A Review of Sustainable Energy Conservation for Residential Buildings

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Abstract:
Scholars have emphasized the need for residential buildings as spaces for rest attain maximum comfort. In attaining such comfort, using sustainable energy strategies is significant. The United Nations (UN) has acknowledged this by establishing affordable and clean energy, sustainable cities and communities as some of its sustainable development goals. Similarly, different studies have expressed diverse views towards attaining sustainable energy solutions in residential buildings across the globe. It is to be noted that sustainable energy solutions in residential buildings are dynamic and contextual. This study therefore investigated the current strategies for sustainable energy conservation in residential buildings across the global landscape using the semi systematic review method. Data was collected through desk study which involved the exploration of academic research repository using the key terms: sustainable energy, residential building, clean energy and renewable energy. The findings of the research showed that several strategies have been established as solutions towards sustainable energy conservation in residential buildings However, Nigeria is yet to explore the application of the sustainable strategies that are suitable. In conclusion the paper suggests suitable solutions and how they can be implemented in residential buildings to achieve sustainable energy conservation in Nigeria.

Keywords: Energy conservation, Residential buildings, Sustainability, Renewable energy, Green energy.

BACKGROUND

Energy conservation is reducing energy consumption by using less of an energy service (Ramya 2015). According to the organization for economic cooperation and development (OECD) (2015), by 2030, if the current trends in the world are not changed, the world's energy consumption will increase by 53% and 80% of the energy will be produced by fossil fuels which will increase CO2 emissions by 53%.

In Nigeria only 45% of the population has access to electricity (index-mundi, 2018) which is the main source of energy consumption in residential buildings, during the buildings useful phase. This energy is generated majorly with fossil fuels (80%) while the other 20% is through hydroelectricity. However, this 45% of the population, make up the faction that consumes the most energy in the county as seen in Figure 1, the residential sector of Nigeria has the highest amount of energy consumed. This energy consumed by the residential sector is relatively high compared to some other nations as seen in figure 2, irrespective of the amount of the amount of megawatts generated by the country yearly if the current trend continues, the residential sector will always be the largest consumer of that energy in Nigeria.

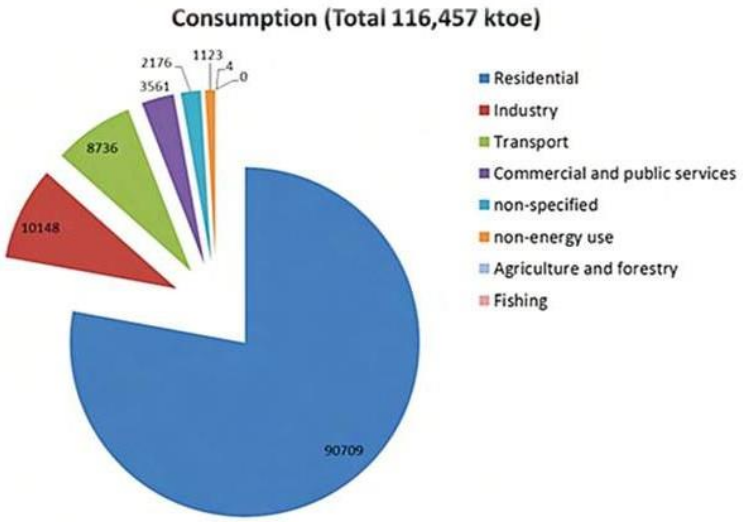

Figure 1: Pie chart showing the rate of Energy consumption in Nigeria, Source: energypedia 2012

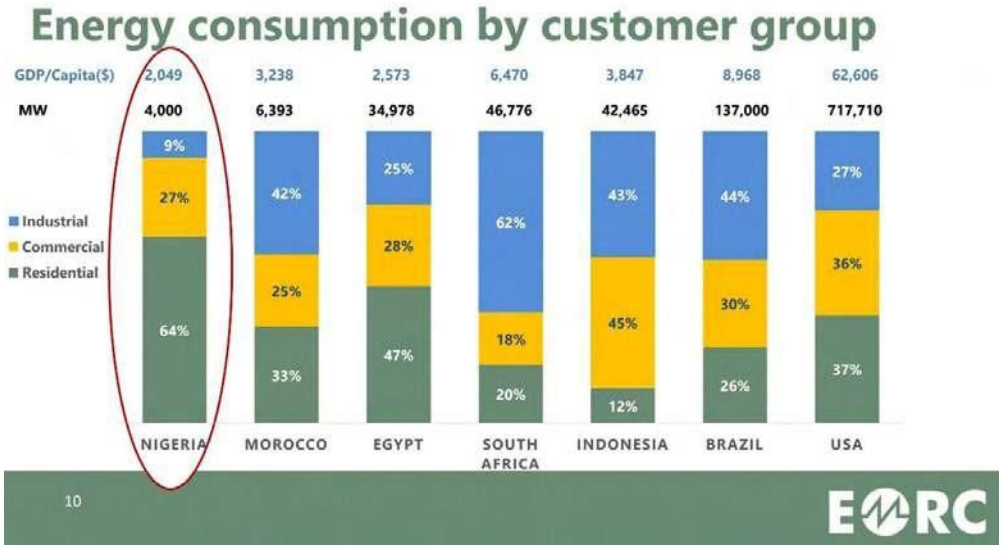

Figure 2: Chart showing the rate ratio of energy consumption in Nigeria and other countries Source: EMRC Nigeria

If the number of houses that has access to electricity is increased, and the source of electricity is not diversified to more renewable sources, it is safe to assume that the energy consumed and CO2 produced will have a lasting degrading effect on the atmosphere and at large the country. It is therefore necessary to come up with sustainable practices to ensure a comfortable life for the current and future generations.

The aim of this research is to establish best strategies for energy conservation in residential buildings.

Energy conservation practices for residential buildings

Ogini *et al*. (2017) proposed contemporary design options to improve the thermal comfort of buildings. They believe that if buildings are made to fit their environment less amount of energy

will be used and there will be adequate thermal comfort. Some of the design options they suggested include creation of microclimate, proper lighting, proper ventilation and using shading devices. They believe that it is possible to have buildings without artificial means of cooling and heating. They however did not make consideration for all types of weather and climate, and no solution to already existing buildings was suggested.

The chief function of a building is to provide a comfortable indoor environment to the occupants (Garima, 2016). He believes the focus of energy conservation practices is to optimize the energy performance of a building while reducing dependence on energy guzzling devices without compromising the comfort of the inhabitants. He also states that the amount and energy used in a building depend mainly on three factors: Quality of life of inhabitants, Climate and Nature of building use. Unlike Ogini *et al*. (2017) he analyzed the different energy use in different seasons, providing necessary data that could be used to propose a balanced design that is functional in all seasons. He, however, did not come up with solutions to already existing buildings and does not share the same belief with Ogini *et al*. (2017)that secondary sources of heating and cooling could be eliminated completely, he believes their use can be reduced, reducing the amount of energy used.

Akande (2015) states that the availability and the use of energy in buildings is pivotal to the building's functionality but if the energy use in buildings is not regulated, it can steadily lead to costly waste to the building users and more importantly to continuous release of CO2 into the atmosphere leading to global rising temperatures and climate change. Unlike Ogini (2017) and Garima (2016), he believes already existing buildings can be retrofitted to conform to current sustainable trends and practices and also improve the indoor comfort of the users. He did not take into consideration the lifecycle of the buildings but only focused on the energy consumed during the middle phase of the building.

Ganahao (2015) recognizes the fact that the building lifecycle is to be considered when establishing sustainable practices to aid energy conservation. He believes the amount of energy used depends on the standard of living of the occupants of the building, people who desire more thermal comfort use more energy services. He believes assessment tools should be used to determine the possible amount of energy a building will use before it is constructed. However, he did not propose possible solutions for the whole life cycle of the building but only the middle phase.

The level of energy provided determines the amount of energy used (Okerieimoh, 2019). A lower amount of energy will have to be used in large amounts and since energy is essential for daily living if it is produced in small quantities large amounts of it will have to be used to achieve the end goal. He believes that energy efficiency does not eliminate the use of energy but it's a process where energy is used in a manner that will minimize the amount of energy needed for services. He believes that there are 2 ways to ensure energy efficiency, technological approach which involves the change of obsolete technology to a more efficient one, and behavioral approach which involves a change in the manner of doing things. He believes that one of the major ways energy can be reduced in Nigerian residential buildings is through the use of energy efficient bulbs instead of the usual incandescent 'yellow bulb'.

Previous researchers have established and recommended the following variables to be considered for studies on energy conservation in residential buildings. The variables were used to analyze literature to determine the best energy conservation practices that should be adopted.

1. Climate: the climate of the area where the building is located determines the amount of energy that will be used for heating or cooling. (Akande 2015)
2. Building use: the nature of activities carried out in the building and their duration determine energy use. (Garima 2016).

3. Quality of life of inhabitants (standard of living): people with a higher standard of living tend to have more need for energy. (Garima 2016).
4. Contemporary design options: orientation, zoning and other factors considered during the design stage of buildings affect their energy use. (Ogini *et al*. 2017)
5. Building lifecycle: the amount of energy expended from inception to demolition. (Ganahao 2015)
6. Amount of energy supplied and used: the lower the energy, the more of it that is required. The type of energy supply is also one of the factors to be considered. (Okerieimoh 2019).
7. Nature of equipment's/additional facilities: the amount of equipment's in the building and their energy consumption rates. (Garima 2016)

METHODOLOGY

Semi systematic review method was used. It is a type of qualitative research method which is used for topics that have been conceptualized differently and studied by various groups of researchers within diverse disciplines (Wong et al 2013). it is applied when it is impossible to review all relevant material concerning a subject and it often looks at how research within a selected field has progressed over time or how a topic has developed across research traditions. In general, it seeks to identify and understand all potentially relevant research traditions that have implications for the studied topic and to synthesize these using meta-narratives instead of by measuring effect size (Snyder 2019). This method was used because of the focus of this research, which involves a study of previously established principles for energy conservation in residential buildings and to postulate the best strategies amongst the numerous proposed.

Survey research design was used in this research, it is a form of research where data is collected from samples to make inferences about a population, and it is used to study attitudes and opinions. Longitudinal survey design was used, it is used to collect data over a long period of time. The Trend studies aspect of longitudinal survey research design was focused on, which involves identifying a population and observing changes within that population over a period. This was used because the focus of this research involves an in-depth study of literature over a wide period. (Creswell 2012).

When applying semi systematic review method, researchers streamline their study to the area of interest in question and observe the theories postulated overtime about it and this serves as their study area (Snyder 2019). Therefore, the study area of this research was energy conservation in residential buildings as the researchers aim was to analyze various theories by several authors in that field. Convenience sampling was used to select a suitable subset of data to be analyzed, because of its ability to select relevant data from a wide range of ideas and this research required precise data gathering from a large selection. Literature were chosen based on the necessary criteria to fit the established study area, Energy conservation practices, sustainable energy & residential buildings were used as criteria in the selection of articles from literature.

Observation schedule was used for this research because of the research design that was adopted, which requires an observation of trends of the various established variables. Primary Data was collected from Academic research repositories based on the developed variables using the observation schedule developed by the researcher. The data was organized using appropriate codes that were assigned to each variable that was identified in the literature review. The organized data was analyzed manually via content analysis which involves a researcher quantifying and analyzing the meaning of words or text and making inferences from it (CSU 2004), This method was used because content analysis is a commonly used technique

and can be broadly defined as a method for identifying, analysing, and reporting patterns in the form of themes within a text (Braun & Clarke 2006).

Results and Discussion

After the data was analyzed the following results were obtained:
Number of resources used = 50
Number of entries of recommendations =64
Number of single recommendations by authors = 35
Number of multiple recommendations by authors = 14
As shown in Table 1, from the 64 recommendations gotten from previous researches majority of the researchers proposed contemporary design options and regulation of the amount of energy supplied and used as strategies to be adopted to achieve energy conservation in residential buildings. This however does not exclude the other variables established.

Table 1: Observed Measures for energy conservation

VARIABLES	CODE	NUMBER OBSERVED
Quality of life	QL	0
Climate	C	9
Building use	BL	0
Contemporary design option	CDO	30
Building lifecycle	BL	3
Energy supplied and used	E	20
Nature of equipment's/additional facilities	EQ	2

Climate

Designing with the climate of a region aids in establishing buildings that are best suited to the environment however they cannot be used as a universal standard, the use of local building materials and natural landscape features also aids in creating sustainable environments.
Further analysis of climatic recommendations by authors can be seen in table 2.

Table 2: Implicit climate data

RECOMMENDATIONS	INTERPRETATION
Use of energy efficient materials	This aids in developing resilient buildings for harsh climate zones
Regular audit of buildings	This aids in observing the reaction to buildings to various weather conditions
Developing and implementing energy building codes	This gives laid down rules to be followed to ensure efficiency of buildings in various climatic conditions
Heat storage and time lag should be minimal	Buildings should be constructed in ways that they give off excess heat to the environment, especially in hot and dry climates
Materials should be permeable to air to provide protection from precipitation	Building materials should be able to allow air efficiently pass through in order to aid thermal comfort and prevent stale air in buildings.
Passive cooling	This is used majorly in hot climatic conditions to aid the indoor comfort of buildings for its occupants
Trees and vegetation at strategic locations	Landscape features shouldn't be installed half hazardly but should be precisely located to ensure shading and protection from harsh climate
Thermal modernization of outer walls	The exterior walls of the building bear the pressure of the climate of the environment and should be fortified i.e. made permeable or air/water resistant depending on the nature of climate

Passive solar techniques	This applies to cold climatic conditions, ways to absorb and trap heat in buildings like insulation should be adopted
Well insulated design	This applies to cold climatic conditions that require compact design with no air leaks
Use of phase change materials	Materials that change based on the nature of the exterior weather condition make designing with the climate less tedious as the weather of an environment changes based on times and seasons
Use of local standard materials	This aids in design as materials found locally have already through the process of evolution adapted to effectively suit the environment

Building Life cycle

Designing with building lifecycle ensures that the whole process from inception to demolition is sustainable, it ensures that the overall cost of the building over a long time is sustainable, although the initial cost of this process may be much.

Table 3: implicit building lifecycle data

RECOMMENDATIONS	INTERPRETATION
Cost effective design options to achieve minimum life cycle cost	The entire life cycle of a building (from preliminaries to demolition) should be simulated and the most cost effective path chosen, this will aid in the reuse of energy and highlight various ways to conserve energy in buildings apart from during its active period of use
Use of green construction to reduce the negative impact on the environment	Green construction ensures that all materials and methods used in the construction of buildings are sustainable
Building condition assessment	The assessment of buildings intermittently help to observe the changes in the energy conservation of buildings as years pass and aid in preparing effectively for future buildings

Contemporary Design Options

The use of contemporary design options have gone a long way in aiding sustainable design as they have evolved overtime with the changes in Architecture and design.

Table 4: contemporary design options implicit data

RECOMMENDATIONS	INTERPRETATION
Use of passive and active systems	This helps create a balance and efficiency, it also involves the use of mixed mode design I.e. the use of both mechanical and natural means of ventilation
Developing and adopting energy use index	The amount of energy used should be monitored effectively
Use of local building materials	Local materials help regulate the building temperature effectively
Contemporary design elements	Design elements like shading and over hangs should be incorporated
Use of appropriate colours	Light or dark colours should be used to trap or release heat from buildings
Proper orientation of buildings	Buildings should be placed effectively on site to maximize the sun direction, slope, wind direction etc.
Proper ventilation	The use and placements of windows is important in maintaining indoor comfort of buildings
Use of shading devices	Shading devices prevent solar glare and heat gain
Proper lighting	Lighting reduces the dependence of mechanical means of lighting and thus reduces the amount of energy consumed
Creation of micro climate	The creation of a sustainable micro climate around the building envelope ensures the buildings efficiency regardless of the prevailing weather conditions
Preventing infiltration	Buildings should be air tight
Insulation	Buildings should be insulated to prevent loss of energy
Use of computer programs	Smart buildings should be proposed to measure levels of energy consumed, indoor comfort and other relevant data

Nature of Equipment

The nature of equipment used buildings must be energy efficient, thus, obsolete equipment's must be updated overtime.

Table 5: nature of equipment implicit data

RECOMMENDATION	INTERPRETATION
Efficiency of electromechanical systems	All equipment's used in buildings should be energy efficient to prevent the overuse of energy
Higher efficiency systems	The systems used in the design and construction of buildings should be the best established by constant improvement and recommendations

Amount of Energy supplied

The amount of energy supplied has to be sufficient in order to prevent demand for more. This will need to be monitored and regulated by governing bodies.

Table 5: amount of energy implicit data

RECOMMENDATION	INTERPRETATION
Tracking energy usage through software	This enables facilities managers and architects to detect how energy is used in buildings and propose counter measures effectively suited
User behaviour modelling for optimization of energy consumption	Simulations of buildings models help to see the amount of energy proposed buildings will likely consume
Building energy simulation programs	Simulations of buildings models help to see the amount of energy proposed buildings will likely consume
Renewable energy sources	Renewable energy makes sure the source of energy is always available and ensures the continuous production of energy
Use of light colour paints	Light paints allow light and heat to bounce off, therefore they do not trap energy
Use of LED bulbs	These have been proven to be better than incandescent or filament bulbs
Sealing doors and windows	This ensures lack of waste of artificial heating or cooling and prevents more amount of energy to be used
Implementation of adequate energy codes	Established building codes should be strictly followed for efficiency
Thermal insulation of the building envelope	Insulation of the whole building envelope prevents air leeks and optimizes the production of energy by artificial means
Managing heat flows by architectural design	Architects should design buildings such that they aid the flow of air within the building
Zero energy buildings	This ensures the use of minimal energy in buildings and creates self-sustaining facilities
Energy-efficient equipment's	All equipment's used in buildings should be efficient to prevent over use of energy
Installation of smart meters	These help monitor building performance

CONCLUSIONS

From the research it is evident that the decisions taken during the design and construction phase of buildings affects the overall performance of the building throughout its lifecycle, it is evidently easier to design energy conservative buildings from inception than it is to retrofit existing buildings to be more energy conservative, as such great care and detail should be taken when designing buildings. The type of energy supplied and the equipment's installed should also be noted as the quality of life of occupants does not have a direct effect on the energy used if all the right principles are implemented

Multiple methods can be used to ensure energy efficiency, however the most widely adopted are contemporary design options which gives specific details on several parts of the building and designing with climate. This can be achieved with standardized building codes for

different localities as general building regulations are not a viable means to ensure conservation of energy. However, buildings should also be designed with the end goal in mind, all or most of the building should be recyclable or reusable after its lifecycle has expired.

It is also clear that the residential sector in Nigeria is the greatest consumer of energy in the country, and these numbers are steadily growing as more people and communities get access to electricity. The implementation of energy conservation strategies not only ensures the reduction in energy usage for individuals but also if sustainable strategies are established and implemented, Nigeria as a whole will become more sustainable and in the long run have healthier neighborhoods. The establishment of sustainable strategies must be thoroughly thought out and an adequate combination of suitable and effective strategies will be most useful. Each strategy has several subsets that can be varied to fit different regions ad this should be the optimum approach, rather than having a general strategy for the whole country.

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