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EXAMINATION OF ENERGY CONSUMPTION REDUCTION MEASURES FOR RESIDENTIAL BUILDINGS IN TROPICAL CLIMATE: A CASE STUDY OF BIRNIN KEBBI, NIGERIA

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Reducing energy consumption in the buildings sector is important and requires significant changes in terms of technology, human behavior, operation and management of the building in order to continue enjoying improved indoor environment without any prejudices on the environment. It is on the premises of this need that this study sought to examine the energy consumption reduction measures applicable to the tropical climate taking the Kebbi state as a case and with particular interest in residential buildings given that household consumption is one of the important factors of reducing energy consumption. It was effected using a structured questionnaire issued to occupant of the residential building (ranging from the less, medium and high energy consuming building benchmarking). Also, information on the energy consumed bills and consumption patterns of the household were collected and examined. Data collected were analyzed using the Statistical package for Social Science (SPSS) version 20 and the result presented using mean and Relative Importance Index (RII) for simplicity and to rank the severity of the energy reduction measures identified as opined by the respondents. The result revealed among others that: 'Consider lower energy consuming appliances, equipment when buying 'and 'the use of Daylight for reading and working in the building 'both (RII=0.8985) were ranked the most promising energy saving measure in the tropical climate. Other measures arranged in their order of viability are: 'keeping light and lighting fixtures clean '(RII=0.8955); and 'Switching off water heater, HVAC systems, pressing iron, and microwave after use '(RII=0.8895) among others. Consequently the Research recommends an orientation residential building occupants on measure that can improve the human behaviour in the use of energy such as paying attention on the energy label of appliances before purchase. Finally, the study recommends the adoption of automatic control system as it will help to cub human behavioural excesses

Keywords: behaviour, benchmark, energy consumption, reduction measure, residential building

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INTRODUCTION

Household consumption is one of the important factors to be considered in reducing energy consumption and its commensurate carbon dioxide (CO2) emission. Because its energy use may directly cause CO2 emission. he enormity of Nigeria's energy problem creates a greater need for energy efficiency practice to be adopted by residential households as electricity demand in Nigeria far outstrips the supply which is epileptic in nature (Sule, Ajao, Ajimotokan,. and Garba, 2011). On the other hand, because much energy is embodied in goods and services, consumption of living commodities and service may result in indirect CO2 emission (Manzuma, et al. 2018). The income growth, improvement of living standard, the increasing amount of home appliance, housing and private transportation, have driven the indirect energy consumption and increased the amount of indirect CO2 emission (Nwofe, 2014). Also, the International Energy Agency (IEA, 2011) estimated that, residential, public and commercial buildings account for 30 to 40 percent of the world's energy consumption and contributes 25 to 35 percent of the current world CO2 emissions.

Growth in the use of a variety of electrical appliances is one factor contributing to the growth of energy use in buildings in recent decades. Therefore, Amann et al., (2007) identified that residential energy intensity, defined as energy use per square foot of living space, declined over the past 30 years in spite of the growing penetration of delivered energy (which is the electricity delivered to a site plus the fuels used directly onsite (e.g., natural gas for heating water). This measure does not account for the losses incurred in generating, transmitting and distributing the electricity.

The energy consumption reduction measures of a building are defined the United Nations Industrial Development Organization (UNIDO, 2006) as the extent to which the energy consumption per square meter of floor area of the building measures up to established energy consumption benchmarks for that particular type of building under defined climatic conditions. Sheila & Alicen, (2011) proposed that reducing existing building energy consumption in residential buildings lie in three synergistic approaches: to reduce energy requirements through implementation of energy efficiency measures in design stage, services design and retrofitting to offset the remaining building energy needs through the use of renewable energy system for existing buildings. It is however important to consider building energy consumption reduction measures before installing renewable energy reduction system, as the outlay cost to invest in energy consumption reduction measures is about half the cost of installing renewable energy generating capacity equal to what the energy reduction measures offsets (IEA, 200). Hence, investments in energy consumption reduction measures in residential buildings generally have much shorter pay-back times than energy supply investment; a particular important consideration in countries where the demand for supplies is growing rapidly (UNIDO, 2006). Africa's rate of urbanization of 3.5% per year is the highest in the world, resulting in more urban areas with bigger population proportional to the expansion of the existing urban areas; there are currently 40 cities in Africa with populations of more than a million; and it is expected that in a few years from now, 70 cities will have population of one million or more (UNIDO, 2006).

Globally, it has been shown that building sector consume more energy than any other sector; consuming about 42% of the world's total energy use. presently, energy consumption in the world is becoming greater and fossil fuels embody large shares to the overall energy use. Japan International Cooperation Agency (JICA, 2005) highlighted that, coupled with the concerned issue on future exhaustion of resources, global warming is also becoming a serious concern due to higher concentration of CO2 emission in the air through the use of resources. Where electricity is intermittent in developing countries and power rotation is frequent, there is a large demand for diesel or petrol and renewable energy-based backup or standby power generation from end users (UNIDO, 2006). The Federal Ministry of Power Works and Housing FMPWH (2017) stated that reducing energy consumption requirement in buildings lessens the principal and running costs of these standby systems; thereby translating to energy consumption reduction, reduction in the cost of energy, profitability of business outlets, reduction in noise pollution and CO2 emissions from buildings. Buildings could be emitting as much as 12, 600 tera-grams of CO2 higher than what they are estimating at present if no proactive measures are taken to abate their energy demands (Forsstrom, Pekka, Esa, Miika, Jari, Kari and Irmeli, 2011).

It is in this view the research intent to assess measures that can be used to reduce energy consumption in residential building of Birnin Kebbi (12.43180N, 4.19560E) with a view to identifying areas of possible improvements in energy usage, using bench marking method.

LITERATURE REVIEW

Energy consumption in residential buildings

Worldwide, buildings consume massive amounts of energy. The United Nations Environment Programme (year) has reported that 30–40 percent of all primary energy produced worldwide is used in buildings. In 2008 the International Energy Agency released a publication that estimated that existing buildings are responsible for more than 40 percent of the world's total primary energy consumption and for 24 percent of global CO2 emissions. it becomes paramount to examine energy consumption in the evolving built environment in a developing world context and pursue energy conscious measures in the short term, while advocating for a coherent and substantive policies as well as institutional frameworks on the long term. Lukić, Tamburić & Stojić, 2012 affirmed that Housing stock uses up to 40 % of total consumed energy which is significantly more than needed to provide comfort and function. Such wasting of energy significantly contributes to the greenhouse effect. For this reason, saving in energy consumption of the residential buildings can contribute to solving of the global problems such as the climate change and energy safety. Therefore, according to Janda, (2011) energy efficiency is perceived as the action of lowering energy demand by reducing ongoing energy usage. According to Nwofe (2014) energy efficiency in buildings is one of the fundamental steps towards reducing the agents/factors that could lead to global warming and climate change. It is a common knowledge that global warming is becoming more severe universally and poses very big risk to man. Hence, Hall (2010a) posited that buildings can incorporate many green features, but if they do not use energy efficiently, it is difficult to demonstrate that they are truly green. That is to say if a building is not

energy efficient, it cannot be said to be green. Although green buildings, on average, use less energy than conventional buildings, energy efficiency remains elusive. Numerous ways to improve a building's energy efficiency ranges from insulating walls to installing automatic shut off switches for lights. Energy efficiency can be and often is mandated by local and state energy codes, which require that new and substantially renovated buildings comply with increasingly stringent energy efficiency requirements. Lukić et al. (2012) observed that due to the high consumption of energy in buildings, and due to the highest potential for energy and environmental saving, energy efficiency is nowadays the priority of contemporary architecture and power industry. The measures for energy efficiency include: a series of directives and incentive mechanisms, mandatory energy certification of buildings, indicate the urgent need to reduce energy consumption in buildings, which results in a more comfortable dwelling in buildings, long service life of buildings, which in turn preserves the environment.The energy crises the country is facing coupled with population and infrastructural growth and the unrelenting rise of energy prices have stimulated research interest towards finding ways of alleviating or eliminating the unnecessary use of energy.

Oyedepo, (2012) stated that energy consumption reduction means improvement in practices and products that reduces the energy necessary to provide services like lighting, cooling, heating etc. These have endeared the principles of energy efficiency to the building occupants thus making it the key driver of sustainable development in many economies in the world Furthermore, increasingly energy efficiency is considered to include not only the physical efficiency of technical equipment and facilities, but also the overall economic efficiency of the energy system. According to Hall 2010b, the energy performance of a building must be calculated using standards that indicate the insulation of the buildings, the characteristics of technical systems and installed equipment, the position and orientation of the building in relation to other climatic aspects, exposure, its own capacity for renewable energy sources and other factors, such as indoor environmental quality, that could influence the energy requirements of the building. Karolides (2002) was of the opinion that the easiest and least expensive way of reducing operational costs in a building is to lower its energy consumption which is best done by increasing energy efficiency. There are great energy-cutting opportunities in simple designs that respond to location and climate. Green buildings are designed to save energy costs by reducing the energy consumption. Conventional (traditional) buildings consume more of the energy resources than necessary and generate a variety of emissions and waste.

Energy consumption reduction in residential buildings

Reducing energy consumption in the buildings sector requires significant changes, but technology alone may fail to guarantee efficient energy performance. Human behavior plays a pivotal role in building design, operation, management and retrofit, and is a crucial positive factor for improving the indoor environment, while reducing energy use at low cost (Tianzhen Hong, Simona D'Oca et.al, 2015). Over the past 40 years, a substantial body of literature has explored the impacts of human behavior on building technologies and operation. The solution to overcome these problems will be to build them green and smart (Samer, 2013). One of the significant components in the concept of green buildings is using renewable energy. Solar energy and wind energy are intermittent sources of energy, so these

sources have to be combined with other sources of energy or storage devices where the variety of energy source and storage devices can be managed very well (Jiang, 2011). The attitude of residential building occupants in Nigeria shows that there is wide ignorance in use of switching off bulbs, appliances (Television, Computers, Microwave, Electric cooker, Water heater (ring), Electric kettle, Blender, Toaster, Oven, and Washing machine and the likes). The awareness on energy saving bulbs and appliance are limited to people in the urban areas while most rural areas are still using conventional bulbs (Tungsten/Yellow filament). Also, the price of a quality energy saving bulbs is still high and turning lights off when not in use would save a gigantic sum of 25,235,680,000 NGN (£55m) and 375000 tons of carbon (iv) oxide thereby preserving the environment and reducing energy cost simultaneously (Nwofe, 2014).

Although the majority of designers appreciate that the behavior of building users can affect energy performance, it is usually considered of little importance compared to engineering solutions to this issue (Janda, 2011). This is despite growing evidence to suggest that the impact of behavior can be extremely significant. Gill et al. (2010) investigated the impact of behavior on energy consumption at a BREEAM Excellent housing estate in the UK. Using a psychological model of planned actions, they discovered that deliberate energy efficient behaviors accounted for 51% and 31% of the variance in heating and electricity use respectively between homes. While the majority of studies on occupant behavior are limited to the domestic sector, Menezes et al. (2012) demonstrated that the level of control occupants believe they possess over lighting and appliances in a commercial office building also accounted for variations in electricity consumption of up to 17%. Traditional biomass fuels have been the single most important energy source in buildings for centuries. They still account for approximately 10% of global total primary energy use concentrated primarily in developing countries. Approximately 60% of all biomass is used in solid unprocessed forms such as firewood, agricultural waste, and dried animal dung burnt in crude and inefficient stoves and open fires for cooking and heating (IEA, 2008). Chronic Obstructive Pulmonary Diseases to which pollution from poor combustion of biofuels indoors contribute are predicted to become the world's third largest cause of death by 2030 (WHO Statistics, 2008).

Measuring energy use in buildings

There are several approaches to reviewing the technologies and design principles available today to make buildings more energy-efficient. Each illuminates a subset of important engineering and physics issues but obscures other subsets. Each approach has its advantages and disadvantages. Therefore, this report does not adopt one preferred style of presentation but instead looks at three different approaches (ASHRAE, 2008). The three methods are:

1. An integrated whole-building or system-wide approach,
2. An approach by end-use and technology description, and
3. An approach by individual "widgets" or detailed energy consumption reduction technologies and measures.

Integrated whole-building or system-wide approach

The first approach looks at integrated whole-building or system-wide energy use and describes the types of technological improvements that could create savings of a given percentage for whole buildings or whole systems. For example, a small but growing subset of new commercial buildings achieve a savings of 50 percent (relative to prevailing model Energy Code ASHRAE 90.1) in regulated energy use (heating, cooling, air-conditioning, water heating, and lighting) (Amman, 2007). Reviews of highly efficient commercial buildings (NBI, 2008; ASHRAE, 2008; Torcellini et al., 2006) show that such buildings incorporate the following measures:

1. High-efficiency electrical lighting systems that not only incorporate state-of-the-art lamps, ballasts, and luminaires (lighting fixtures), but also use luminaires to provide the desired lighting in the right places (e.g., as task lighting) and use controls that limit electrical lighting when daylighting is available;

2. Fenestration systems and designs that reduce heat gain in climates with high cooling requirements;

3. HVAC controls that provide for the effective operation of the HVAC system during part-load conditions;

4. Regulated energy use refers to energy use covered by building energy codes. Such codes do not apply to plug-in office equipment, for example. There are many reasons why efficiency at part load can be lower. Examples range from systems that do not modulate but simply turn on or off, to chiller designs that are optimized for efficiency at full load and work poorly at part load (perhaps because they are not tested or marketed on the basis of such performance), to overall systems controls that continue to operate one part of the system at full-power use even though other parts are at partial power and do not require that support.

5. On-site power generation such as combined heat and power systems or solar photovoltaic generation to reduce purchased energy. Low-energy buildings do not always operate as they were designed to do. Experience shows that in order to maximize real-world energy savings, it is critical to properly commission and monitor the performance of low-energy buildings and to ensure that control systems are working properly and are adjusted to account for occupancy conditions (Torcellini et al., 2006; Mills, 2009). The net incremental first cost of achieving a 50 percent reduction in energy use through an integrated approach can be at or near zero; the savings from downsizing and simplifying HVAC systems generally pay fully for the additional costs of measures such as additional insulation, better windows, and daylighting (Goldstein, 2008). But the next increment of savings, up to 60 percent, has very few exemplars. For residential buildings, a whole-house energy management approach can result in a 50 percent or greater savings in heating and cooling and a 30–40 percent savings in total-home energy use, and also cost-effectively (DOE, 2004a; Dunn, 2007).

6. An integrated approach involves the design of the HVAC system with that of the envelope system and the lighting system and its controls. Current design practice involves designing the envelope of the building independent of such

integrative consideration, then passing the design onto HVAC engineers, who design the HVAC system without looking back at what could be done differently at the envelope or without looking forward to how lighting designs could enable improved HVAC designs.

Approach by end-use and technology description

Because whole-building studies focus on the level of savings achieved and the cost of getting there, they often do not specify the kinds of energy-saving measures used and how relevant they would be to broad-scale application across the economy. Instead, the savings estimates sometimes are based on measured results from demonstration buildings or multi building projects, or on case studies; they sometimes consider simulated energy savings based on integrated designs of new buildings or retrofits; and they sometimes are based on more than one approach. Other studies, however, rely on the end-use and technology description approach to identifying energy efficiency potential. This approach assigns energy use to major end-use categories and reviews the specific technologies and measures available for reducing energy use in each category (often ordered by cost-effectiveness). The end-use approach is based on text and explanation of technologies and measures. Most of these technologies and measures could be incorporated into existing buildings. As an example, space heating is the largest user of energy in residential buildings, and cooling is the second-largest or close to second-largest user. Similar energy-saving measures and strategies can be applied to both. These efficiency measures and strategies include the following (Scheckel, 2007; Amann et al., 2007)

Increasing insulation in all components compared with what is done according to current practice, including the use of selective coatings on windows. These coatings are chosen on the basis of the local climate, to reduce thermal transmission (by increasing the thermal-infrared emissivity and reflectivity of the window). They are most effective on west-and east-facing windows in climates requiring cooling or in transitional climates where an efficient shell can obviate the need to buy an air conditioner. Moving ducts into the conditioned space for new construction, and reducing leakage through on-site pressure testing in both new and existing homes. Improving heating and cooling systems themselves, for example, by using programmable thermostats, by using higher-efficiency furnaces that condense water vapor produced by the combustion of methane (or other fuels) to extract additional energy and achieve efficiencies over 90 percent, by using variable-speed and higher-efficiency motors and fans for air circulation, and by using ground-source heat pumps (for electric heating) or gas-fired heat pumps.

Upgrading equipment for cooling, focusing on better heat transfer from evaporators and condenser coils in air conditioners and employing variable-speed drives that allow units to operate efficiently at partial loads (rather than turning on and off frequently). This measure can control humidity more effectively, as well as save energy.

Changing ventilation systems to provide sufficient fresh air to a system that uses the proper amount of mechanical ventilation while sealing the home to nearly airtight standards. Controlling ventilation can greatly mitigate indoor air quality

and mold problems while also offering the opportunity to recover both latent and sensible heat from the exhaust airstream.

Using evaporative cooling. While once-through evaporative coolers work well only in desert climates, indirect systems that transfer sensible heat from the humidified airstream can provide comfort in a much broader zone of climate while using about one-quarter or less of the energy of compression-based cooling.

Making greater use of passive solar heating and cooling, although this design technique has not yet found widespread acceptance in the marketplace owing to the difficulties of custom designing the orientation and thermal characteristics of each home. After space heating and cooling, the next-largest user of energy in residences is water heating. Water-heating energy use can be reduced both by improving the efficiency of the water-heating device itself and by reducing the demands for hot water, including for clothes washing and bathing, throughout a home. Substantial gains have been made in the best-performing clothes washer and showerhead products compared with standard products. Heat-pump water heaters, which have become very popular in Japan, can reduce electricity use by two-thirds relative to an electric-resistance water heater. Older showerheads use 3.5 or more gallons per minute; newer ones meeting current standards use 2.5 or fewer gallons per minute, and a few newer models use about half this level of water flow to provide a comfortable shower (Harrod & Hain, 2007). Similar lists of technologies for residential lighting and appliances are found in most studies of efficiency potential. Beyond technologies themselves, efficiency can be improved through residential lighting design that raises the ratio of productive light output (lux on the visual task) to power use in homes to a level comparable to that in office buildings.

The major sources of energy use in commercial buildings are heating, ventilation, cooling, and lighting. Studies of energy efficiency potential usually look at specific measures within these categories, such as improving the rated efficiency of rooftop air conditioners by 20–30 percent or substituting 100 lumen per watt lamp-ballast combinations for existing product combinations that provide fewer than 70 lumens per watt.

Energy benchmarking method

Benchmarks are representative values for common building types against which a building's actual performance in terms of energy use can be measured. The benchmarks permit the comparison of the performance of a building to established standards to know whether or not the building's use of energy is efficient (Manzuma, 2020).

Chung, Hui and Lam (2006) describe energy benchmarking as a tool for enhancing the reduction or efficient use of energy in residential and office buildings. Also, Bloyd, Mixion and Sharp (1999) in their work shows that "benchmarking can be viewed as the first step in understanding and setting goals for energy consumption reduction improvements in buildings". Energy consumption reduction benchmarking can be seen as a tool used for monitoring changes in energy use, it also served as a basis for the design and retrofit in the budgeting for efficient energy use in efficient residential buildings (Lee, 1998 and 2004). However, energy benchmarking approach enable building owners understand the performance of

their buildings compared to similar buildings. Filippin (2000) in his work used a sample of energy consumption data and the floor area to calculate the Energy Use Intensity (EUI); for school buildings in central Argentina. The calculated Ellis were then ranked as a benchmark table and often used for judging the energy-use performance of a commercial building (Kinney and Piette, 2002). Therefore, energy saving potential by the method of benchmark can be classified as whole building metered approach or retrofit isolation approach.

Whole building metered approach

The whole building metered approach uses a main meter to measure the energy flow to the whole building (ASHRAE Guideline 14. 2002). Energy flow is usually electric, gas oil and thermal. These approaches involve the use of monthly utility bill data or data gathered more frequently from a main meter. The ''whole building metered" approach, also called "main meter" approach encompasses procedures that verify the performance of the retrofits for those projects where the whole building pre- and post-retrofit data are available to determine the savings. Utility billing data (usually monthly data) are the basis of data analysis. Continuous measurements of the whole-building energy use before the retrofit and after the retrofit on a more detailed measurement level (weekly, daily or hourly) are also required (APEC, 2001). Consumption and demand values taken from sub-meters are acceptable for use under the whole building approach, where the meter measures energy use of a significant portion of the building area or a group of subsystems (e.g., motor control center). The data will have to meet all the requirements for a utility meter. Sub-meters arc particularly useful in multiple building sites served by one utility meter (Energy Star, 2004). It is most appropriate to use a whole building metered approach when the total building energy performance is to be assessed, rather than the performance of specific retrofit (Energy Star, 2004). According to Cui (2006) there are two paths for the whole building approach with the respective criteria and requirements for its applicability, namely, the whole building prescriptive path and the whole building performance path. The former one is most appropriate when the expected savings are greater than 10% of the measured energy use or demand and when the data are continuous and complete with no data points to be excluded, and are expected to remain this way in the post-retrofit period.

METHODOLOGY

Research design

This study was conducted through field survey. The field work of this research was conducted using various research instruments, each adopted to meet a particular research need. The work involves the collection of quantitative data through energy benchmarking, and the use of a well-structured questionnaire as the instrument for primary data collection. The survey yielded data from the meter energy bills and on the energy consumption patterns of the household.

The study area

The research was conducted in Kebbi State (11.49420 N, 4.23330 E) in the northwestern part of Nigeria. It has a tropical continental-type climate with a wet season that lasts from April to October in the south and from May to September in the north—the dry season lasts for the remaining period of the year. The

temperature is generally high with a mean annual temperature of about 26°C in all locations. But during the harmattan season (December to February) the temperature can go as low as about 21°C; between April and June, it can rise as high as 40°C (Bello & Jeb, 2014).

The State was created out of a part of Sokoto State on 27th August, 1991. Kebbi State is bordered by Sokoto State to the North, Niger State to the South, Zamfara State to the East. Dosso region in the Republic of Niger to the West and Benin republic to the Southwest (Mukhtar, 2016).

Data collection

Firstly, questionnaires were distributed and data collected used to categorize the households into low, average and high energy consumption respectively. A more detailed examination of selected houses in each category furnished some peculiar energy use behaviors and consequently measures through which energy use can be reduced were identified. Energy benchmarking approach enables building owners understand the performance of energy consumption of their building compared to similar buildings. In this case, an examination of the actual investigated residential buildings, including a visual inspection of each of the associated equipment in the selected houses, dimension of space and energy measurements were carried out. Historical data of purchased energy were reviewed to identify patterns of electrical energy usage and compare them with distribution company average benchmark. The energy benchmark for a two-bed room building measuring 95M2 to 120M2 in Birnin Kebbi range between 200KWh and 250KWh while for three bed room measuring 121M2 to 145M2, it ranges between 300KWh – 350KWh monthly with eighteen hours (18hrs) daily of electric energy supply (KEDCO, 2019).

Data analysis

Responses from the questionnaires survey were analyzed using a computer-based software called Statistical Product and Service Solutions (SPSS) IBM version 20 and results were presented as percentages. Relative importance index (RII) was used to identify area of energy wastage and its reduction measures, which when implemented will make the energy usage more efficient, less expensive and more environmentally friendly.

The weighted average for each item was determined and ranks were assigned to each item, representing the perception of the respondents

Relative Importance Index (RII) $= \frac{\sum fx}{\sum f} \times \frac{1}{k}$ ..... (1)

Where,

∑fx = is the total weight given to each attributes by the respondents.

∑f = is the total number or respondents in the sample.

K = is the highest weight on the likert scale.

Results are classified into three categories as follows (Othman et al, 2005) when;

RII<0.60 -it indicates low frequency in use

0.60≤RII<0.80 -it indicates high frequency in use.

RII≥0.80 –it indicates very high frequency in use.

FINDINGS AND DISCUSSION

Demographic information on sampled buildings

From the result presented in Table 1, nine (9) of the buildings falls under less energy consuming building (LECB) with an average energy consumption of 2640KWh (year), Twenty one of the buildings falls under the more energy consuming building (MECB) with an average energy consumption 3840KWh (year) and the remaining Thirty seven buildings falls under high energy consuming building (HECB) with an average energy consumption of 4680HWh (year) forming the population of the study are in Birnin – Kebbi (KEDCO, 2019).

The table show the number of building under each category of energy consumptions from energy billin company, nine of the residential buildings were the LECB, which represented 13.43% of the studied residential buildings; twenty one(21) were in the category MECB representing 31.34% of the residential houses surveyed while thirty seven (37) residential buildings were in the category of HECB, which represented 55.22% of the studied residential buildings

Table 1 Categories of residential buildings to benchmark

S/N	Building Categories	Energy consumption from the Bills (KWH/year)	Number of Buildings assessed	Percentage (%)
1	less energy consuming building (LECB)	0-2640	9	13.43
2	more energy consuming building (MECB)	2641-3840	21	31.34
3	high energy consuming building (HECB)	3641-4680	37	55.22
Total			67	100

Source: Field Survey, (2019)

Table 2, show a comparative examination of the energy consumption of the billing company, the benchmarked energy consumption and the actual energy consumption. From the Table it can be discovered that the LECD used less energy compared to the benchmarks, indicating consumption reduction use of energy in these buildings, most of the MECD building used more energy than the benchmarks and the remaining. Similarly, most of the HECB buildings used high energy compared to the benchmarks, indicating inefficient use of energy in the residential buildings

However, the estimations from the energy audits show that all the buildings were energy efficient. This implies that all the buildings including those that were energy-efficient from the bills can be operated on lower quantities of energy if some measures aimed at avoiding wasteful use of energy are adopted. The variations in the quantity of energy between consumptions from energy bills and

estimates from the audit could be as a result of differences in actual durations of use of appliances and the durations used in the estimations, weather conditions, behaviour of end-users and poor energy efficiency and management practices.

It will also be observed from Table 2 that the differences in consumption from the bills and the audits were quite large. The implication of this is that the occupants in the residential buildings will be able to significantly reduce their expenditure on energy if some of the assumptions used for the audits are adopted.

Table 2 Comparison of the energy use (KWh\year) in the residential buildings to benchmark

Buildings	Consumption from Bills	Consumption from Audit	Benchmarks	Difference From Bill (%)	Difference From audit (%)
LECB	2640	1200	3000	-12%	-60%
MECB	3840	1800	3600	6.67%	-50%
HECB	4680	2400	4200	11.43%	43%

Source: Field Survey, (2019)

Ranking of energy consumption reduction measures

The occupants in the buildings studied ranked their opinion willingness to embrace the possible energy consumption reduction measures identified and the result of the analysis is as presented in the Table 3.

The respondents willingly agree with the finding on the human behaviour to reduction of energy consumption in residential building in Birnin Kebbi, Kebbi State Nigeria. Buying lower energy consuming appliances with RII of 0.8985, Daylight for reading and working in the building with RII of 0.8985, Keep light and lighting fixtures clean with RII of 0.8955, Switch off water heater, pressing iron, microwave after use with RII of 0.8895, Switch off and remove TVs, Computers... plugs when not in use with RII of 0.8805, Ensure all openings are air tight during cooling with RII of 0.8805, Unplug all power loads when not in use with RII of 0.8716, Lighter colour paint on walls and ceiling reduce heat emission with RII of 0.8567, Replace all incandescent bulbs with energy saving types with RII of 0.8507, Clean the reflectors underneath the burners on the stove tops with RII of 0.8388, Reduce heat gain by planting trees and flowers around the building with RII of 0.8268, Turning off light and appliances when not in use with RII of 0.8179, Fill the freezer by ensuring efficient usage of the space with RII of 0.8089, Switching from electrical to solar water heating with RII of 0.8059, Switching from the conventional roofing system to cool roofs with RII of 0.8029, Installation of renewable energy technologies with RII of 0.8029, Use occupancy sensors controls switches for lighting with RII of 0.8000 and Ensure food is cooled before it goes in to the refrigerator with RII of 0.7850 were ranked first, second, third, fourth, fifth, sixth, seventh, eighth, ninth, tenth, eleventh, twelfth, thirteenth, fourteenth, fifteenth, sixteenth, seventeenth and eighteenth respectively are considered very significant factor because their relative significant index is above 0.76. why replacing appliances over ten years old with reduce energy consuming once with RII of 0.7582 and clean cooling coils on a regular basis for efficiency with RII of 0.7164 was ranked nineteenth and twentieth respectively and were considered significant factor between the range of significant index of 0. 67 – 0.75.

Table 3 Building occupants willingness to embrace energy consumption reduction measures

S/N	Energy Consumption Reduction Measures	WEIGHTNG/RESPONSE FREQUENCY							Mean	RII	Rank
		1	2	3	4	5	(∑f)	∑fx			
1	Consider lower energy consuming appliances, equipment when buying?	0	0	0	34	33	67	301	4.4925	0.8985	1
2	Daylight for reading and working in the building	0	0	3	28	36	67	301	4.4925	0.8985	1
3	Keep light and lighting fixtures clean	1	1	2	24	39	67	300	4.4776	0.8955	3
4	Switch off water heater, pressing iron, microwave… after use	0	0	0	37	30	67	298	4.4478	0.8895	4
5	Switch off and remove TVs, Computers… plugs when not in use	1	1	0	33	32	67	295	4.403	0.8805	5
6	Ensure all openings are air tight during cooling	0	1	1	35	30	67	295	4.403	0.8805	5
7	Unplug all power loads when not in use	0	0	4	35	28	67	292	4.3582	0.8716	7
8	Lighter colour paint on walls and ceiling reduce heat emission	1	2	9	20	35	67	287	4.2836	0.8567	8
9	Replace all incandescent bulbs with energy saving types	1	2	12	16	36	67	285	4.2537	0.8507	9
10	Clean the reflectors underneath the burners on the stove tops	0	0	8	38	21	67	281	4.194	0.8388	10
11	Reduce heat gain by planting trees and flowers around the building	0	4	12	22	29	67	277	4.1343	0.8268	11
12	Turning off light and appliances when not in use	3	7	7	14	36	67	274	4.0896	0.8179	12
13	Fill the freezer by ensuring efficient usage of the space	1	1	7	43	15	67	271	4.0448	0.8089	13
14	Switching from electrical to solar water heating		2	15	29	21	67	270	4.0299	0.8059	14
15	Switching from the conventional roofing system to cool roofs	2	3	11	27	24	67	269	4.0149	0.8029	15
16	Installation of renewable energy technologies	0	3	13	31	20	67	269	4.0149	0.8029	15
17	Use occupancy sensors controls switches for lighting	2	3	10	30	22	67	268	4.0000	0.8000	17
18	Ensure food is cooled before it goes in to the refrigerator	2	6	9	28	22	67	263	3.9254	0.7850	18
19	Replace appliances over ten years old with reduce energy consuming once	2	6	17	21	21	67	254	3.7910	0.7582	19
20	Clean cooling coils on a regular basis for efficiency	5	15	6	18	23	67	240	3.5821	0.7164	20

Source: Field Survey (2019).

Where: (1 = Very Unwilling, 2 = Unwilling, 3 = Fairly Willing, 4 = Willing, 5 = Highly Willing)

From the findings on human behaviour to reducing energy consumption in residential building, it can be deduced that buying lower energy consuming appliances, daylight for reading, working, clean lighting fixtures, switch off and unplug all power loads when not in use, finally, using lighter colour paint on walls and ceiling reduce heat emission were found to be the most difficult challenges in human behaviour bedevilling the reduction of energy consumption in residential building in Birnin Kebbi, Kebbi State Nigeria. This deduction tallies with that of Howe (2011), Keith & Cassie (2009), Oyedepo (2012) and Samer (2013).

RECOMMENDATIONS AND SUGGESTIONS ON ENERGY SAVING MEASURES

93.05% of the respondents suggest other means or measures and state government role in ensuring that respondent can adopt to reduce energy use in residential building, only 50.00% of them suggested four (4) ways to reduce energy consumption in residential building are: 16.67% of the respondent suggested that the government should regulate through its agency the importation and local manufacturing of sub-standard electrical appliances, 9.90% of the respondent recommended the use of automatic control system to reduce energy consumption, 20.00% of the respondent believe that all building should be provided, installed and protected prepaid meter in an open save place, finally 8.43% of the respondent suggested alternative source of energy (solar, wind turbine, bio gas) as different ways of reducing energy consumption in Gesse Housing Estate phase (1 & 2) Birnin Kebbi area of Kebbi State Nigeria.

On the state government having a role to play in ensuring energy consumption reduction to avoid the consequences of energy wastages, 38.05% of the respondents suggested that providing policies, regulations and sensitisation of the people to ensure efficient response, enforcement and implementation. The result tally with (Sovacool et al., 2015) are therefore, currently been geared towards reducing energy consumption due to the global problem of insufficient energy.

CONCLUSION

From the data gathered and analysed by the researcher and the major research finding above, the researcher drew the following conclusions:

a. Less than half of the sampled residential buildings had no formal policy for reducing energy consumption.

b. Most of the building users don't check energy label before buying energy consuming appliances.

c. The most selection options by building users in Nigeria is government policies.

d. The major challenges against successful implementation of reduced energy consumption in residential building are both building design and implementation.

e. The building services design have a lot of impact on the performance of energy consumption reduction measures in the Nigerian residential buildings.

Conclusively, for residential building in Nigeria to continue to maintain competitive advantage of reduced energy consumption, they must embrace innovative and pragmatic approaches in their building services design and selection of automatic control system.

RECOMMENDATIONS

The importance of the reduction of energy consumption in residential building in Birnin Kebbi, Kebbi State Nigeria, practices cannot be over-emphasised. Therefore, the following recommendations as drawn from the conclusions above must be well noted.

a. For residential building to successfully achieve reduced energy consumption they must have in place building services designed policies to guide in giving approvals for building construction in Nigeria.

b. Certified professionals have to check and recheck building services design before any approval of building design will be adopted,

c. The building owners and residents needs to have a full knowledge of the building they are residing, this will enable them to fix up the specific duties and responsibilities of every appliance in their facility.

d. The state government should try and eliminate estimated billing and prove all residential building with meter to reduce over billing to the barest minimum.

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