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APPLICATION OF BUILDING INFORMATION MODELING TOOL FOR EVALUATION OF ENERGY UTILIZATION IN KADUNA STATE UNIVERSITY MAIN CAMPUS BUILDING.

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Abstract

In the context of environmental policy, several institutions in Nigeria have implemented a range of activities with the goal of promoting energy efficiency, in line with their commitment to reducing energy usage. Improving the energy efficiency of buildings has many benefits, such as lowering energy use, which helps clean up the air. Additionally, the building's internal comfort has significantly improved, which promotes both efficiency and the health and happiness of its inhabitants. Due to the abundance of educational buildings within the institution, the energy usage of these buildings' accounts for a substantial portion of the overall energy consumption. Consequently, this leads to increased costs for the institution's budget in terms of operating and maintaining the buildings. Exploring alternative strategies to decrease energy usage in educational facilities is a crucial technique for ensuring long-term sustainability and economic growth of the institution. The purpose of this paper to investigate the extent of Energy use intensity and cost at faculty of science of University building in Kaduna state University main campus and optimized the building energy model under study. The results obtained shown that the EUI before optimization was 299kWh/m^2/yr, while after the optimization was 153kWh/m^2/yr. Hence 146kWh/m^2/yr was conserved for EUI and 9.7USD/m^2/yr saved for the cost of the faculty of science building under study. It is therefore necessary to carry out energy analysis using BIM as retrofitting strategies after the building construction, reduce energy consumption while maintaining the necessary interior thermal comfort conditions.

Keywords: BIM, Energy efficiency, environment and air pollution

1. INTRODUCTION

Examining alternative methods to decrease energy consumption in educational facilities is a crucial strategy for promoting sustainability and fostering economic growth inside institutions over an extended period of time (Mytafides et al., 2017). Autodesk® Ecotect® Analysis is a software tool for simulating energy usage in buildings. It is designed to work with BIM software like Autodesk Revit Architecture and is used to conduct detailed analysis of a building's energy performance (Peng, 2016). Moreover, Energy Analysis for Autodesk® Revit® software is a cloud-based energy simulation service that is fueled by Autodesk® Green Building Studio® and facilitates sustainable design (Hachem et al., 2014). It is feasible to model the adoption of potential energy conservation measures that will enhance the energy efficiency in a certain building (Roslizar et al. 2014). Various technological techniques have been implemented to conserve energy, including enhancing the utilization of eco-friendly materials, minimizing waste through reuse and reduction, and implementing renewable energy sources.

Energy conservation and reduction of greenhouse gas emissions through technological means can be achieved by implementing various steps throughout the lifecycle of buildings. These strategies include enhancing energy efficiency in heating, ventilation, and air conditioning (HVAC) systems, utilising locally sourced materials, and promoting material recycling. Significantly reducing energy consumption and carbon emissions in the institution can be achieved by cost-effective measures such as enhancing energy management, promoting environmentally friendly behaviour change, and raising awareness. (Jiang et al., 2013).

The Earth's temperature is rising, leading to increased energy usage in buildings. The building industry consumes 40% of the world's energy and significantly contributes to carbon emissions. Research by the US Green Building Council shows that building energy performance is crucial for environmental degradation. Analyzing the energy consumption and CO_2 emissions of a typical institutional building using Autodesk Revit and Green Building Studio is essential to assess their environmental impact.

In addition, study in (Mahiwal et al., 2021) concluded that according to their energy study, applying BIM can assist to implement better design alternatives before building construction by optimizing the yearly energy budget spent compared to traditional approaches, which may contain inaccuracies in estimates. The study aims to inform university management about the significance of energy-efficient building design, focusing on the Faculty of Science building at Kaduna State University's main campus in Nigeria (Hasan & Akter, n.d.). Several studies have explored ways of reducing energy consumption, energy cost and CO_2 emission. Some studies even went further to demonstrate retrofits for various kind of buildings(Zheng et al., 2018).The aim of the study is to determine the extent of energy usage of the building under study and optimized the energy model of the building selected at Kaduna State University Main Campus.

2. MATERIAL AND METHODS

The study explores the use of Building Information Modelling (BIM) software for energy analysis at Kaduna State University's Faculty of Science. It aims to integrate BIM with Revit and Green Building Studio (GBS), cloud-based tools, to aid engineers and designers in conducting thorough building studies and optimizing energy use. Autodesk Revit, when

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combined with GBS, can conduct energy studies and assess design alternatives for more energy-efficient structures.

Furthermore, the Revit programme serves as a software tool for creating a comprehensive model of a building. It allows users to input all the necessary data regarding the building materials, enabling the determination of general information about the structure. The interface between GBS and Insight software was performed for energy analysis. GBS provides a comprehensive presentation of data collecting, whereas Insights focuses on data visualisation.

The simulation using BIM software can generate an estimation of the Energy Use Intensity (EUI) value, based on the ASHRAE 90.1 and ASHRAE 2030 benchmarks. The study evaluated projected energy consumption in a facility using various factors such as structure, weather conditions, building design, envelope properties, and operational systems. It considered the interconnection of buildings to reduce energy consumption. The construction modelling process was done using BIM Revit software, GBS, and Insight 360. The highest energy use intensity (EUI) value was generated and compared to the corresponding ASHRAE90.1 standard.

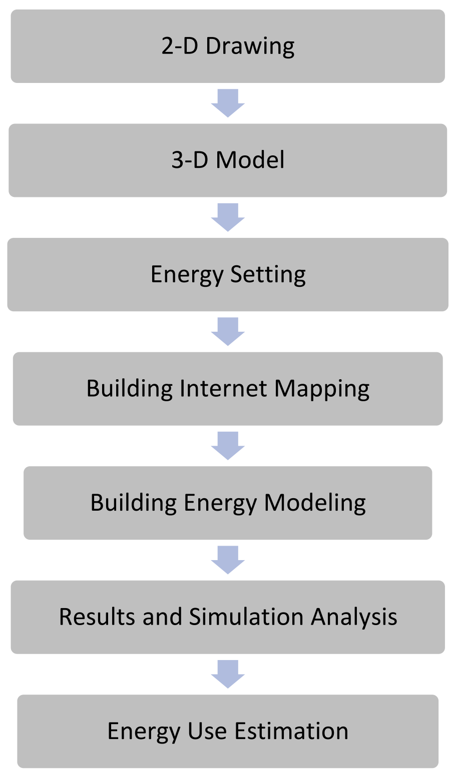

Figure 1: Methodology flow chart

2.1 Study Area Description

The law establishing Kaduna state University was promulgated in May 2004. The promulgation was a consequence of the obvious and felt need to boost higher education in the state. Furthermore, the institution located in Kaduna northwestern part of Nigeria, at latitude10.5° N and longitude 7.4° E. It has a total population of both undergraduate and postgraduate of 8,400 students, like any other institution in Nigeria, KASU consumes

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a lot of energy daily due to lack proper energy conservation measures and energy wasted due to negligence. If proper conservation measures are evaluated and implemented, it will save the institution a huge amount of energy, cost and carbon dioxide emission. Figure 2 show Basic Information of the institutional buildings and Google Earth Map of the Study Area Site respectively.

Figure 2: Building location at Kaduna state University Main campus, Kaduna.

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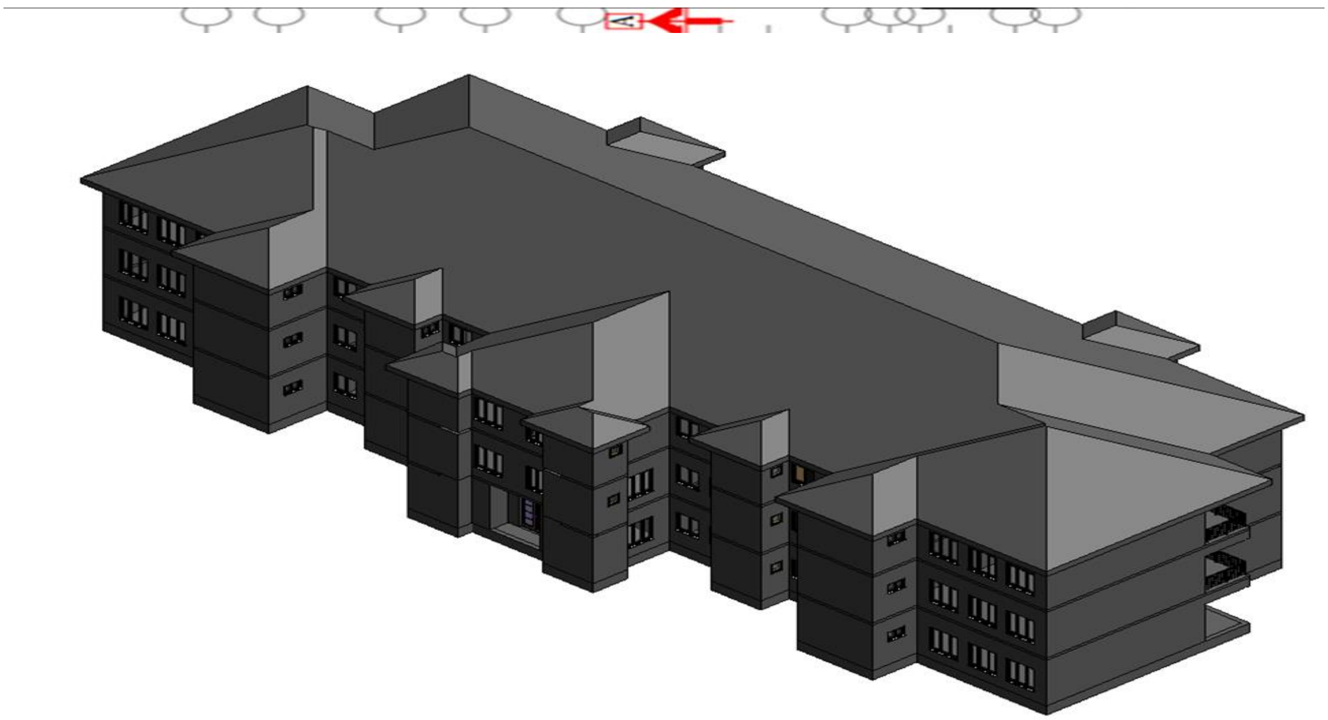

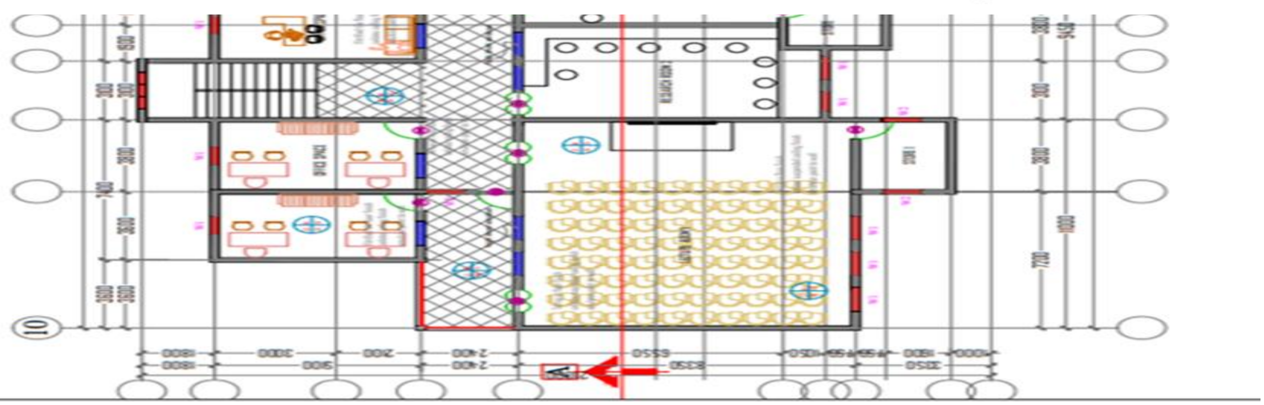

Figure 3: 2-D Drawing of Science Faculty

Figure 4: 3-D model of Science Faculty

An energy simulation was conducted to analyze energy usage, cost, and carbon dioxide emissions, and an energy model was developed by choosing the building location, HVAC system, building type, and material attributes, followed by an energy simulation.

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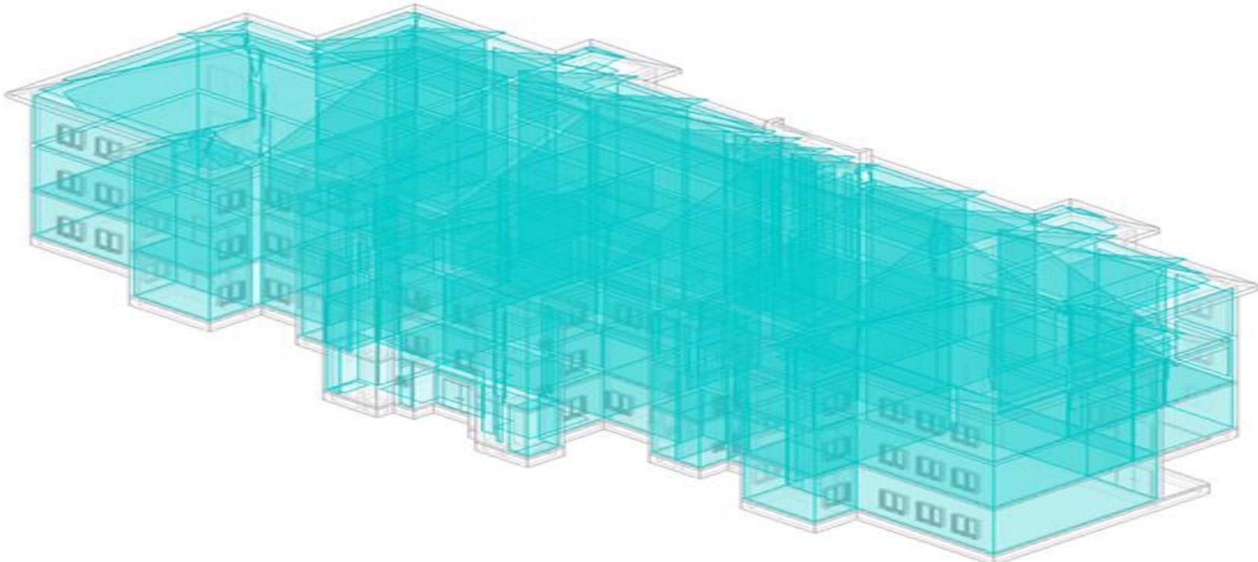

Figure 5: Energy Model of Faculty of Science

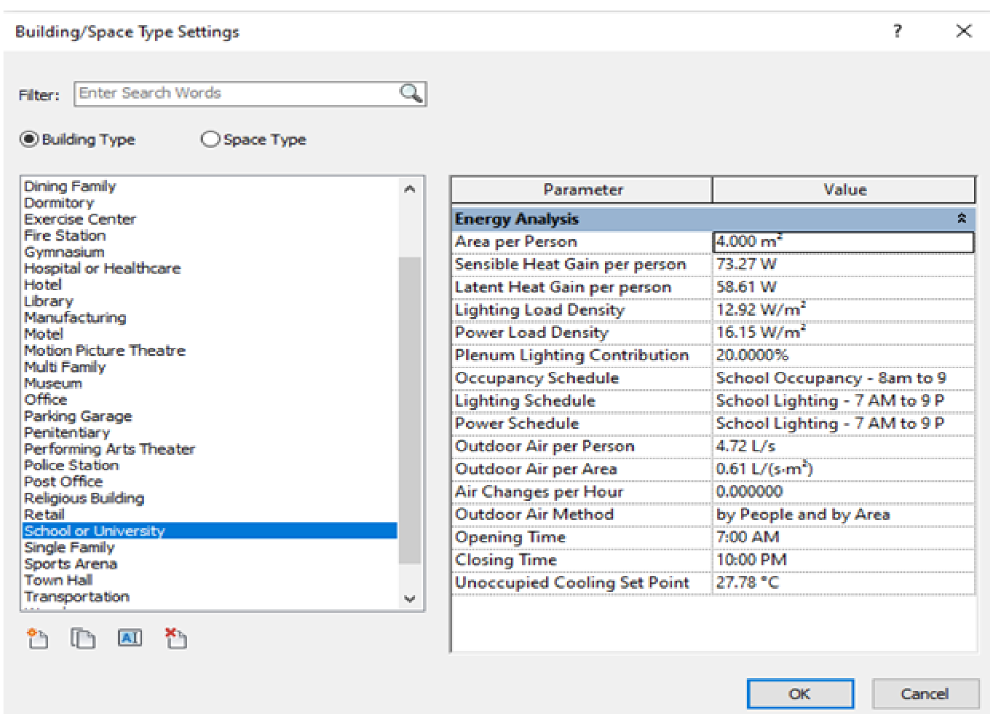

Figure 6: Energy Setting in Science Faculty

As shown in Figure 6, the following are the steps involved in selecting a relevant Building Type in the Building/Space Type Settings dialog.
To adjust the operational hours for a space type, follow these steps:

i. Select the space type from the list,
ii. Adjust individual parameters in the right panel,

iii. Click on the value field for each schedule (Occupancy, Lighting, and Power Schedule) to open the Schedule Settings dialog, and
iv. Select the operational hours by clicking the value field for Opening/Closing time and using the up/down arrows to adjust the time for the building's opening or closing time.

3. RESULTS AND DISCUSSIONS

The study calculates the building's Energy Use intensity (EUI) in kWh/m2 per year, total energy consumed by a building in one year is calculated by dividing its gross floor area. It offers design alternatives like operating schedule, plug-in load efficiency, HVAC systems, building orientation, and lighting efficiency to regulate energy consumption. The report also provides the Energy Use Intensity (EUI) and energy cost per square meter per year.

Table1: Energy Use Intensity Conservation Scenarios of Science faculty building

	BEFORE ($kWh/m^2/yr$)	**AFTER ($kWh/m^2/yr$)**
SCENARIOS (EUI)		
All options range	299	
Operating Schedule (BIM)	222	77
Window to Wall Ratio WWR (BIM)	203	19
Window Shades (BIM)	205	-2
Window Glass (BIM)	198	7
Wall Construction (BIM)	197	1
Lighting Efficiency (BIM)	189	8
HVAC (BIM)	166	23
Plug Load Efficiency (BIM)	154	12
Building Orientation (BIM)	153	1
Total EUI conserved		146

It can be seen from Table 1 and Figure 7 that 146 ($kWh/m^2/yr$) are conserved for EUI while Table 2 and Figure 8 show that 9.7 ($USD/m^2/yr$) are conserved for cost. The Operating schedule scenario tremendously contributed to the conservation of both EUI and the cost of the Science faculty building. While the window shades scenario contributed negatively to EUI and cost. HVAC contributed positively to the EUI conservation with zero contribution to the cost conservation as shown in Table 2

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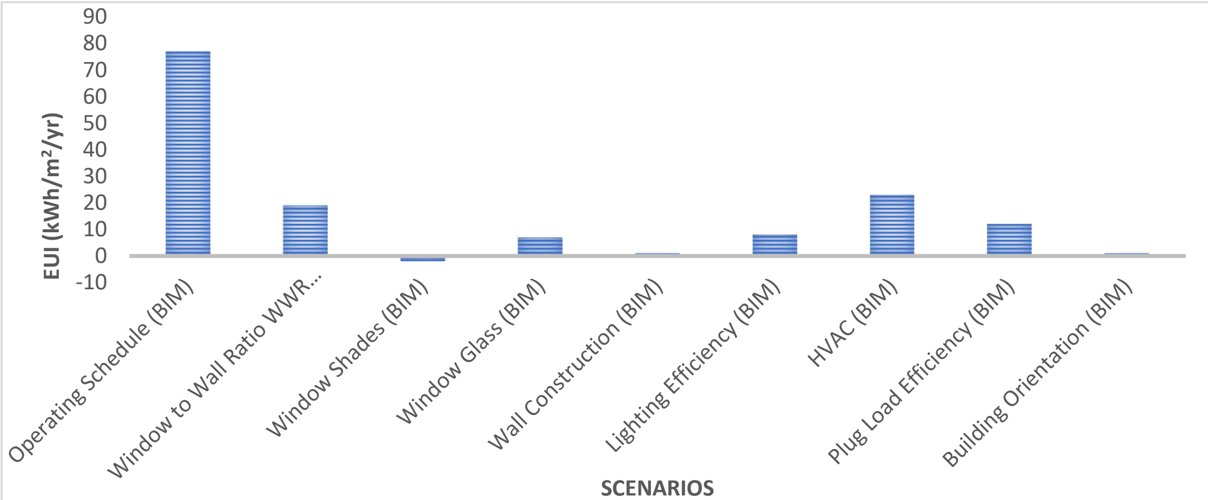

Figure 7: Shown the EUI Scenarios faculty of science

Table:2: Energy Use Intensity Cost Scenarios of Science Faculty Building

	BEFORE (USD/m^2/yr)	AFTER (USD/m^2/yr)
SCENARIOS (COST)		
All options range	22.2	
Operating Schedule (BIM)	14.8	7.4
Window to Wall Ratio WWR (BIM)	14.2	0.6
Window Shades (BIM)	14.5	-0.3
Window Glass (BIM)	14.4	0.1
Wall Construction (BIM)	14.5	-0.1
Lighting Efficiency (BIM)	13	1.5
HVAC (BIM)	13.2	-0.2
Plug Load Efficiency (BIM)	13.2	0
Building Orientation (BIM)	13	0.2
Total Cost conserved		9.2

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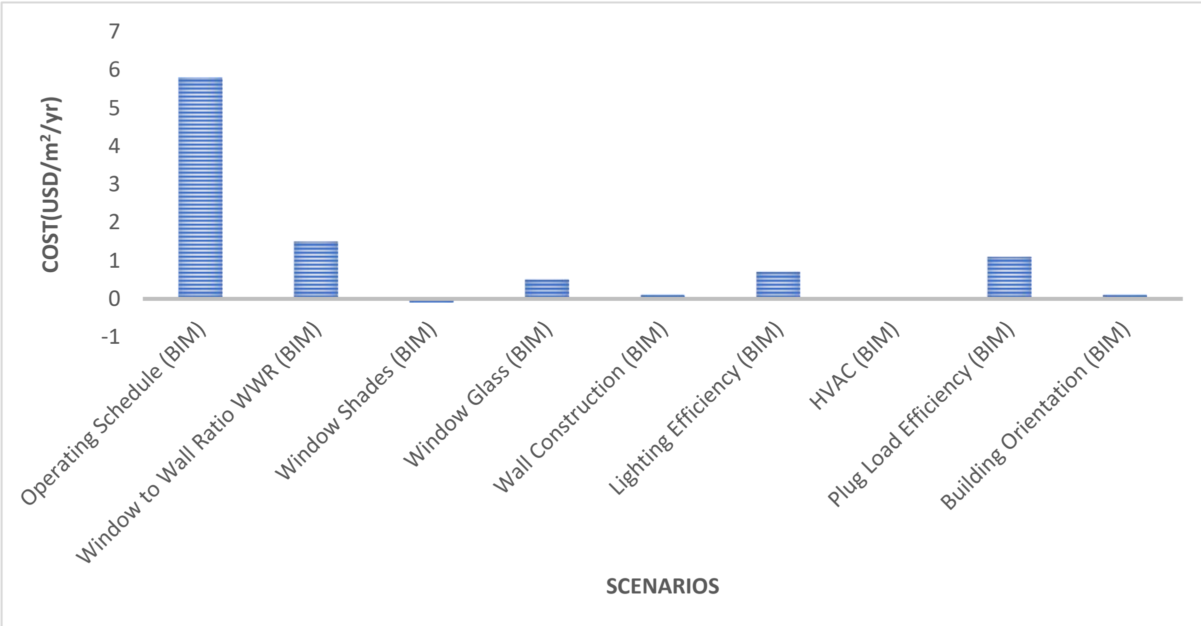

Figure 8: Shown Cost scenarios faculty of science

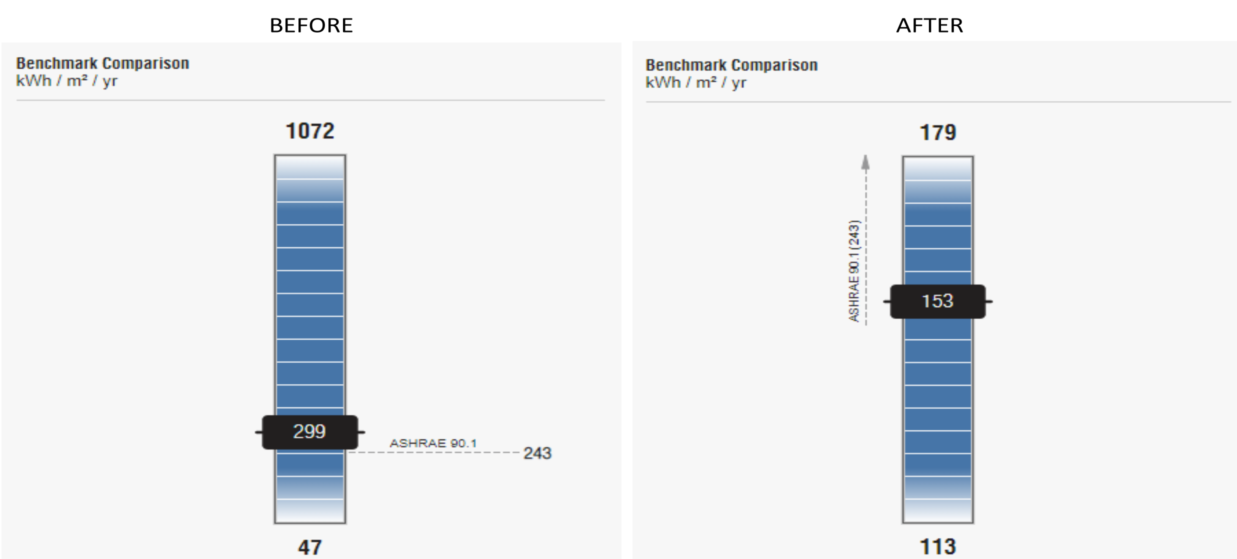

Figure 9: Annual Energy use intensity (EUI) savings of faculty of science

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Figure 10: Annual Cost savings of the faculty of science

3.1 Optimization Analysis in Building Under study.

To achieve optimal EUI values, several scenarios must be analyzed using Insight 360 software. The scenario development analysis for enhancing energy efficiency is based on available factors in the software, with performance diagrams analyzed using simulation software. The building operates 24/7, resulting in an initial EUI value of 299 kWh/m2/year.

After optimization, the EUI value decreased to 153 kWh/m2/year, resulting in energy savings of 146 kWh/m2/year. The initial EUI cost before optimization is $23.0USD/M2/Yr, whereas after optimization it is reduced to $13.3USD/M2/Yr, resulting in a cost save of $9.7 USD/M2/Yr. The utilization of Building Information Modelling (BIM) in energy analysis holds great importance in accurately assessing the energy consumption in institutional buildings. Nevertheless, a significant drawback is that the scenarios were built using exclusively the characteristics provided by Revit software, necessitating adaptation to suit the specific local requirements in Nigeria. However, the results can serve as a model for understanding the potential of BIM in relation to energy consumption at the institution being examined.

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3.2 Energy and Energy End-Use Analysis Faculty of science

Energy, Carbon and Cost Summary	
Annual Energy Cost	$30,911
Lifecycle Cost	$421,008
Annual CO_2 Emissions	
Electric	0.0 Mg
Onsite Fuel	4.2 Mg
Large SUV Equivalent	0.4 SUVs / Year
Annual Energy	
Energy Use Intensity (EUI)	635 MJ / m² / year
Electric	322,567 kWh
Fuel	83,710 MJ
Annual Peak Demand	97.0 kW
Lifecycle Energy	
Electric	9,677,022 kW
Fuel	2,511,293 MJ

Figure 11: Shown the Annual Electric End Use Faculty of Science

The study utilized a systematic energy analysis method, focusing on the Autodesk Green Building Studio Life Cycle Energy Use & Cost data, to obtain the aforementioned results as depicted in Figure 10, the Faculty of Science building incurs an annual energy cost of $30,911 and a lifecycle cost of $421,008. The lifecycle energy for electricity consumption is 9,677,022 kilowatts, and for fuel consumption, it is 2,511,293 megajoules. It is also visible in Figures 11 and 12. HVAC accounts for the largest proportion of annual electricity use and does not contribute to annual fuel consumption.

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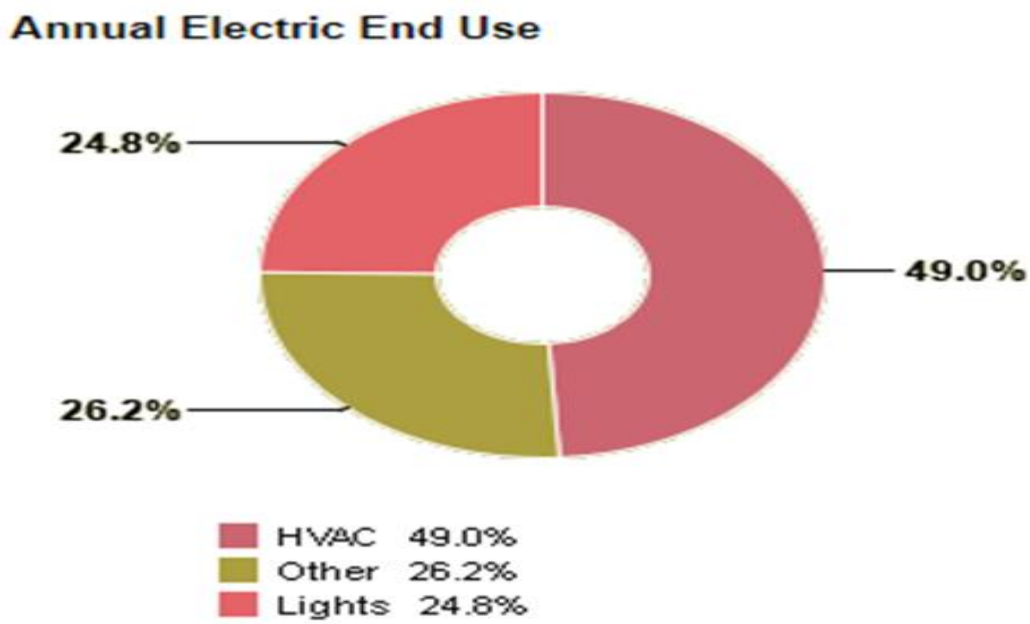

Figure12: Shown the Annual Electric End Use Faculty of Science

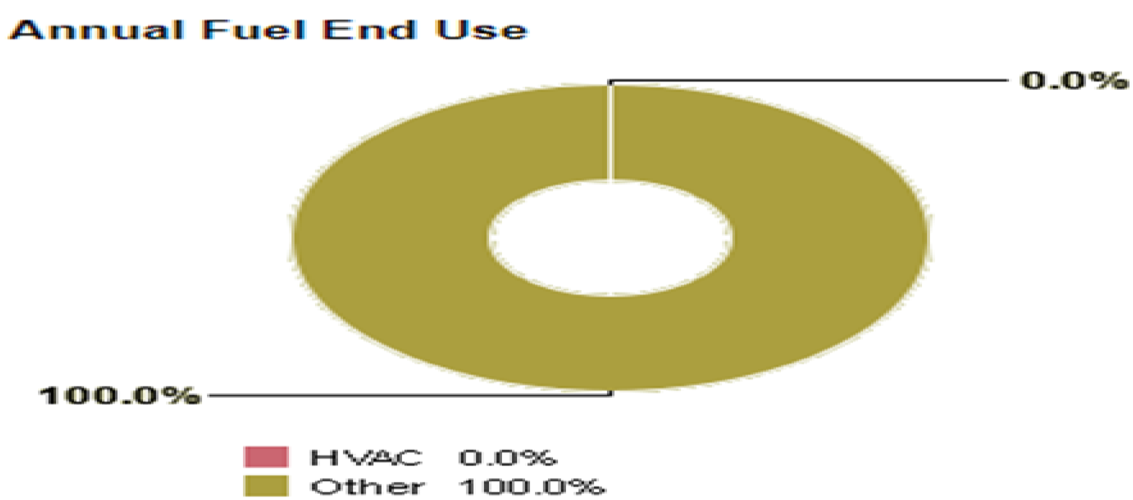

Figure13: Shown the Annual Fuel End Use Faculty of Science

4. CONCLUSION

The Faculty of Science building in Kaduna State experienced significant energy efficiency improvements after optimisation. The Energy Use Intensity (EUI) decreased from 299kWh/m2/yr to 153kWh/m2/yr, resulting in a reduction of 146 kilowatt-hours per square metre per year. The energy expenditure also decreased from $23.0 per square metre per year to $13.3 per square metre per year, saving $9.7 per square metre per year. The building's annual energy cost is $45,483, with a life cycle cost of $619,479. The HVAC system accounts for 49% of the total energy use, followed by lighting at 24.8% and other end-users at 26.2%. The use of Building Information Modeling (BIM) technology has shown its ability to optimize energy use intensity and expenditure in institutional

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buildings. Therefore, it is recommended to extensively implement BIM technology for energy performance assessment in the construction industry to achieve significant reductions in carbon dioxide emissions and costs.

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