural light, air quality, and noise. It can be equally simple as putting in new heating, ventilating, and air-cooling parts, mounting solar panels on a ceiling. According Ma *et al.* (2012) greening existing buildings is one of the primary approaches to achieving sustainability in the built environment at relatively low cost and high consumption rates. Although there is a broad range of retrofit technologies readily available, methods to identify the most cost-effective retrofit measures for special projects is still a major technological challenge.

Across the world, several attempts have been made in developed countries like the US, Australia and UK towards improving energy efficiency of existing buildings. These attempts include approaches such as provision of policy guidance, financial and technical support to implement energy efficiency measures. Likewise, a substantial number of works by numerous authors (Asadi et al., 2012; Flourentzou and Roulet, 2002; Goli *et al.,* 2011) have been carried out to explore energy efficiency through diverse avenues directed for improved performance in energy use of existing residential houses.

Cohen *et al.* (1991) investigated saving energy and efficiency in cost retrofit options of individual single family buildings and analysed metered energy consumption with the real cost of installation. The author's findings indicated that insulating ceilings and walls are cost effective retrofit and window replacement a feasible retrofit option but has a result of smaller normalised annual energy saving (of between 2–5 percent. Gorgolewski (1995) produced a method to optimise renovation strategies for housing retrofit by adopting a life cycle cost approach to evaluate and compare performance of different retrofit measures. The outcomes indicated that the paybacks are higher than the entire retrofit measures.

Goldman *et al.* (1998) reported findings from their studies on the retrofit of US multifamily buildings. The authors' results were based on analysing data that were measured and obtained from a record of different apartments. It was found that it cost much less to retrofit a fuel-heat buildings when compared to electric-heat buildings with the payback periods for the two buildings indicating six (6) and twenty to twenty five (20–25) years respectively. Al-Ragom (2003) examined residential buildings retrofit in hot and arid climates the study revealed that significant energy reduction is achievable if the cost of implementing the retrofit cost was supported fully by the government.

Alanne (2004) performed an analysis of a Finnish apartment and tested the applicability and functionality of a multi-criteria 'knapsack' model proposed by the author. The model was developed to aid in the selection of the most viable renovation actions in the conceptual phase of a renovation project. Mahlia *et al.* (2005) used annualised costs and cash flow in calculating the economic impact of lighting retrofits in residential sector in Malaysia. The authors presented the cost–benefit analysis and emission reduction of lighting retrofits. Their findings indicated that in the retrofit of efficient lighting systems, cost–benefit was a determinant factor for saving energy.

A different method undertaken by Zavadskas *et al.* (2008) was adopted to know the effectiveness of retrofitting houses on the basis of expected energy savings and increase in the worth of refurbished buildings in the market. The study found that choosing retrofit situations depends on strategic urban development programmes, renovation cost, heating energy saving and expected increment of market value. Dodoo *et al.* (2010) evaluated the implication of primary energy through life cycle assessment in the retrofit of a four-storey apartment building to the standard of a passive house. The results showed that reduction in final energy use was achieved, although the primary energy is still determined by the type of energy supply system used.

Bin and Parker (2012) observed the environmental performance of a century home and compared its original and after retrofit environmental footprint. The findings indicated through renovation, energy performance of existing buildings' can be enhanced and be made environmentally sustainable sound. Additionally, research on existing non-residential buildings by several other scholars such as Hestnes and Kofoed, (2002); Chidiac *et al*. (2011); and Ardente *et al*. (2011) showed significant reduction in the use of energy from existing buildings is achievable through appropriate retrofit or renovation defined by Flourentzou and Roulet (2002) as the work that require upgrading an existing old building.

In Africa, a few demonstrated pilot projects carried out in South Africa shows both economic and societal benefits of more sustainable design in low-income housing. The greening interventions into existing houses were not only found to translate into energy savings, but also resulted in water and financial savings and reduced associated illness, safety risks, greenhouse gas emissions and environmental impact. Similarly, it was also noted that job creation also became a crucial component in the successful delivery of the projects. Thus, according to Ma *et al.,* (2012) retrofit or refurbishing of the building constitutes a type among several methods to achieve a reduction in energy use and the consequent greenhouse gas emissions from buildings.

Based on the foregoing, while it is can be seen that there is a global drive for improving the existing building stock yet the available literature indicated that there is less drive and attention paid to improving the environmental performance of existing low cost houses in Nigeria. This is in spite of building retrofit technologies available to maximise energy savings. Thus, this paper has identified and posits the need to find retrofit solutions to reduce energy consumption and rising carbon footprint in existing residential buildings.

Discussion

Energy Conservation and management Strategies for greening existing buildings

In recent years, there has been an increasing effort in the building industry to develop and apply different retrofit strategies and management tools to ensure improved performance in existing building energy consumption. The current state of the art of the strategies employed to date according to Ma et al. (2012) is categorised into three, namely: supply and demand side management, and change in energy use patterns (i.e. human energy use behavioural factors).

Supply side management

The strategies for building retrofit through supply side management comprise of electrical systems, and the use of renewable energy (e.g. solar hot water, solar photovoltaics (PV), wind energy, geothermal energy, etc.) as alternative energy supply systems to provide electricity and/or thermal energy for buildings (Ma *et al.,* 2012). Recently, there has been an increase in the attention given to the use of renewable energy technologies as one of the building retrofit strategy due to the greater impact of environmental damage. The application of renewable energy technologies in retrofitting millions of houses in Nigeria will be more beneficial to several households. This is as a consequence of a cost increase in electricity tariffs with energy consumption charged per kilowatt hour without a noteworthy improvement in electricity generation, transmission, and distribution in the state. The Nigerian Electricity Regulatory Commission (NERC) has estimated that about 60% of electric power customers fall within the R2 band (i.e. a consumer who uses his premises as a residence – house) with R2 as one of the categories of residential electric power consumers.

Demand side management

Ma *et al.,* (2012) points out that retrofit through demand side management is made up of reduction in cooling and heating demand strategies along with the usage of energy efficient equipment and low energy technologies. The demand for cooling and heating a building can be minimised through building fabric retrofitting and the application of other strategies such as air tightness, windows shading, etc. Other low energy strategies applicable to building retrofit projects include natural ventilation, advance control schemes, etc. Ma *et al.,* (2012) noted that retrofitting building fabric, building services systems and metering systems will require a reduced cost in investment with considerable environmental benefits when compared with other retrofit interventions such as renewable energy technologies.

Change in occupant's energy consumption pattern

This is the biggest and the most significant strategies for energy conservation and management in low income houses. It requires proper orientation of the building users on their consumption pattern and closely working early and frequently with occupants in the process of retrofitting. This would enhance the occupants' understanding of energy management required at different times of the year through behavioural and system controls.

Implementation Challenges of Retrofitting for Energy Savings in Existing Houses

To execute retrofitting projects and achieving improvements to existing low income houses means having to deal with some challenges. For instance, in Nigeria, the estimated number of existing housing units is about 10.7 million (Pison Housing Company, 2010) putting the existing housing stock at 23 per 1,000 inhabitants (Makinde, 2014) and of these, about 88% are self-built with evidence of poorly constructed and under maintained houses. The success of implementation will largely depend on the combination of readiness and involvement of the federal and state government, support from local authorities, and cooperation of the householders, appliance and energy supply industries. This implies that active stakeholder engagement would be necessary throughout the implementation project and particularly with the community of local residents. Other anticipated implementation challenges include the technical aspects of retrofitting projects in the following areas:

Insulated ceilings

In tropical and sub-tropical climates, insulated ceilings tend to trap heat built up during the day, unless there is effective ventilation and sufficient levels of insulation or heat moderation (through methods that keep summer radiant heat out). Different technologies may be more applicable or appropriate due to difference of climatic zones. For instance, **s**olar water heaters (SWHs) could be the most appropriate intervention in a particular zone while insulated ceilings could be the most applicable in others.

Electrical rewiring

In most cases the occupants of several low-cost houses are not the only electricity users connected to a household meter. It's not unlikely that one or more other informal house shares the same electricity source as a particular tenant might be giving electricity to extended family members or selling it to a neighbouring non-electrified tenant's house. Meanwhile, the number of occupants on these properties can vary significantly, which could affect any retrofit measure on metered data. Thus, electrical rewiring of the entire building may be required in such retrofit where many illegal and non-compliant electrical installations to safety standards exist.

Absence of rainwater harvesting mechanism

In Nigeria, most houses are not designed with guttering or built in such a way to make gutter retrofits simple for rainwater harvesting purposes. Hence, innovative guttering systems would need to be devised as part of retrofitting strategies. However, installing guttering systems to existing houses could become challenging, especially where the houses are not designed with external timber rafters, purlins or trusses to which gutter brackets could be attached. This could result in having functionality problems and may not last as long as conventional gutter systems.

Poor quality roofing

Poor quality roofing can become a significant hazard to workers installing SWHs and can impact the potential success of the SWH installation. Where roof structures are weak, installation of

SWHs becomes a challenge as great care needs to be taken to prevent further damage and workers falling through the roof which poses a danger to both people and the property. Furthermore, roof leaks will require some repair before insulated ceilings can be installed. Hence, the budget would need to be set aside for repair of leaks or replacement of roof members.

Recommendations for green retrofitting of existing residential buildings in Nigeria

Nigeria's existing housing stock present energy efficiency problems that require urgent attention. This needs to be driven by increasing focus from the Government and the private sector to find ways of helping households save money on their energy bills, decrease their emissions, and make their homes comfortable to live. To achieve this, the following should apply for effective green and sustainable retrofitting of existing residential buildings:

- Existing energy and water systems should be examined and upgraded to ascertain that they function properly and enhance significant reduction in energy consumption.
- Occupancy energy and water consumption patterns should be assessed and efficiency strategies introduced where necessary.
- As much as possible areas where natural ventilation and fresh air intake is required should be identified and introduced as replacements to reduce cooling loads.
- Solar shading devices should be introduced for windows where practicable.
- Installation of smart meters to monitor real-time electricity and water consumption, control demand and increase users behavioural energy use awareness should be introduced if the houses are not already metered.
- Renewable energy installation options should be encouraged by the government to lessen the long term financial burden of purchasing fossil fuel-based energy. Many domestic activities that take place in Nigeria houses involve the constant use of hot water. This requires a substantial amount of energy use if the hot water kettle is used. And since most households cannot afford gas and electric cooker, the solar water heaters (SWHs) and pipe reticulation systems could be installed to deliver hot water directly into the house. A 100-litre, low pressure, and evacuated tube-type systems with no electrical backup connection is recommended. The solar water heaters have superior performance qualities with the capacity to deliver balanced cold/hot pressure and 'safe' tempered water at 50 to 60 degrees Celsius.
- In most existing low income houses, ceiling conditions are in deplorable conditions leading to excessive heat into the interior. Retrofitted ceilings could make a marked difference to the internal comfort levels of the houses. In place of the present ceiling board in lower income houses, a 30mm thick Isoboard (insulated ceiling board) having a thermal resistance value (called 'R' value) of 1 could be installed as a replacement for improvement in the interior thermal performance.
- A nationwide standard for electrical installation should be developed and their retrofitting coordinated by well-trained registered technicians. Dangerous and exposed electrical wires that prevailed in many of the houses should be replaced to prevent excessive electricity consumption and to ensure safety. It is most likely that many electrical wires have exceeded lifetime. Therefore, qualified electricians should be employed to conduct electrical inspections to produce the required compliance certification during the retrofit.
- A national residential lighting energy efficiency standard should be developed to mandate the replacement of incandescent bulbs within a stipulated period with Compact Fluorescent (CFL) bulbs in all residential buildings as they are more energy efficient. The cost of the bulb replacement nationwide should be highly subsidised by the government to encourage com-

pliance. Dimmable switches should be introduced along with other lighting energy efficiency techniques such as the use of timers or sensors for electrical appliances.

- The low pressure solar heating system that delivers water at a low flow rate (less than ten litres per minute) should be installed to encourage water conservation and improve efficiency. Existing inefficient water delivery services should be replaced with water efficient taps having aerators, sensors with designing flow rates. Similarly, PVC pipes should be substituted with High Density Polyethylene (HDPE) pipes. This is considered to have better properties for water conservation through its properties such leak-free performance, better resilience and flexibility than PVC in terms of damage from digging and surges. Additionally, existing old WC should be exchanged with low flush capacity WCs or be incorporated with a dual flush toilet with lesser Litres of water per flush. On the alternative, extra space within the WC tank can be reduced using a lightweight block to minimise the quantity of water used.
- Active stakeholder participation should be encouraged with adequate resources directed towards the process. Collaboration with services providers such as electricity suppliers and involvement of the local community leaders through community briefing is essential to ensure the achievement and the smooth running of the project. This way, less literate residents would have time to get to grips with the project.

Conclusions

To contribute to the global efforts in alleviating the challenges associated with climate change, Nigerian government needs to explore and employ innovative approaches and tools to lessen its contributions to global CO2 emissions. A synergistic relationship is needed between house owners, housing developers and housing industry take advantage of the opportunities of retrofitting of inefficient existing houses which hold huge prospect for reducing energy consumption. Meanwhile, the use of policy to establish and mandate resource conservation and energy management in existing buildings would serve as an effective mechanism through which residential building retrofit can be successfully implemented. Thus, the current proposed climate change policies in Nigeria need to be reviewed to integrate minimum energy use standards for existing buildings. In the meantime, mandatory building codes as a form of regulatory mechanism have the potential to influence the retrofit of existing residential houses. Thus, this regulatory mechanism to the extent that it exists and applied in Nigeria can deliver a pathway to improving energy efficiency of the existing building sector. Retrofitting operations supported by utilities and included in emissions reduction mechanisms are a decisive solution to the problems of energy expenditure and cost.

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