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Energy Efficiency Design Strategies in Office Buildings: A Literature Review

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Abstract. The growing concerns over the adverse effects of buildings on the environment and the need to achieve users' thermal, visual, acoustic, spatial and indoor environmental air quality comfort have given rise to the demand for energy efficient buildings. This paper relied on a review of 36 articles published between 2007 and 2019 to identify and categorise energy efficiency design, planning and construction applicable to office buildings. The data were randomly selected using Science Direct and Google Scholar search engines on the internet and analysed by thematic textual analysis. The results revealed 29 energy efficiency design strategies applicable for office buildings which were categorised into the three distinct phases of building projects: pre-construction (design and planning), construction and post construction stages. The strategies were further categorised into energy efficient landscape designs, site selection, building orientation, building plan and appropriate space organisation. The study also established that building envelope systems, building orientation, integration of renewable energy sources and day lighting design strategies were the most implemented in office buildings. The review concluded by highlighting the key areas of focus in energy efficiency design strategies in office buildings, the extent research has progressed on the subject and future possible directions on the topic.

Keywords: Energy Efficiency Design Strategies, Office Buildings, Sustainability and Literature Review.

1. Introduction

Office buildings consume a lot of energy during construction and occupation and these have adverse consequences on the environment and users' health and comfort. [1] observed that the Intergovernmental Panel on Climate Change (IPCC) meeting in South Korea reported that greenhouse gases (GHGs) emission had reached an alarming rate, thus this requires immediate attention by countries across the world. The report also noted that carbon dioxide was the most dangerous greenhouse gas released into the environment with 8.6 billion metric tons and that this will double by the year 2030. According to [2], studies in Europe have shown that energy use and consumption in office buildings have reached an alarming 36% and that non-residential buildings are known to consume about 27.5%. Therefore, to assemble a building that places energy efficiency as its primary priority, the process begins by understanding the right approach to design, while it is also important to consider the surrounding climate and unique conditions within the environment.

It has also been acknowledged that proper building orientation on site, building form, construction materials and building envelope systems are all very essential in minimizing building heat gains [3]. [4] argued that office buildings have major characteristics that differentiate them from other building types. These major characteristics include high energy consumption capacity due to a

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high dependence on mechanical heating and cooling systems and artificial lighting. In fact, evidence in the literature [5] showed that in a developing country like Nigeria with complex and epileptic power supply situation, office air-conditioning for heating, ventilation and air conditioning accounted for between 40% and 68% of electrical consumption. This is followed by energy for lighting, which accounts for between 13% and 37% and office equipment that consumes between 12% and 25% of energy, respectively. Whereas, previous authors [6] noted that building types are different, buildings that consume less energy otherwise referred to as energy-efficient buildings have certain distinct features that stand them out amongst other buildings. These distinct features are mainly the passive design features incorporated into the building at the design, planning and construction stages. Other energy efficient design strategies incorporated in energy efficient buildings are (active design features), which include design features that have a different result on the building like renewable panels, accumulation of water in ponds and landscaping as explained by [7].

Energy efficient buildings are expected to meet other design objectives which include enhancing occupant's health and well-being, their ability to use water and energy and other resources more efficiently and minimizing the heavy impacts of the building on the surroundings. As a result, different countries have been developing building codes with focus on energy efficiency design solutions. Many of such codes have taken cognizance of the use of bioclimatic design concepts and principles and the incorporation of several energy efficiency saving measures with the overall target of making office buildings more energy efficient and at the same time promoting the comfort and health of users of such buildings [8].

Due to the large amount of energy, office buildings usually consume, designers are constantly engaging different design strategies to conserve energy in such buildings and their like. To this end, several energy efficiency design strategies have been identified in some previous literature [7; 2; 4; 8; 5]. However, the strategies specifically applicable to office buildings are yet to be fully aggregated and categorised in literature. Also, a survey of published literature indicated preponderance of different conceptions, ideas and opinions on the various strategies for achieving energy efficiency in buildings in general and office buildings in particular. In view of the growing literature and evolving body of knowledge on energy efficiency design strategies, it has become increasingly difficult to identify and classify the existing energy efficiency design strategies applicable to office buildings. Moreover, there appears to be a lack of conscious effort at identifying and classifying the existing strategies applicable into different building typologies to serve as a guide for building designers and developers on the available options. These, among other things, have firstly, obscured our knowledge of the number of strategies available and the different groups they can be classified into; secondly, contributed to the lack of understanding of the trend in research on the subject.

In the light of the forgoing, the study was conceived to identify and categorise existing energy efficiency design strategies integrated in office buildings from literature, towards contributing to the general discuss on ways of promoting energy efficiency strategies in the development of the built environment. The following three objectives were set towards achieving the aim:

i. To identify the energy efficiency design strategies integrated in office buildings;
ii. To identify the categories of energy efficiency design strategies used in office buildings; and
iii. To establish the most implemented energy efficiency design strategy in office buildings.

The scope of the study is limited to office buildings and covers all the three different phases in the lifespan of buildings which are: pre-construction (planning and design), construction and post-construction stages. The focus of the study was restricted to office buildings, because such category of buildings usually consume a higher amount of energy compared to residential buildings. The literature was searched through the use of the internet. The scope of the search was limited to articles in Science Direct and Google Scholar databases, because they both have a large repository of peer-reviewed articles. Also, limiting the literature search to the two databases allowed the study to be manageable within the funds available for the research.

The study is justified in that it: aggregated and categorized existing energy efficient strategies in office buildings; empirically established the mostly used among the strategies; and contributed to the general discuss on energy efficient buildings. The study also established a new empirical resource base for scholars, educators, professionals' and policy makers on issues relating to energy efficiency in office buildings. In addition, the study serves as a pointer for further research on the subject. In general, the study highlighted the current trend and sign posted future directions in research on energy efficiency design strategies in office buildings in particular and buildings in general. The article is generally structured into 8 parts as follows: abstract, introduction, methodology, results, discussion, conclusion, acknowledgments and references.

2. Methodology

This paper is a systematic review article, as the aim of the study centres around identifying and categorizing the existing energy efficiency design strategies used in office buildings from literature. According to [9], a systematic review of literature helps to identify, select and critically appraise research in order to answer clearly formulated question(s). It is also expected to follow a clearly defined protocol or plan where the criteria are clearly stated before the review is conducted, as presented with research questions in this study. It is observed that previous studies [10] & [11] used the same approach to conduct their research.

A six step process was used in carrying out the document review process: (i) Identification of the research problem; (ii) Formulation of research questions; (iii) Identification and selection of relevant literature; (iv) Evaluation of selected literatures; (v) Summarizing data from the literatures and (vi) Interpretation of findings. The articles reviewed were identified from the searches conducted in two prominent online databases of research and academic literature namely: Science Direct and Google Scholar. These databases were chosen because they have a large repository of research materials of peer reviewed articles. In conducting the searches, the two keyword phrases used were *'energy efficiency design strategies* and *office buildings*. The search in Google scholar for articles published between 2007 and 2019 with citation returned 17, 900 results, including patents. Similarly, the search in Science Direct for materials on the subject published during this period produced a total of 25, 983 results comprising 1, 946 review articles, 16, 999 research articles, 371 encyclopedias and 3, 988 book chapters. The top three leading journals where these materials were published are: Energy and Building with 1, 756 articles, Energy Policy with 1,082 articles and Applied Energy with 847 articles.

Examination of all the articles identified from the searches revealed that some of the articles in Google Scholar were also in Science Direct. It was also observed that articles that had the phrase '*energy efficiency design in buildings'* were included in the results of the search. Most of the articles identified focused on energy efficiency in buildings, hence there was a need to sieve out those related to office buildings. In the selection of the articles reviewed, inclusion and exclusion criteria were set. The first inclusion criterion used was that only materials whose focus are on energy efficiency design strategies in buildings were selected. This category of articles was identified by reading through the abstracts. Then the final selection was done by identifying articles that focused directly on energy efficiency design strategies in office buildings. How recent the articles are, was also taken into consideration. Eventually, 36 articles published between 2007 and 2019, found to be directly relevant to the scope of the study investigation were selected and reviewed. Thematic textual analysis was used to analyse and synthesize the data. The data was first coded after which relevant themes in line in the aim and objectives of the study were identified and reviewed. The findings were presented descriptively using texts, tables, plates and a figure for easy understanding and clarity in the following section.

3. Results

3.1. Concept of Energy Efficiency

Energy efficiency is a vital component of the global process to reduce CO_2 emission and seeks to reduce the primary energy consumption to between 11% and 20% by the next 10 years and between 30% and 41% by 2050. Based on these targets, some authors [12] have explained that as it relates to buildings, energy use deals with the amount of energy used in heating, ventilation and lighting in buildings. [13] explained that energy efficiency is the effective use of energy to support economic growth and social development, while also improving occupants' health and well-being, with little or no adverse effect on the environment. [14] further advanced more light on this by noting that with the rate at which the climate around the world is changing, countries are beginning to change their perceptions about energy use and the way fossil-based energy is harming the environment. Consequently, [15] suggested that the global community in trying to proffer solutions towards arresting the effects of global climate change, has started insisting on efforts at standardizing solutions that make it mandatory for the built environment to be more energy efficient.

From the foregoing, it is evident that there is a consensus among authors that energy efficiency simply means using less energy or minimal amount of energy to achieve optimal result. Put succinctly, it is the elimination of waste in the use of energy by different authors. [16] noted that energy efficiency measures create long-lived reduction in electricity use as they are built into equipment and appliances. Based on this understanding, [17] explained that several energy-efficiency technologies have been developed and many such as refrigerators, clothes washers and dryers, hot water heaters, electronics and lighting systems are found in homes across the world.

3.2. Energy Efficient Buildings

Evidence in literature revealed that the sudden rise of temperature in urban areas, increase in risk of global warming and climate change are among the reasons why energy efficient buildings are needed now than ever before [18]. It has also been reported that other harmful effects of climate change include increase in heat radiation from the sun which penetrates the indoor space of buildings through openings in walls, roofs, and fabrics thereby leading to overheated indoor space and discomfort [19]. Literature also revealed that buildings are the major culprits that account for one-third of the greenhouse gases emission with its attendant harmful effects to the ecological environment. It is argued that buildings contribute one-third of global CO_2 emissions. Based on this understanding, energy efficient buildings have been described as buildings that reduce the level of energy consumption and at the same time guarantee users' comfort [20]. Figure 1 captures the various aspects of energy efficient buildings.

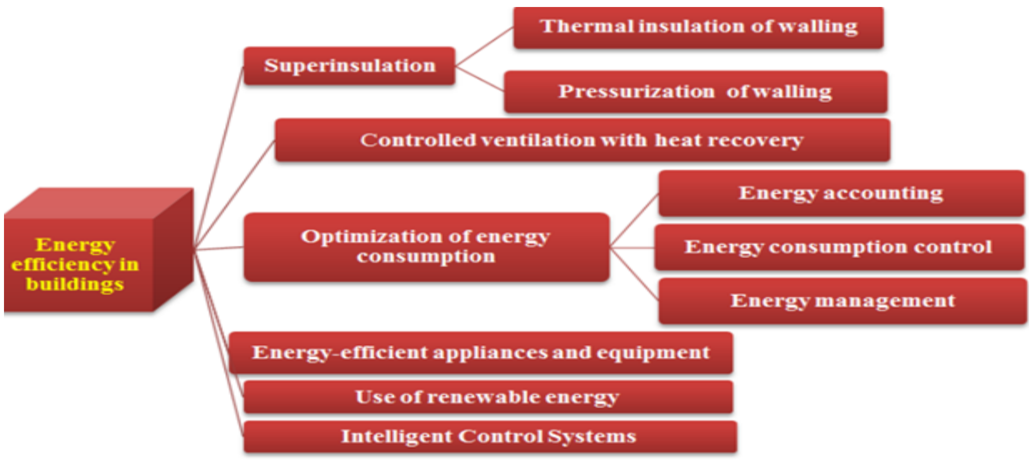

Figure 1: *Concept of Energy Efficiency in Buildings*
Source: *[21].*

Figure 1 indicates that to achieve energy efficient buildings, it will require having super insulation of the building envelope systems, a good controlled ventilation with heat recovery systems and good optimization of energy consumption systems. These are having effective energy efficient appliances and equipment systems and the use of natural resources like renewable energy, as well as having a very effective remotely controlled electrical appliances systems. In their study, [1] noted that the primary purpose of erecting a building structure is to provide a habitation or dwelling for a man with the aim of protecting him from the vagaries of the environment. What this means is that buildings are designed and erected for the main purpose of providing occupants certain degree of comfort that enable them to function effectively.

Among the several areas of comfort building occupants are expected to enjoy are thermal and visual comfort. This suggests why [22] observed that recently, there has been awareness on the part of building professionals about climate change and issues relating to energy use in buildings and their ability to ensure that energy is efficiently used to provide occupants with acceptable levels of thermal and visual comfort. Moreover, some authors [23] & [24] observed that energy efficient buildings are first and foremost associated with lower maintenance cost and reduction in adverse environmental impact and a reduction in CO_2 emission associated with building operations, which is largely responsible for climate change. Secondly, they help to limit further damages within the ecosystem by reducing the use of natural resources like energy, land, water and depletable materials in their entire life cycle. These might help to explain why the need to have energy efficient buildings has been a subject of discussion among authors from different research and academic backgrounds

3.3. Energy Efficiency Design Strategies

The study investigation revealed that technologies abound that enable actualisation of energy efficient buildings. Energy efficiency design strategies refer to those measures and features incorporated at the design stage of buildings in ensuring that buildings become more efficient in the use of energy for lighting, heating and ventilation. Energy efficiency design strategies can be integrated within buildings at project inception stage or can be integrated while renovating older and existing buildings. [25] observed that energy efficient design strategies in buildings in general and office buildings in particular, have been made popular via the existing building codes and company policies that insist on protecting the environment.

[26] revealed that there are a lot of strategies available in achieving energy efficiency in buildings and these include but not limited to effective sustainable urban planning, optimised site planning and design, including natural ventilation and suitable orientation; solar, geothermal and other renewable energy integration, bioclimatic architectural design and enhanced mechanical ventilation with optimised heat recovery system. [27] identified bioclimatic designs, mixed-mode (natural and mechanical) ventilation systems and effective wall to wall ratio as strategies that reduce the HVAC loads in office buildings, thereby making them more energy efficient. On the one hand, [28] argued that facade properties in office buildings and design factors dependently affect the energy demand in these buildings. [29] recommended a mix of strategies, including building orientation, facade design treatment, strategic landscape, space planning, natural ventilation, natural lighting and sun shading design.

Furthermore, some authors [25] revealed that majority of energy consumed in buildings are used for lighting, space heating, cooling, ventilation and water heating. These authors explained that building energy consumption is subject to many factors which include: climatic conditions, building design, building envelope, occupant behaviours, systems and controls and maintenance. [30] observed that for a building to be energy efficient, it will consist of the process where less energy is used for its functional requirements of cooling and lighting, while also maintaining comfort with the well-being of the buildings users. Notably, all the aforementioned strategies can help to ensure that there is a reduction of energy use in buildings while providing much superior thermal and visual comfort for occupants. Summary of the various strategies and the number of articles they were mentioned in is presented in Table 1.

Table 1: *Energy Efficiency Design Strategies Identified in Literature*

SN	Energy Efficiency Design Strategies	Number of Articles with Evidence of Implementation	Ranking
1	Building Envelope	17	1
2	Building Orientation	8	2
3	Making Provisions for Renewable Energy Sources in the Design (solar and photovoltaic cells)	8	2
4	Day Lighting Design	8	2
5	Mixed-mode Ventilation System (Natural and mechanical ventilation systems)	6	3

6	Design for Future Retrofit	6	3
7	Occupancy and CO_2 Sensors	6	3
8	Building Form	5	4
9	Specification of Energy Efficient Building Materials	4	5
10	Building Shape	3	6
11	Exterior Shading Design	3	6
12	Building Plan and Appropriate Space Organization	3	6
13	Effective Wall to Wall Ratio	2	7
14	Day Lighting Control Mechanisms	2	7
15	Site Selection	1	8
16	Site Planning	1	8
17	Integrated Design Process	1	8
18	Energy Efficient Landscape Design	1	8
19	Specification of Bright Coloured Roofs	1	8
20	Specification of Bright Coloured External Wall Paints	1	8
21	Green Roofs	1	8
22	Biophilic Design	1	8
23	Bioclimatic Design	1	8
24	Solar Hot Water Heating Mechanisms	1	8
25	Service Core Placement	1	8
26	Sky Garden	1	8
27	Double Skin Facades	1	8
28	Night Ventilation (E.g. air flow patterns, user behaviour, building characteristics, heat transfer, energy balance)	1	8
29	Eco Feedback System (Collection of energy-use data)	1	8

Table 1 shows that a total of 29 energy efficient design strategies were found to have been linked to office buildings in literature. The Table indicated that the most common energy efficiency design strategy integrated in office buildings is the nature of the building envelope. This is reported in 17 articles in different countries around the world. This is followed by building orientation, making provisions for renewable energy sources in the design (solar and photovoltaic's) and day lighting design strategies mentioned in 8 different articles identified and reviewed. Next to these are those identified in six different articles which include mixed-mode ventilation system (natural and mechanical ventilation system), design for future retrofits and occupancy and carbon dioxide sensors. The least reported energy efficiency design strategies are site planning, site selection, biophilic design, bioclimatic design and eco feedback system (collection of energy-use data).

3.4. Categories of Energy Efficiency Design Strategies in Office Buildings

Evidence from literature [30] suggested that there are several categorisations of energy efficiency design strategies and techniques. Therefore, in an attempt to categorise the 29 energy efficiency design strategies identified, a review of an existing classification was conducted. [30] further revealed that energy efficiency design strategies have been categorised based on building envelope, lightings, energy recovery ventilation, advanced control systems, ground source heat pump systems, efficient refrigerant systems, radiant systems, plug loads and fault detection and diagnostics. To map these strategies with the different phases of building project namely, design and planning, construction and post construction phases, the 29 energy efficient design strategies identified, were categorized into three groups as follows: (i) Design Strategies at the Pre-building phase (DSPb); (ii) Design Strategies at the Building phase (DSBp) and (iii) Design Strategies at the Post-building phase (DSPBp).

Tables 2, 3 and 4 are data that show the identified energy efficiency design strategies at the various construction stages of pre-construction (planning and design), construction and the post-construction phases. The first category is the DSPb displayed in Table 2 which are 15 in number. Following the Table, are Plates 1 and 2 showing examples of how building shape and double skin facade respectively, respectively, were used as energy efficiency design strategies at the pre-building stage.

Table 2: *Energy Efficiency Design Strategies at the Pre-Building Phase (DSPb).*

SN	Energy Efficiency Design Strategies	Description
1	Building Envelope	The physical separator between the conditioned and unconditioned environment of a building
2	Building Shape	Configuration of a building
3	Building orientation	Positioning of a building in relation to seasonal variations in the sun's path as well as prevailing wind patterns
4	Building Form	The point of contact between mass and space
5	Specification of Energy Efficient Building Materials	Materials that consume less energy
6	Building Plan and Appropriate Space Organisation	Space plan will also define the circulation patterns that show how people will move through the space
7	Site Selection	Involves measuring the needs of a new project against the merits of potential locations.
8	Double Skin Facades	The double-skin facade is a system of building consisting of two skins, or facades
9	Energy Efficient Landscape Design	A well-designed landscape not only can add beauty to your home but also can reduce your heating and cooling costs
10	Making Provisions for Renewable Energy Sources in the Design (Solar and Photovoltaic')	A renewable resource is a natural resource which will replenish to replace the portion depleted by usage and consumption,
11	Effective Wall to Wall Ratio	Measure of the percentage area determined by dividing the building's total glazed area by

		its exterior envelope wall area.
12	Integrated Design Process	Integrated design is a comprehensive holistic approach to design which brings together specialism's usually considered separately
13	Specification of Bright Coloured Roofs	The lighter the colour, the better the energy efficiency
14	Solar Hot Water Heating Mechanisms	Solar water heating (SWH) is the conversion of sunlight into heat for water heating using a solar thermal collector
15	Site Planning	A site plan is a "set of construction drawings that a builder or contractor uses to make improvements to a property.

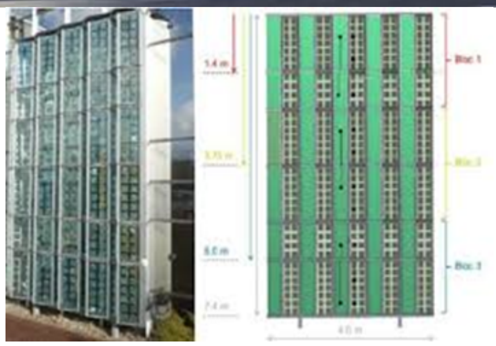

Plate 1: *Building Shape*
Source: *[31].*

Plate 2: *Double Skin Facade*
Source: *[32]*

Table 3 shows the DSBp category which are 11 in number. Following the Table, are Plates 3 and 4 showing examples of how biophilic design and green roofs respectively, were used as energy efficiency design strategies at the building stage.

Table 3*: Energy Efficiency Design Strategies at the Building Phase (DSBp)*

SN	Energy Efficiency Design Strategies	Description
1	Mixed-mode ventilation system (natural and mechanical ventilation system)	Mixed-mode ventilation refers to a hybrid approach to space conditioning that uses a

		combination of natural ventilation from operable windows.
2	Biophilic Design	Incorporates natural materials, natural light, vegetation, nature views and other experiences of the natural world into the modern built environment.
3	Bioclimatic Design	Refers to the design of buildings and spaces (interior – exterior – outdoor) based on local climate.
4	Service Core Placement	A multi-storeyed space in a tall building, usually centrally located, that houses essential building services such as elevators.
5	Sky Garden	A garden situated on one of the upper floors of a high-rise building.
6	Night Ventilation (E.g. air flow patterns, user behaviour, building characteristics, heat transfer and energy balance)	The operation of natural ventilation at night in order to purge excess heat and cool the building fabric.
7	Specification of Bright Coloured External Wall Paints	The lighter the colour, the better the energy efficiency.
8	Green Roofs	A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane.
9	Daylighting Design	The controlled admission of natural light, direct sunlight, and diffused-skylight into a building to reduce electric lighting and saving energy.
10	Design for Future Retrofits	Providing something with a component or feature not fitted during manufacture or adding something that it did not have when first constructed.
11	Exterior Shading Design	Any mechanical equipment or textiles that are used either internally or externally or in between the internal and the external building space.

Plate 3: *Biophilic Design*
Source: *[33].*

Plate 4: *Green Roofs*
Source: *[34]*

Table 4 is the presentation of the DSPBp category which are 3 in number. Following the Table, are Plates 5 and 6 showing examples of how day lighting mechanism was used as an energy efficiency design strategy at the post-building stage.

Table 4: *Energy Efficiency Design Strategies at the Post-Building Phase (DSPBp)*

SN	Energy Efficiency Design Strategies	Description
1	Eco Feedback System (collection of energy-use data)	Collection of energy-use data.
2	Occupancy and CO_2 Sensors	Devices that detect when a space is unoccupied and accordingly automatically turn off (or dim) the lights, thereby saving energy.
3	Daylighting Control Mechanisms	Lighting control system that is responsive to the amount of daylight entering the building.

Plate 5: *Daylighting Control Mechanism*
Source: *[35].*

Plate 6: *Daylighting Control Mechanism*
Source: *[36]*

From Tables 2, 3 and 4, it is evident that in terms of applications of energy efficiency design strategies in office buildings, the pre-building stage lends itself to this than any other stage in the development of office buildings. This is followed by the building phase before the post-building stage.

4. Discussion

This study was guided by three main research objectives which are: to identify the energy efficiency design strategies integrated in office buildings; to identify the categories of energy efficiency design strategies used in office buildings; and to establish the most implemented energy efficiency design strategy in office buildings. Firstly, the study found that 29 energy efficiency design strategies have been linked to office buildings. The top three of these strategies are those associated with building envelope. This finding is not surprising, because of the key role building envelopes plays in protecting building occupants from elements of climate and in determining the indoor comfort of occupants. The implication of this result is that building envelope can easily be manipulated in order to achieve energy efficient buildings. The nature of manipulations can be majorly seen in the use of materials and finishes and these usually have cost implications in terms of purchase of the materials, as well as techniques and expertise required for their installation and maintenance. Next to building envelopes is building orientation, that is, making provisions for renewable energy sources in the design (solar and photovoltaic's) and day lighting design strategies. These are relatively cheaper strategies compared to those associated with building envelope. Whereas building orientation and day lighting design strategies are aspects of bioclimatic design strategies identified by [30]. Whereas, the use of solar panels and photovoltaic cells fall under energy-efficiency technologies identified by [17]. The key implication of these findings is that when it comes to research in energy efficiency design strategies for office buildings, progress has been made in the use of building envelope than any other strategy.

Secondly, three categories of energy efficiency design strategies were found to exist. They are: design strategies at the pre-building phase; design strategies at the building phase; and design strategies at the post-building phase. Based on this categorization, it is observed that the energy efficiency design strategies implemented at the design and construction stages of office buildings are more at the pre-building phase with 15 design strategies closely followed by design strategies at the building phase with 11 design strategies. The phase with the least energy efficiency design strategies is the post-building phase with three design strategies. These findings are also not surprising, because the pre-building phase can be described as the planning stage of the building when critical decisions about the building form, spatial morphology and building orientation and relationship of the building to its surroundings and others take place. Consequently, there is bound to be several of such energy efficiency design measures and options available and considered at this stage. Closely followed by this phase is the building stage, which is the design stage when the actual implementations of the decisions made at the pre-building phase takes place. The decisions made at this stage have significant influence on the building characters and other vital components of the building that have direct bearing on energy consumption. The stage with the least number of energy efficient design strategies is the post-building phase, which is the stage where data are collected to serve as feedback on the performance of the strategies engaged at the pre-and post-building phases. It is evident from the results that energy efficiency design strategies in office buildings are better integrated at both the pre-building and building phases.

Lastly, the review also revealed that the pre-design stage lends itself to energy efficiency design strategies than any other stage in the development of office buildings. This is followed by the building phase and lastly by the post-building phase. These findings are not out of place, because the main focus of the review is the identification of energy efficiency design strategies. The implication of this is that a high majority of the strategies identified should be those applicable at the planning and design stages of office buildings. Moreover, an elaborate explanation of the reasons for this findings has been provided in the preceding paragraphs.

5. Conclusion

This review article has identified and categorized the different energy efficiency design strategies integrated in the design and construction of office buildings, as well as established the most predominantly used. Arising from the findings, the following deductions are made. The first being that at least 29 different energy efficiency design strategies have been implemented in the design and construction of office buildings. Prominent among them are those applicable to the building envelope, building orientation and making provisions for renewable energy sources in designs (solar and photovoltaic cells). Secondly, existing energy efficiency design strategies linked to office buildings can be categorized into three major groups, namely; design strategies at the pre-construction stage, design strategies at the construction stage and design strategies at the post-construction stage. Lastly, a greater number of the energy efficiency design strategies are implemented at the pre-design stage than any other stage in the life cycle of office buildings.

Notably, the findings of the study are valuable for guiding built-environment professionals in making decisions on the appropriate energy efficient strategies to employ at the planning, design and construction stages in the development of office buildings. The study also showed the extent to which research in energy efficiency design strategies have progressed, thus uncovering the efforts made at improving energy efficiency in office buildings within the context of the global drive to reduce the level of CO_2 emission in buildings. The article contributes to knowledge in that it identified and categorized the existing energy efficiency design strategies suited for office buildings, as well as established the hierarchy of how often the strategies are utilized by professionals in the development of office buildings. This will enhance the understanding of the available strategies, particularly as they relate to office buildings, which will further help to guide stakeholders better on which of the strategies to implement.

The authors are aware that the internet search engines used to gather the literatures reviewed in this research constitute a limitation of the study. Perhaps if the literature search scope is widened, more discoveries could have been made. Consequently, similar studies can be conducted using a wider literature search approach which may lead to the discovery of new themes. Also, related studies can be conducted to investigate other building types such as residential, commercial, industrial or sporting facilities.

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