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RETROFITTING EXISTING OFFICE BUILDING FOR EFFICIENT ENERGY MANAGEMENT AND PERFORMANCE

MODERNIZACJA ISTNIEJĄCEGO BUDYNKU BIUROWEGO DLA EFEKTYWNEGO ZARZĄDZANIA ENERGIĄ

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Abstract

This study focuses on designing an efficient energy utilization protocol for the University of Lagos Senate office building, to ensure the reduction of energy consumption, reduce the cost of power and also ensure energy efficiency. Pre-retrofitting, the energy consumption cost for the UNILAG senate office building was calculated to be ₦20, 236, 962 i.e. 776.78 EUI (kWh/m²/y) using the appliance approach. The impact of various retrofitting methods was also simulated and measured utilizing BIM tools such as Autodesk Maya, Autodesk Revit and Autodesk Insight. This resulted in an estimated reduction in energy consumption cost to between ₦19,304,038.05 and 18,549,199.3 post retrofitting, this translates to about 712 EUI (kWh/m²/y). Results show that a 4.61-8.34% reduction in energy usage for the senate house can be achieved using the methods proposed in this research.

Keywords: Building Information Management (BIM), Energy Retrofitting Interventions, Heating Ventilation and Air-Conditioning (HVAC), Green Building Extensible Mark-up Language

Streszczenie

Praca koncentruje się na opracowaniu procedury efektywnego wykorzystania energii w budynku biurowym Senatu Uniwersytetu w Lagos w celu zapewnienia redukcji zużycia energii, redukcji jej kosztów i zapewnienia efektywności energetycznej. Przed modernizacją koszt zużycia energii w budynku Senatu został obliczony jako ₦20, 236, 962, tj. 776.78 EUI (kWh/m²/y) w oparciu o zamontowane urządzenia. Symulowano wpływ różnych technik modernizacyjnych i prowadzono obliczenia korzystając z narzędzi opartych o technologię BIM, tj. Autodesk Maya, Autodesk Revit i Autodesk Insight. To doprowadziło do przewidywanej redukcji kosztów energii pomiędzy ₦19,304,038.05 i 18,549,199.3 po modernizacji, co odpowiada ok. 712 EUI (kWh/m²/y). Wyniki wskazują, że możliwa jest redukcja zużycia energii dla budynku Senatu na poziomie 4.61-8.34% w oparciu o metody przedstawione w pracy.

Słowa kluczowe: modelowanie BIM, modernizacja energetyczna, ogrzewanie, wentylacja i klimatyzacja (HVAC), oprogramowanie Green Building Extensible Mark-up Language

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LIST OF ABBREVIATIONS

BIM	–	Building Information Management
CFL	–	Compact Fluorescent Lamp
CF	–	Cubic Foot
CFM	–	Cubic Feet per Meter
DISCO	–	Distribution Company
EE	–	Energy Efficiency
ERI	–	Energy Retrofitting Interventions
FGN	–	Federal Government of Nigeria
GBCN	–	Green Building Council of Nigeria
gbXML	–	Green Building Extensible Markup Language
GENCO	–	Generation Companies
HVAC	–	Heating Ventilation and Air-Conditioning
IC	–	Initial Cost
IEA	–	International Energy Agency
IPP	–	Independent Power Producers
LCC	–	Life Cycle Cost
LED	–	Light Emitting Diode
MEP	–	Mechanical Electrical and Plumbing
NIPP	–	National Integrated Power Projects
OECD	–	Organization for Economic Co-operation and Development
SC	–	Shading Coefficient
SCL	–	Solar Cooling Load
SE4ALL	–	The Sustainable Energy for All Action Agenda
SHGC	–	Solar Heat Gain Coefficient
SF	–	Square Foot
SRR	–	Skylight-to-Roof Ratio
UN	–	United Nations
US	–	United States
VAV	–	Variable Air Volume
WWR	–	Window-to-Wall Ratio

1. INTRODUCTION

Buildings provide shelter for human beings to protect them from dangerous and hazardous social, environmental and economic implications. No wonder it is one of basic necessities of life aside from food and clothing. Significant amounts of the day as humans are spent in the building, whether as home, office, factory, workshop and so on. This means that the effect of buildings in the social, environmental economic wellbeing of humans cannot be overemphasised.

Several social activities go on in the building in the form of play, work, lodging, family bonding, gaming, relaxation and so on which could have almost impossible without a building. This gives the building a strategic role to play in the existence of a balanced human life in maintaining social stability which will enhance social performance. The idea of environmental sustainability arose as a result of themetamorphosis of trying to reduce the energy level consumption and the depletion of natural resources which was highly necessary given it importance in the built environment. This brought about the concept of going green in the built environment to maintain environmental sustainability. The pursuit of this sustainability has become one of the most important design objectives of building design in the built environment [1]. The concept of economic sustainability will always be achieved if there is social and environmental sustainability. When social sustainability and environmental sustainability is increased, it increases satisfaction, desire, want and the urge to acquire which will definitely increase demand and economic value will increase. This process will increase economic sustainability. Green building is therefore the main panacea towards achieving sustainable development while drawing a balance in the social, environmental and economic areas [2]. The creation of green buildings through sustainable development can be used to reduce the negative effects of the building on the environment as well as human life [3]. Also, it will increase the economic value of the building, increase the occupants urge to live in the building as well as their satisfaction [4].

The use of fundamental energy has grown incredibly in Nigeria. It is basic to observe that monetary improvement is a critical clarification behind the high energy use in different countries; this has led to the increase in the amount of force eating up electrical and mechanical assemblies. Along these lines it is basic to research more achievable energy use strategies, approaches and utilization techniques.

Energy retrofit of buildings can help accomplish cost and energy proficiency by improving the productivity of building envelopes, central air frameworks, lighting (outside and insides) and electrical machines. Retrofits for building relate to various objectives, for example, environmentally friendly power energy and zero-discharge building retrofits. Green structure retrofits improve the natural reaction of a structure, decrease water utilization, and increase the solace and estimation of the space with respect to a few variables, for example, light contamination, air contamination, and commotion contamination. Then again, energy building retrofits centre around enhancing the energy execution of a structure [5].

As indicated by Khoshbakht [6] "To compute the energy productivity of a structure, one should consider the energy utilization per square meter or square foot of the space, in correlation with standard energy utilization benchmark of such structure types under certain climate conditions". Benchmarks are applied fundamentally to warming, cooling, ventilation, lighting, fans, siphons and controls, office or other electrical hardware, and power utilization for outside lightings. Amusingly, the immense interests in the force area haven't yielded the ideal yield of power supply.

The economic development and expectation for everyday comforts of any nation is a sign of the size of its power industry. This is on the grounds that the feasible and stable force supply is apropos in advancing the expectation for everyday comforts just as the financial exercises of any country. It likewise shows an impression of the residents' admittance to clean water, improved medical care offices, development and advancement of the different portions of the public economy, for example, correspondence, industry among others. From the above affirmation, power supply is critical to public improvement in Nigeria.

A research carried out by Momoh [7] on the ramifications of helpless power supply on Nigeria's public improvement arrived at the precise resolution that the financial development and expectation for everyday comforts of any nation are a sign of the size of its power industry. He went further to express that the non-appearance or restricted stock of power has antagonistically influenced financial exercises in Nigeria like business exercises. This will prompt infrastructural rot and breakdown, conclusion of ventures just as a fast decrease in the accessibility of social pleasantries, for example, consumable drinking water, improved medical care administrations among others.

Energy utilization soared over in recent years because of the quick development of innovation, with utilization of energy not easing back down whenever soon [8], researchers and scientists the same have investigated different strategies to achieve more productive energy use worldwide and in Nigeria specifically. This literature review will assess a portion of the astonishing works that educated my choices in executing this venture, a portion of the evaluated works will be works done both in Nigeria and abroad to accomplish energy effectiveness in structures through retrofitting.

Onyenokporo [9] in 2018 left on a venture to create reasonable retrofit techniques and materials that can be utilized in existing private structures to improve tenants' warm solace in Lagos Nigeria. Their examination demonstrated that property holders might have the option to decrease their yearly energy utilization by up to 47% by going through a basic energy retrofit; they likewise reasoned that building retrofits might be done not simply to lessen energy utilization by central air and lighting frameworks, yet additionally to improve warm solace inside a structure. He and his group suggested the utilization of aloof plan systems by draftsmen at the configuration phase of making a structure to improve energy execution and advance supportability.

Andoni affirms that energy systems are undergoing extremely fast changes to contain the rapid increase in the number of embedded renewable energy generation like solar PV and wind [10]. Radwan [11] from the mechanical designing division of both Bedouin Institute of Science and Alexandria College in Egypt met up only a year prior to the Francesco group to go through a practically comparative examination in 2016 labelled retrofitting of existing structures to accomplish better energy-effectiveness in business working, with their contextual investigation likewise being an emergency clinic in Egypt. The primary focal point of their work anyway was extraordinary; they cantered around clarifying and considering the issue of building energy productivity execution and to distil helpful encounters and data to apply to building energy guidelines. Their re-enactment indicated that the use of DVC frameworks for air control saves an expected 41% of electrical energy burned-through and that divider protection diminishes energy utilization by 8%.

Khairi [12] and his colleagues in their project: The application, benefits and challenges of retrofitting the existing buildings had the aim to provide information on the application, benefits and challenges of retrofitting an existing building. Two buildings were chosen as case studies followed by site visits and observation to the buildings. At the end of their study they came to the conclusion that retrofitting the existing buildings is one of the most environmentally friendly, economical competent and proven as an efficient solution to optimize the energy performance and could also help to prolong the life of the existing building especially to the historical buildings. Thus, the application of retrofit should be promoted across the construction and conservation industries. More research need to be done in order to have complete sets of detail data on the direct and indirect impacts of retrofit to the environment, cost differences between retrofit with the normal construction of a building, cost of maintenances as well as, the impacts to the end users and to the surround area of retrofitted buildings.

Khoukhi [13] presented in their study; retrofitting an existing office building in the UAE towards achieving low-energy building, a real case study of the retrofitting of an existing building to achieve lower energy consumption in UAE, a monthly computer simulation of energy consumption of an office building in Sharjah was carried out under UAE weather conditions. Several parameters, including the building orientation, heating, ventilation, and air conditioning (HVAC) system, external shading, window-to-wall ratio, and the U-values of the walls and the roof, were investigated as also in this project and optimized to achieve lower energy consumption. Their simulation showed that the most sensitive parameter in the retrofitting alternatives is the roof component, which affects the energy savings by 8.49%, followed by the AC system with 8.34% energy savings if well selected using the base case. Among the selected five components, a new roof structure contributed the most to the decrease in the overall energy consumption (approximately 38%). This is followed by a new HVAC system, which leads to a 37% decrease, followed by a new wall type with insulation, resulting in a 20% decrease.

Dixon [14] in his article found that the inflexible regulations, complicated validating and approval process for new technologies, selective authorized lists of technologies are all seen as aspects that can reduce the entry of new retrofit products into the market. Even though retrofit bring benefits to the buildings, environment and end user of the buildings, the planning of making good the existing buildings such as the historical buildings need to be done with manner and respect to its authentic building elements and the surrounding community. Fail to do so may result on negative impacts such as damaging the most authentic building elements of the buildings or creating nuisance to the community.

Ochedi et al. investigated the methods in energy efficiency approach in achieving energy efficient buildings in Nigeria. This was conducted through the adoption of the passive design approach. The result indicated that the method reduced energy consumption in the range of between 40-60% when compared to the normal buildings. The research proposed the passive design method in obtaining high energy efficiency [15].

Ozarisoy et al. researched on the capacity of retrofitting methods in the optimization of existing energy performance in residential buildings. It investigated the performance of energy before and after retrofitting using Autodesk Revit 2017 and Insight 360 software for its energy performance analysis and simulation. The result indicated a cost effective and efficient energy system [16].

Oluseyi et al. [17] used building information modelling (BIM) approach for the simulating, analyzing and assessing energy usage in buildings. It was used to improve energy in a university office complex and the result indicated savings in energy and cost. The results also show that the consumption of energy could be reduced to at least 40% if energy efficiency practices are applied using BIM. The research indicated that if retrofitting is applied to buildings for the purpose energy savings it will solve the lack of access to energy.

Electricity supply is critical to the public improvement in Nigeria and that energy utilization has a huge relationship with economic development in Nigeria. This was my inspiration to leave on this venture, a more supportable utilization of energy in Nigerian structures will no uncertainty straightforwardly impact the public and monetary advancement of the nation. Contrasted with different techniques these improvements can be accomplished, retrofitting for effective energy use is considered around the world less expensive and more practical over the long haul.

According to the World Bank 2019 report [18], Nigeria has a population of over 200 million people with the potential of future population explosion, there will undoubtedly be a relative increment in the utilization of electrical and electronic machines. The usage speed of energy has been on the climb and Nigeria's ability industry has not had the option to coordinate the interest of energy needed with its developing populace and may not probably accomplish this even sooner rather than later. Because of this energy shortfall in Nigeria, many are left in obscurity without fundamental power, devastating family units and significant areas like medical care.

The aim of this study is the design of an efficient energy utilization protocol for an office complex in a university in Nigeria to ensure the reduction of energy consumption through energy retrofit measures. To achieve this; the following objectives shall be pursued:
– to appraise and analyse the existing energy consumption management for an office complex in the University of Lagos, Nigeria;
– to design energy consumption management and performance procedure for existing office buildings;
– to optimize the energy consumption management and performance for existing buildings;
– to model the energy cost model of the existing building pre and post retrofitting exercise.

As part of efforts to support the Federal Government of Nigeria (FGN) in achieving its target for The Sustainable Energy for All Action Agenda (SE4ALL), this study will focus more on how to redesign the energy distribution channel of an office complex in the University of Lagos in Nigeria to consume minimal electrical power, reduce the cost of self-generating power and also ensure energy efficiency within the building while at the same time reducing the carbon footprint.

Focusing on the reduction of the amount of electricity consumed by a building and how best to optimize usage, this study has the potential to:

1. Reduce the emission of carbon into the atmosphere, thereby, securing the ozone and improving general health.
2. Reduce cost of electricity bills incurred by households and organizations alike as their dependencies on electricity may reduce significantly.
3. Bring more awareness upon the importance of retrofitting and adoption of more efficient and sustainable methods of energy within building.

The paper is structured into four sections. Section 1: The "Introduction" provides the research objectives, Problem statement presents the research motivation, detailed problem definition and literature review. Section 2: "Methodology" describes the approach, including main assumptions, equations and data sources applied to the case study building carried out by using design software. Section 3 is dedicated to discussion and results and te last section is dedicated to Conclusion.

2. METHODOLOGY

2.1. Materials Used

In order to carry out the effective retrofitting of an office complex in the University of Lagos in Nigeria, certain Building Information Modelling (BIM) tools came into use which proved effective in creating a digital twin of the civil and electrical functionality of the case study building. The tools used are Autodesk Maya, Autodesk Revit and Autodesk Insight Cloud.

2.2. Case Study Description

The office complex is a marvel, towering above other buildings in the university campus, the 11 storey edifice was designed in 1980 and completed in 1985. It is a combination of executive offices for the Vice Chancellor and Registrar, a new Senate chamber and general offices for the university administration. The case study site lies between latitudes 6°26′ and 6°50′N and longitudes 3°09′ and 3°46′E and was also built to lay across one of the main pedestrian routes of the campus and the design maintains this route, allowing it to pass under the building, rather than diverting it around the building. The building also houses the first university radio station in West Africa.

Fig. 1. University office complex

The topography of the location of the building is important because of the effect the angle of incidence of solar radiation, slope, and orientation of the land in terms of the use of daylight, solar radiation and natural ventilation within the building. It is also extremely important to analyse the climate and demography of Lagos because this directly affects and informs my approach to retrofitting the building.

Lagos is located in the South-western region of Nigeria in West Africa. On the globe, Lagos lies between a latitudes 6°26' and 6°50'N and stretches between longitudes 3°09' and 3°46'E. Lagos is made up of two major region i.e. the Lagos island which comprises of the areas such as Ikoyi, Victoria island and Lekki which are all highbrow areas and the Lagos mainland which makes up other parts of the state [19]. Lagos has a landmass of around 3,577.28 square kilometres, it has a wetland of about 22% and a population density to tune of 5,926 persons per square kilometre [20]. Lagos is Nigeria's main commercial centre harbouring over 70% of the country's economy and industries [21]. An investigation done by Amadi and Hingam showed that during the design of buildings in Nigeria, designers pay little or no attention to climatic conditions [22]. These climate and climate conditions are typically not thought about during arranging, building and development in the nation, yet they should be contemplated during retrofitting to accomplish the most ideal reasonable preservation of energy planned, how they influence my simulation will be investigated in future sections.

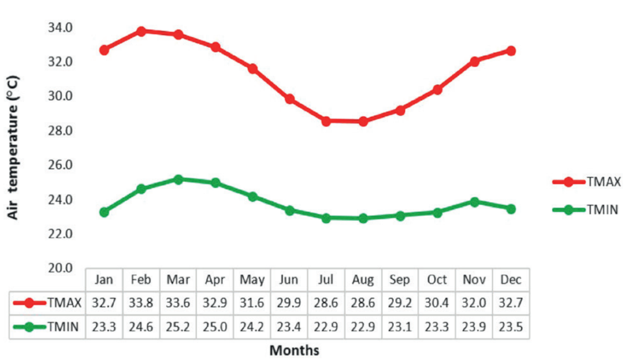


Fig. 2. Average temperature and precipitation for Lagos state [23]

Buildings are designed for a particular number of people, the occupation density of a building is the quantity of individuals involving a square foot (ft2/individual) [24], knowing the quantity of people that possess a territory in the university on a normal day is significant in the investigation of the building warmth and ventilation, the occupation density of a structure is typically determined by separating the region of rooms or storey(s) (m²) by a story space factor (m² per individual), the space factor esteem being utilized here is gotten from the endorsed Britain building standard of 1965 [25].

$$\text{Occupation Density} \; \frac{\text{Total of in the building}}{\text{factor}\left(\text{m}^2 \text{ per person}\right)} \quad (1)$$

In order to simulate the performance of heating and cooling plants and systems, each subsystem (generators, distribution, emission, and control) and auxiliary electric consumption were assessed, the office complex currently uses air-conditioning systems for ventilation, although there are varying brands of air conditioning systems in use in the building, the major ones taken into consideration in this research are National and SAN air conditioners, both with average heating power of 6.2 kW and 7.9 kW with wide range capacities (between 1.4 kW to 12 kW) as stated by their manufacturers. The building also uses hybrid illumination i.e. combination of sun light and electricity.

2.3. Architectural Modelling and Design with Autodesk Maya

Autodesk Maya is an industry leading 3D modelling and design software application developed by Autodesk incorporated that enables engineers and architects to create hyper-realistic architectural models. Many architectural firms are adopting Maya for 3D visualization as a way to help sell a design or idea mainly because of the amount of flexibility it provides for shapes and architectural forms [26]. It is a powerful digital drafting tool, which means projects and models are represented geometrically and has replaced two-dimensional (2D) and three-dimensional (3D) modelling manual hand animation tools as a multi-purpose modelling engine, which made it the right software candidate for the architectural modelling of the case study.

Maya was used to develop the architectural twin model of the case study, this twin model was then exported to Revit which was then used to apply selected energy settings, as observed from the actual case study such as wall types and electricity consumption, to the twin model in order to analyse outcomes for a range of conditions for the final energy management simulation to be carried out.

2.4. Energy Management Simulation with BIM Autodesk Revit and Autodesk Insight Cloud

Energy settings control the behaviour of the energy model created for the case study. Various energy settings had to be made on Revit to ensure proper energy analysis is performed on the building model in order to establish current electrical energy consumption of the building, a 3D model was created in the Autodesk Revit software using the floor plans of the building.

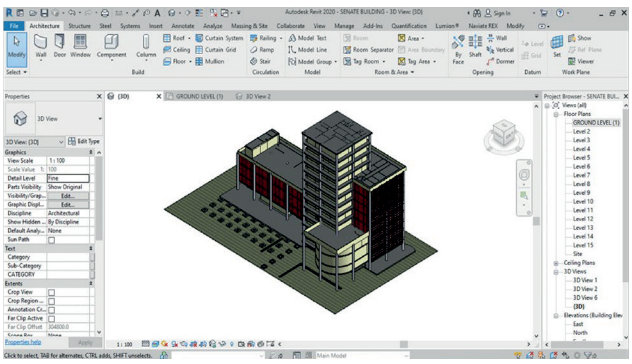


Fig. 3. 3D Revit Model of the university office complex

Fig. 4. Third floor plan with orientation set relative to True North in Revit

Room tags were created on Revit room tool to help identify each room as this helped when exporting the file to gbXML format. gbXML is a type of XML file that has over 500 types of elements and attributes that allow you to describe all aspects of a building. The way gbXML works is, a tool such as Autodesk Revit has an option in the "File" menu that allows you to "Save As gbXML" after designing 3D representation of a building as started on Maya and finished on Revit, there were a few parameters that needed to be established.

These included the building space tolerance, building type, the location of the project in-building elements and all 500 gbXML attributes that clearly describes all aspects of the building. Below are examples of such settings and their relevance to determining and simulating the energy consumption of the case study:

Space Tolerance: This is a setting on Revit MEP used to help manage and simulate heating and cooling loads around narrow unoccupied spaces, like plumbing chases in buildings. For calculating heating and cooling loads it is important that all volumes are accounted for and there are no gaps in the analytical model.

Perimeter Zone Depth: This is the space where the receiving of the bulk effect of the ambient condition is done. Setting the perimeter zone depth is a valuable part of automatic thermal zoning, especially for large buildings such as the case study buildings for energy saving. The core of a building has heating and cooling loads that differ from the perimeter because it is not directly exposed to external weather conditions or daylight through windows.

Mode: Revit offers 3 modes for creating the energy model from the architectural model. For all cases, the mode selected for this project is "Conceptual masses and Building Elements" mainly because it is more suitable for the architectural model of the case study as it is more flexibleand suitable for simulating jointly or independently the energy impacts of masses and elements in the building.

2.5. Steps Taken to Analyse the Existing Energy Consumption management for University Office Complex

The total stepwise technique and work process embraced for the examination pointed towards investigating, planning, and improving the current energy utilization, the executives and execution for the university office complex is depicted underneath.

2.5.1. Simulating Energy and Environmental data in Autodesk Insight Cloud Subscription

After generating the energy model on Autodesk Revit MEP, an optimization on the model, to strip away possible inaccuracies in the inputted environmental data was done. The next stage was to simulate the whole building energy, including daylight analysis, heating and cooling load, HVAC and Plug/Appliances load.

The yellow colour indicatesthat the sunlight intensity in this room is higher as compared to the other room. Looking at the bench mark at the right hand side of the image, the color difference shows the intensity.

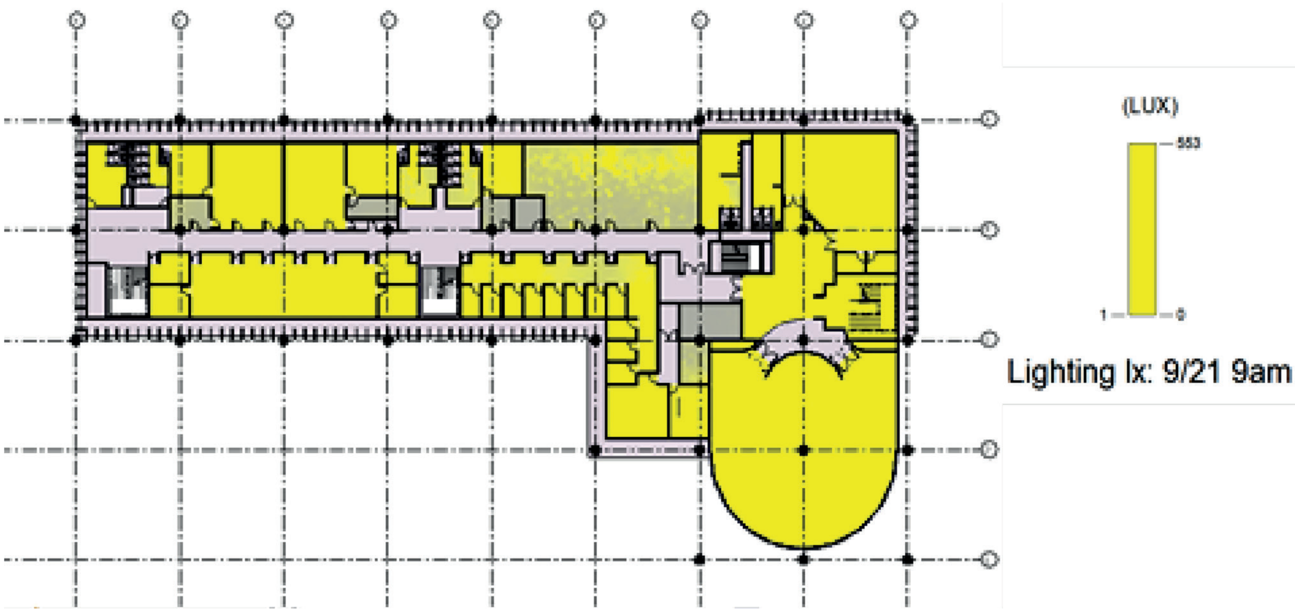


Fig. 5. Floor 2 Illuminance Lighting Analysis Results

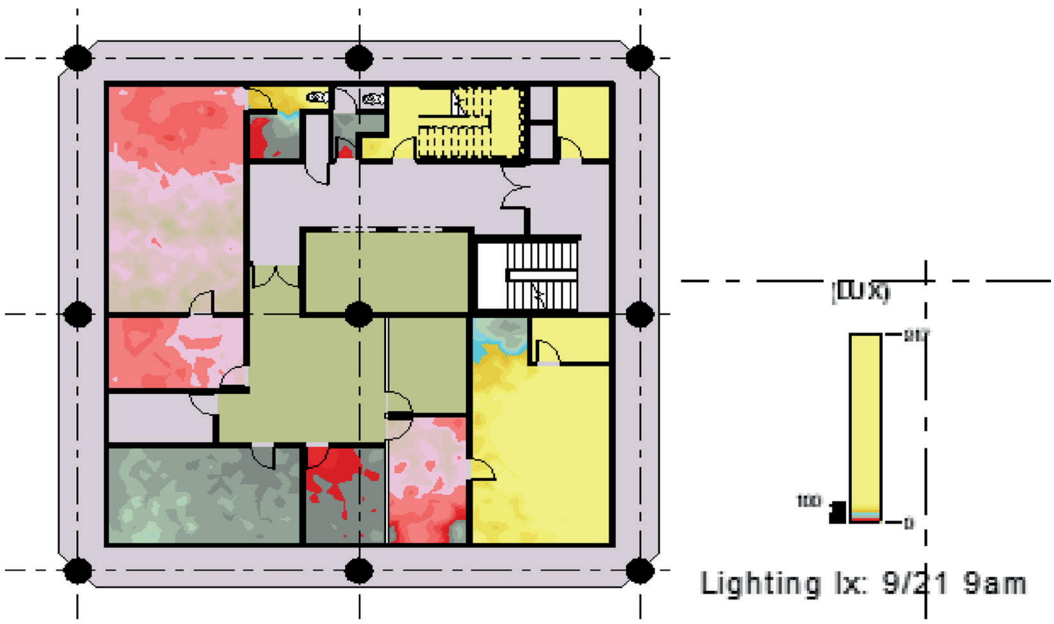


Fig. 6. Level 8 Illuminance Lighting Analysis Results

Primary data was based on a physical observation of both the interior and exterior parts of the building with the support of the building floor plans, while secondary data are based on research and information gotten from the school and academic contributors online, these gathered data were useful in creating a 3 dimensional model replica of the case study building in Autodesk Maya and Revit MEP. The energy twin model of the building was generated in Autodesk Revit while detailed simulation and analysis was done using Autodesk Insight.

2.5.2. Optimizing the University Office Complex Energy Consumption Management and Performance in Revit MEP

The Energy Analysis done on the University of Lagos office complex comprises of 11 focus components which perfectly describes the energy model of the building, and was done to determine the state of the energy management of the building after the application of retrofitting procedures which were then compared with the mathematically calculated state before retrofitting, this simulation was done with Autodesk Insight also known as green energy studio and the result of the simulated conditions for the case study after the input of all data is in the EUI (Energy Use Intensity) which expresses a building's energy use while following the standard energy analysis steps required both in Revit MEP and Autodesk Insight, the 11 focus components are listed with their simulation results below. The results gotten from the simulation are displayed in images captured from the simulation software.

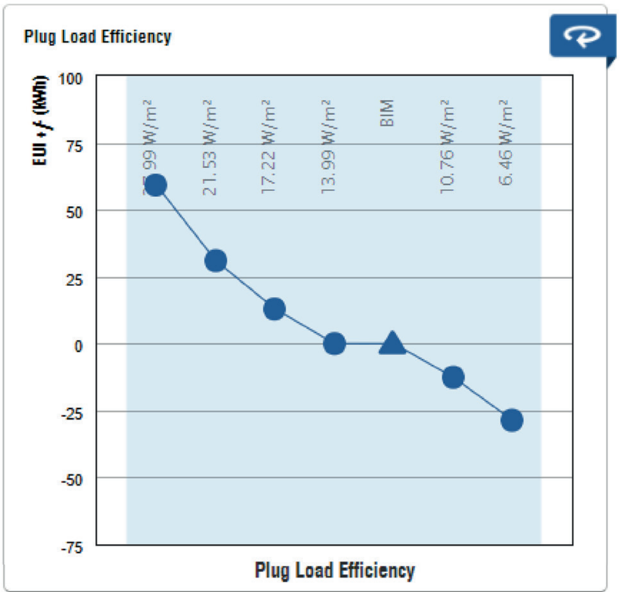


Fig. 7. EUI of the Plug Load Efficiency for the case Study

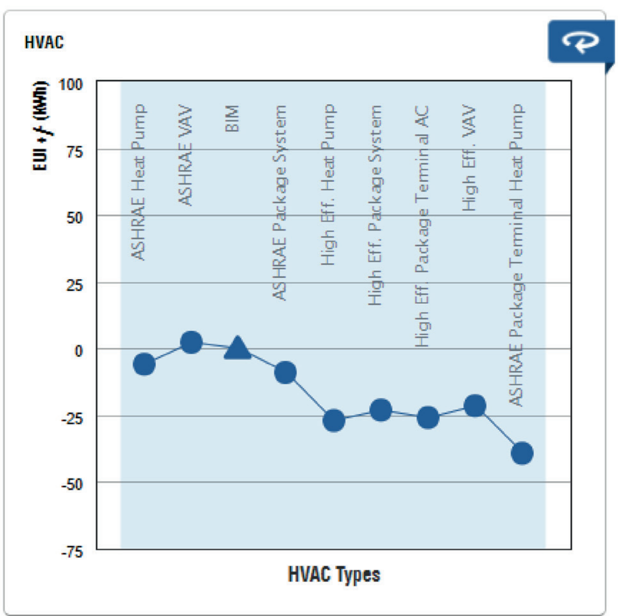


Fig. 8. EUI of the HVAC system

3. RESULTS AND DISCUSSION

The results presented in this study were obtained from focusing on two key methods. The first method is the appliance use approach which deals with the use of relevant mathematical equation to determine energy consumption; the calculated data are used to determine the major outlets where energy is being consumed. The second method is the use of the BIM Tools for the energy simulation, taking into consideration some of the data gotten from the first method.

3.1. Appliance Approach to Analyse the Existing Energy Consumption management for the University Office Complex

This approach is used to determine the case study building electricity consumption depending on data obtained from measurement and observation of key electrical aspects and outlets of the building. As seen in Table 1 below, the AC units seem to be the largest consumer of electricity in the building, with an annual cost of 9,771,210 naira, with a staggering 101 units within the building, and the fire alarms has the least power rating (2 W) while the microwave have the highest (1400 W).

The Refrigerators are run for 24 hours/day and still consumes less amount of electricity and costs less; 2,152,656 naira compared to the AC units which run for just 12 hours. Appliance approach involves summing up end-use energy consumed by various electrical appliances in the course of common office activities.

Table 1. Electrical Energy Consumption for Appliances on all floors of the University of Lagos Office Complex Building

S/N	Appliances	Qty	Rating (Watts)	H (hrs)	Annual Cost (naira)
1	Lighting	147	36	12	590,351
2	AC units	101	1250	10	9,771,210
5	Computers	67	220	10	1,335,444
4	Printers	62	360	10	2,022,192
5	Photocopier	30	1200	10	3,261,600
6	Scanner	10	40	10	36,240
7	Television sets	30	200	8	420,384
9	Toasters	5	1200	2	108,720
10	Laptops	22	90	10	179,388
11	Microwave	6	1400	3	253,680
12	Shredders	12	259	2	72,480
13	Fire Alarm	75	2	24	32,617
14	Refrigerators	33	300	24	2,152,656
	Total	**602**	**6,557**	**135**	**20,236,962**

3.2. Optimizing the Energy Consumption Management and Performance in BIM (Revit and Insight Cloud)

For the BIM energy simulation, various conditions and different elective evaluations were performed to think about framework game plans and obtain extra AEU (Annual Energy Usage). The results obtained from the case building analysis after applying retrofitting (i.e. applying the Energy Protection Methods) and performing the simulations are discussed below. The Annual Energy Usage to be determined depends on both EUI and Building total area. It is important to note that EUI stand for Energy Use Intensity and is given as a building's Annual Energy Use divided by the total area, with the computation of EUI in revit insight, we can simply calculate energy Annual Energy Use of the building before and after retrofitting to compare if there has been a significant decrease.

As stated previously, in calculating the annual usage of electricity, a key component is the total area of the building, this has been computed through the addition of all areas of rooms in the building, made easy through the energy twin GBS model used in Autodesk Insight Cloud, the total area of the building was computed to be 5653 m^2.

Table 2. Data table containing EUI Max and Min gotten from Autodesk Insight after simulation of Retrofitting procedures

EUI Max (kWh/m^2/yr.)	883.91
EUI Min (kWh/m^2/yr.)	712
EUI Mean (kWh/m^2/yr.)	282.02

Thus, as seen in equation (2) the range values of the Annual Energy Usage of the University office complex can be calculated by multiplying both ranges of Energy Use intensity gotten through BIM simulation seen in Table 2 with the total area in meter squared of the building. The AEU value for the building was calculated to be between 4,188,364.23 kWh/y and 4,024,936 kWh/y.

$$\text{EUI}=\frac{\text{Annual Energy Usage}\left(\text{AEU}\right)}{\text{Building gross Squarefeet}} \quad (2)$$

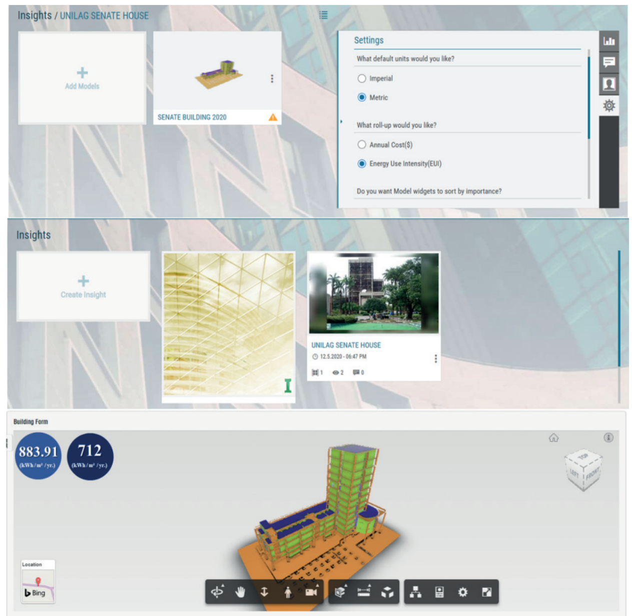


Fig. 9. University of Lagos office complex building 3D model and simulated energy consumption range from insight applying various retrofitting techniques

The results gotten after modelling the energy cost model of the existing building pre and post retrofitting exercise in Revit MEP and Autodesk Insight are shown in Table 3 below.

Table 3. Comparison of the current consumption vs the application of retrofitting simulations with BIM tools

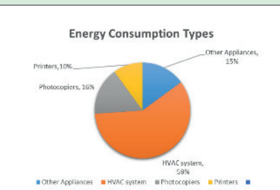
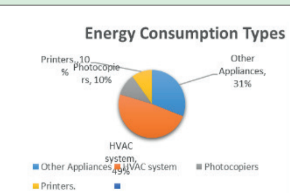
<table>
<tr><th></th><th>Case study before retrofitting</th><th>Impact of retrofitting on BIM</th></tr>
<tr><td>Total Area (m²)</td><td>5653</td><td>5653</td></tr>
<tr><td rowspan="2">Energy Use Intensity (EUI (kWh/m²/y))</td><td rowspan="2">776.78</td><td>712</td></tr>
<tr><td>740.91</td></tr>
<tr><td rowspan="2">Annual Energy Cost (Naira)</td><td rowspan="2">20,236,962</td><td>18,549,199.37</td></tr>
<tr><td>19,304,038.05</td></tr>
<tr><td>Annual Electric End-Use</td><td>
</td><td>
</td></tr>
</table>

Table 3 compares the analysis and results of the case study building with the Energy Use Intensity simulation of the building with BIM tools. For this case, it is observed that energy consumption of the building can be reduced by 4.61–8.34% at minimum and maximum impact of the retrofitting strategies, consumption is projected to move from 4,390,988 kWh per year as calculated mathematically to as low as 4,024,936 kWh per year – 4,188,364.23 kWh per year.

The annual electric consumption cost for the case study building mathematically calculated from the appliance approach are; for HVAC system (58.92%), Photocopiers (16.12%), Printers (9.99%) and other appliances (14.97%) totalling 20,236,962 kWh/year. The annual electric consumption cost after retrofitting with BIM tools, it became; for HVAC system (48.70%), Photocopiers (10.44%), Printers (9.99%) and other appliances (30.97%) totalling 4,024,936 kWh/year, projecting a significant improvement.

By examining the case study building used in this paper, as well as the other reports, papers and guides, there is proficient evidence that Energy Retrofits using the Integrative Design Process can drastically reduce carbon emission for existing office buildings. Every case study resulted in an Energy Use Intensity far below pre-retrofitting; proof of the energy reduction potential of Energy Retrofits. This shows that Energy Retrofits provide an excellent way to reduce our societies contribution to climate change. The most obvious benefit of Energy Retrofit is the operational cost savings that can be achieved making it a financially viable option for office buildings.

In contrast to previous approaches, this study provides an integrated framework to identify the stakeholders' requirements and potential energy efficiency measures, to build and optimize a large design space, and to determine the best solutions, in a holistic way. In addition, mathematical optimization and evaluation techniques are incorporated into the decision making process, which simultaneously considers the important role of stakeholders in carrying out the analysis procedure.

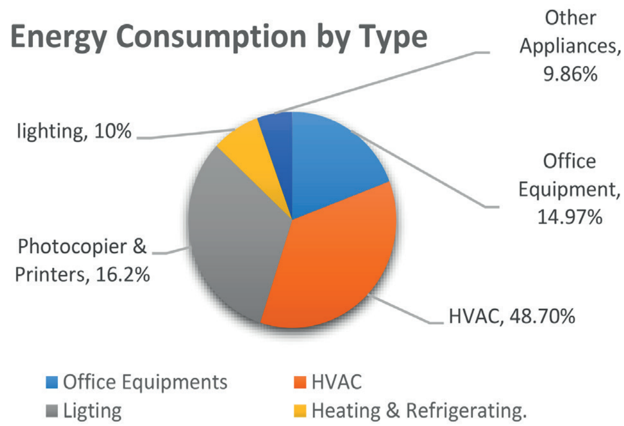


Fig. 10. A distribution of energy consumption types within the case study building

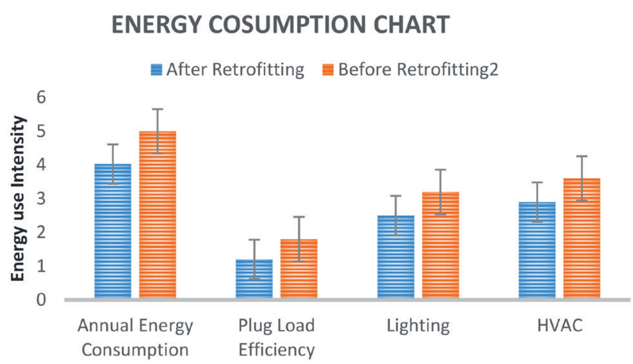


Fig. 11. Comparison of consumption before and after retrofitting

Table 4. Comparing results of finical cost of retrofitting interventions and energy improvements of similar studies

SN	REF	LOCATION	BUILDING TYPE	COST SAVING	% ENERGY SAVING
1	[27]	Empire State Building – Manhattan, New York City, USA	Commercial building	$4,400,000	38%
2	[28]	Kuykendall Hall – Hawaii Mānoa (UHM) campus, Honolulu	Commercial building	$2,702,000	84%
3	[29]	The Christman Building –Lansing Michigan, USA	Commercial building	$45,659	44%
4	[30]	Lucknow, India	Residential building	50,400INR	30%
5	Present study	Senate House – University of Lagos Campus, Nigeria	Commercial building	₦1,687,762	8%

4. CONCLUSION

There are many significant ways energy efficiency can be achieved in everyday activities; a list of energy saving methods was designed during the course of this study specifically for the case study building. The optimization of the building was done on BIM, various conditions and different elective evaluations were performed to think about framework game plans and obtain extra AEU. The results obtained from the case building analysis after applying retrofitting (i.e. applying the Energy Protection Methods) and performing the simulations established that with energy saving procedures explored in this project about 971,807.23 kWh of energy and 1,687,762.63 naira could be saved per year.

It is a clear issue that power generation in Nigeria is inadequate, to worsen these challenges, there is no proper energy metering system to ascertain the actual amount of energy distributed. This has resulted in distribution companies over billing customers and over pricing the cost of energy. In addition to this, there are clear indications that Nigeria as a whole could still tap into several other greener means of generating power both on a small and large scale, to companies and individuals. The energy saved through retrofitting from the university's office building can simply be redirected to other buildings in need of it within the school premises making for more efficient energy usage and a drastic reduction in cost of energy usage of the office building per year.

4.1. Future Research

It is worthy to note that one of the greatest drawbacks in this study was the availability of data from the case study building for this research, hence other key approaches to estimating Annual Energy Usage such as Appliance Approach and Expenditure approach could not be pursued in this study, these could be used as basis for future research.

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