GSJ: Volume 8, Issue 1, January 2020, Online: ISSN 2320-9186

www.globalscientificjournal.com

ENERGY MANAGEMENT IN RESIDENTIAL BUILDINGS: A CASE STUDY OF GOLF HOUSING ESTATE, TRANS-AMADI, PORT HARCOURT

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ABSRACT

Globally, energy consumption in buildings take up the largest proportion of world's energy production. This consumption is more in developing countries including Nigeria and the least developed economies than the developed worlds. Researches are currently geared towards reducing energy consumption due to the global problem of insufficient energy needed to meet the demand and the attendant environmental issues associated with the production based largely on fossil burning. In Nigeria, energy consumption in buildings takes up about one third of the total electricity production with Lagos accounting for the larger percentage of the total energy production due to the fast rising population, crawling economic growth and increased rate of construction across the state. This paper investigates the energy consumption in residential buildings (Golf Estate, Trans-Amadi), Rivers state. Survey analysis approach was adopted in this work. Field trips to the study area were conducted, measurements were taken and the design features of the buildings were analyzed. The household equipment were also taken into consideration. The work also analyzed the present electricity use in residential typical buildings of high income households in Port Harcourt and the possible energy saving by adopting certain energy efficient features in the building studied. The Enveloped Thermal Transfer Value (ETTV) equation was utilized to account for the quantity of heat taken into the building through the buildings envelop. Results obtained indicates that doubling the thickness of external walls, reduces the cooling load of the building and its total energy consumption. The study established that Perlite plaster has a lower thermal transmittance value when compared to that of Cement screed hence a better energy reducing material option in building construction.

Keywords: Energy Efficiency, Survey Analysis, Perlite, ETTV, Residential buildings, Golf estate.

INTRODUCTION

Sustainability is a great debate about global warming and about the big compromise humanity has to accept in order to continue having a healthy life on this planet. Von Weitzsaecker et al. (1998) talked about “four factors”: the necessity to augment the technologies eco-efficiency four times, doubling the comfort and halving the resources used. Considering the demographic growth and the increase in wellness demand throughout all developing countries, some authors propose that we should rather talk about the “ten factors” (Manzini and Vezzoli 1998). In other words, the human kind should live with only the 10% of the resources which are actually used (Fregolent and Indovina 2002) which in turn means lowering the resources consumption of about 90%. During the 70s, the System Dynamics Group at the Massachusetts Institute of Technology (MIT) started a debate about humanity’s dilemmas on the threshold of the Technology Age. Its researchers started to think about possible Limits to the Human and Development Growth as well as about the eventual necessary changes to maintain a certain sustainability in the western socio-economical organisms. Now scientists and many politics all over the world agree that there is no more doubt about the connection between human activities and global warming.

There are two basic reasons that make sustainability strongly and full lengthy connected to the building trade. On one side, the construction sector has the main ambient impact if compared to other human activities: the 25-40% of all energy used in Organization for Economic Co-operation and Development countries goes to the building and construction sector, including production and transportation of the needed materials and the 40% of the world greenhouse emissions comes from the “built” environment. On the other side, the human beings dwelling in those buildings would tend to make their houses the most comfortable and healthy place possible. It is thus evident how the building sustainability issue is related to two kind of relations that are between the building and the environment and between the building and the people living in it. Also, sustainability runs down different scales: the territory, the urban scale, the building, and the single dwelling unit, the resources’ exploitation, the territory use, the energy consumption in every life-cycle step of the building product and the wrecking garbage are activities that cannot stand apart from any environmental issue.

Energy is an integral part of life today. It comes at a fiscal price but more than that it comes at environmental cost too. The generation of energy requires natural resources which are depleting day by day. On the other side, use of energy is increasing exponentially. Energy management is defined as “The judicious and effective use of energy to maximize profits and enhance competitive positions.” The primary objective of energy management is to maximize profit and minimize costs by optimizing energy procurement and utilization, throughout the organization to minimize energy costs without affecting production and quality and to minimize environmental effects.

The Upsurge in energy use and emission of greenhouse gases is as a result of the development, occupancy and operation of new buildings. These buildings within and around the environment have massive impact on the energy use and the environment ranging from the design to the construction stage and beyond. Research shows that the building area embodies 36% of energy related to carbon dioxide emissions in most of the industrialized countries. Designing processes of conventional building can have a negative effect on the total energy performance and lack of study related to energy saving strategies implemented during the design stage of construction at the moment could be detrimental on the long run. Hence, energy management strategies should be considered optimally during the design stage of buildings with the aim of increasing energy efficiency.

In developing nations like Nigeria, in terms of the distribution of the energy demand, in 2012, the total energy consumption was 116,457 ktoe, of which the residential sector accounted for most of the energy consumed (IEA, 2014). Thus the need to improve and maintain energy efficiency in residential facilities is strongly felt to survive in present scenario of rising energy costs and volatile energy markets and to gain competitive advantage. On the other side, consumption of energy resources in residential facilities lead to damages in the environment. This research is aimed at promoting more efficient utilization of energy and avoidance wasteful and less non-productive patterns of energy consumption in residential buildings in Nigeria.

The application of energy efficient technologies to improve energy efficiency in residential buildings are often suggested as a means of reducing carbon emissions. In many cases where climate change is not a concern; improvements in energy efficiency will pay for themselves through reductions in energy costs. Hence, the structures and construction materials for residential building design and energy-efficiency should be appropriately chosen and designed for energy-saving management in the building. The design concept and approach have been clarified and numerous previous studies specified the importance of design stage of building construction to overcome any uncertainties in building variations or environmental changes that could influenced the energy consumption for the whole building within the operational and maintenance stage. Design stage basically consists of Schematic Design and Design Development.

The Schematic Design stage is the first step to developing a design with the objective of simple diagrammatic documents delineating room sizes and their relationships, elevation studies of the building exterior as well as interior spaces. It is required to be done within a period of two to four months.

The Design Development stage is the further steps where the approved schematic design is then developed into definitive plans and elevations. At this stage the materials selection, lighting fixtures, as well as other equipment and building elements are reviewed by building committee. At the meantime, in Design Stage, the designer can tune the thermal characteristic of buildings and moderate external environmental conditions and maintain internal condition using minimum resources and building materials by implementing 'passive design' or 'active design'. Residential buildings could include both active and passive design in the outline. Passive design is the way to maximize the use of natural sources of heating, cooling and ventilation to create comfortable conditions for occupants inside buildings for instance solar radiation, cool night air and air pressure differences. Meanwhile, active design makes use of mechanical or electrical systems, such as boilers and chillers, electric lighting and so on.

2.0. METHODOLOGY

The system we will study is the building. As every system, several inter-related components characterizes it and the user could be considered as an active element of the building, an element that can be not systematically controlled, rather educated and informed. This system is separated from the surroundings by a boundary side that is the building envelope. Through this envelope, the system and the surrounding exchange some energy fluxes in both senses, depending on the energy quantity required, produced and consumed inside the same building and the one coming from the external environment.

In achieving the aim of this research, primary and secondary data were obtained. Meanwhile, secondary data were based on selected available articles and article journals and books for further reviews and analysis.

Issues investigated/ units of analysis

Apart from the design aspects that were identified in the theoretical framework, the following issues in the case study apartment have also been investigated:

- Energy use practices of households (appliances used, energy used by those appliances)
- Energy use for cooling and lighting in typical residential buildings of Port Harcourt
- Cooling load analysis of the households
- General living pattern of the households

Data gathering strategies

Data gathering strategies were divided into a mixture of qualitative and quantitative approaches.

The following different combinations of data gathering strategies were adopted;

Physical survey of the case study building

Semi-structured interviews

Quantitative calculation of energy use and Architectural drawings of the case

Quantitative statistics from newspaper clippings.

Envelope Thermal Transfer Value (ETTV)

The ETTV takes into account the three basic components of heat gain through the external walls and windows of a building. These are:

Heat conduction through opaque walls,

Heat conduction through glass windows,

Solar radiation through glass windows.

These three components of heat input are averaged over the whole envelope area of the building to give an ETTV that represents the thermal performance of the whole envelope.

The ETTV formula is given as follows:

$$ETTV = 12(1-WWR)\,UW + 3.4(WWR)\,Uf + 211(WWR)\,(CF)\,(SC)$$

Where;

ETTV: envelope thermal transfer value (W/m2)

WWR: window-to-wall ratio (fenestration area / gross area of exterior wall)

Uw: thermal transmittance of opaque wall (W/m2 K)

Uf: thermal transmittance of fenestration (W/m2 K)

CF: correction factor for solar heat gain through fenestration

SC: shading coefficients of fenestration

3.0. FINDINGS AND DISCUSSIONS

Building orientation

The long axis of the building runs east-west, i.e. the facades on the north and south are bigger than the east and west elevations. The orientation of the case study building is in line with the recommendation of Gut and Ackerknecht (1993) and Wong and Li (2007). It has been established that the best orientation for buildings in tropical climates is for the longer axis of the building to lie along east-west direction to avoid solar heat gain.

Room orientation

The orientation of rooms in the three bedroom flat is discussed.

Dining	Master bedroom	Bedroom 2	Bedroom 3	Living room	Kitchen	Toilet
Central	South	North	North	North	South	South

The orientation of bedrooms and living room in this type of flat is good because none of these rooms is located in the west. According to Gut and Ackerknecht (1993), stores and other auxiliary spaces should be located on the disadvantaged side, mainly facing west. The kitchen too is well positioned except for the dining space that does not have a proper orientation in all flat types. Gut and Ackerknecht (1993) pointed out that bedrooms can be located on the east side because it is coolest in the evening.

External wall and building material

Both external and internal walls have a cement plaster over the concrete blocks and off white color wall finishes. According to Cheung et al. (2005) it is possible to save 12% on cooling energy by using white or light color external wall finishes. Hence, this building is therefore successful in saving 12% on cooling energy because of the light color external wall finishes.

Thermal Insulation

In general, residential buildings in the estate do not have insulations because it is considered expensive and difficult to maintain. In the case study building, neither walls and windows nor roofs, have any type of insulation.

Roof

The roof is flat, about 100 mm thick. It is made of reinforced concrete slab with weathering course and neat cement finish.

Windows

The window to floor area ratio (WFR) of the three bedroom flat was calculated by dividing the area of the window by the area of the floor. Similarly, the window to wall area ratio (WWR) in the different units was calculated by dividing the window area by floor area.

	Window orientation	Floor area(m2)	Window size(m2)	Wall area (m2)	WFR	WWR
Master bedroom	South	12.87	3.00	12	0.23	0.25
Bedroom 2	North	12.21	2.60	10	0.21	0.26
Bedroom 3	North	10.82	2.52	9.3	0.23	0.27

GSJ: Volume 8, Issue 1, January 2020
ISSN 2320-9186

Living room	North	14.10	2.10	9.5	0.15	0.22
Kitchen	South	5.80	1.50	6	0.26	0.25

The table above shows the Window to floor area ratio (WFR) and window to wall area ratio (WWR) of rooms in 3 bedroom Flat apartments Rooms The windows on the north of the flats are effective in allowing day light and airflow because of their orientation. As a result, the lights in these units need not to be kept on throughout the day.

For proper cross ventilation, Mathur and Chand (1993) recommend windows located diagonally opposite to each other. However, only the living room of all the three flat types in this building have provision for cross-ventilation through two pairs of windows located on side walls. As the location of the outlet is very far to the inlet, most of the space inside the room is affected by the air current.

Shading devices

Shading devices are not necessary needed in this building. The building is built to ensure protection from the rain and solar heat gain. The windows in the building were built inside the balcony.

Survey of the Various Households Equipment

Fittings/type	Sitting room	Bedroom1	Bedroom2	Bedroom3	Kitchen	Bathroom	Passage	Total
13amps socket	96	72	72	72	48	4	48	412
15amps socket	12	12	12	12	12	12	-	72
Lighting fittings	48	24	24	24	12	24	36	192
Air conditioner	12	12	12	12	-	-	-	48
Water heater	-	-	-	-	-	12	-	12
Cooker	-	-	-	-	12	-	-	12

Envelope Thermal Transfer Value (ETTV) of Case study building

From the building‘s plan, the ETTV is given as;

ETTV = 12(1-WWR) Uw+3.4(WWR) Uf+211(WWR) (CF) (SC)

ETTV=64.98W/m2

Re-designing the building with less heat gain

The cement in the case study building is replaced with perlite, the ETTV then gives;

ETTV=57.60

4.0. CONCLUSION AND RECOMMENDATION

This study has identified apart from other energy efficient building features that doubling the thickness of external walls or using a different plaster will improve the energy efficiency of residential buildings, in the context of Port Harcourt, Nigeria. In this work, it was established that using perlite plaster in place of the cement plaster, improved the cooling inside the building, thereby making the building to be more energy efficient. It is recommended that perlite, with less thermal transmittance value (U), and should be used for wall plastering instead of cement.

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