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# Optimization Strategy for Energy-Efficiency in Institutional Building: A Case Study of Bells University, Ota

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***Abstract* - Enhancement of human and environmental wellbeing due to gas emissions has prioritised national development towards decreasing energy consumption in buildings. Unfortunately, building design and methods in developing nations are not sufficient to achieve reduced no energy consumption. Therefore, this study aimed to assess strategies for energy-efficient buildings in the institution. To know the different design strategies available to build and maintain an energy-efficient building in an institution; literature analysis, structured questionnaire, observation and simulation analysis was performed using Insight 360 software to analyse the building within the Bells University of Technology, Ota. The questionnaire showed that different energy efficiency indicators and strategies analysed from the literature were adequately utilized (41.14%) in the institution. Also, built professionals (students and staff in construction, architecture and designing section) have a background to moderate knowledge of energy efficiency. The simulation result showed a reduction in energy consumption of the building in response to building orientation, window shade, wall-to-wall ratio, wall construction and roof construction. This shows a great ability to reduce energy consumption and improve human health and well-being. The study concludes and recommends that one of the factors to put into consideration when designing is the nature of the building envelope because it determines the energy required to heat and cool. The government should increase awareness on Energy efficient buildings and appropriate laws should guide the implementation of Energy efficiency in building design policy.**

***Keywords:*** Building, Design, Energy, Energy-efficiency, and Simulation.

## I. INTRODUCTION

Buildings have the highest percentage of the world's energy compared with other sectors. Due to this assertion, studies have shown that 40% of the total energy account is been consumed by buildings which account for about one-third of the global greenhouse gas emissions. The energy consumption by buildings has a negative impact on the environment and people's well-being such as thermal discomfort. Institutional building is one of the important buildings where students can learn the correct pattern of energy consumption inspired by energy efficiency. This has led to a major concern in several nations of the world and made professionals take adequate steps towards more saving and energy efficiency in the institution building. A number of moderately aggregated energy efficiency indicators for buildings have been documented and tested with simulation (Marzi, Farnia, Dasgupta, Mysiak, & Lorenzoni, 2019). It has been documented that when used together as a set, they offer a sufficiently broad and detailed picture of the energy efficiency of a building covering the major interests related to quantifying the energy efficiency (Grillone, Mor, Danov, Cipriano, & Sumper, 2021).

The global construction market is forecast to grow by over 70% come 2025 and that in a way is a call to be worried about energy consumption, embodied energy, and carbon emission among other projected negative consequences (Wang, et al., 2018). Nigeria's Architecture, Engineering and Construction (AEC) industry is not yet proactive in the consciousness of the need for energy consumption rate reduction. Global warming has not stopped increasing at a geometric progression rate and that is the major reason to find a solution for reducing energy use in buildings (Chegari, Tabaa, Simeu, Moutaouakkil, & Medromi, 2021). The building and its components designers in Nigeria should already have a framework for designing for building energy efficiency.

Also, to achieve energy efficiency in buildings, appropriate decisions, strategies and efforts are necessary by all stakeholders. The architect has a major role to play, his understanding of the life cycle of the building positions him at the highest hierarchy of stakeholders and experts that must contribute to the building energy optimisation. The strategies to fulfil the energy efficiency of buildings in all of these phases must be well defined by the architect and other building professionals. Energy use in buildings is estimated to be 45% of the world's total energy consumption, leading to a substantial amount of greenhouse gas emissions (Geissler, Österreicher, & Macharm, 2018). Therefore, the objectives of the study are; to identify the indicators of energy efficiency in

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buildings and to examine the influence of materials and technology in energy-efficient buildings.

## II. METHODOLOGY

In this investigation, a cross-sectional study design was employed. The study utilized both quantitative study through questionnaire administration and qualitative study approach and the theoretical study was based on what was discovered in existing works of literature

### 2.1 Study Area

The third-highest industry concentration in Nigeria is in Ota (Tunji-Olayeni, P. F., Osabuohien, E. S., Oluwatobi, S. O., Babajide, A. A., Adeleye, B. N., & Agboola, M. G., 2021). Just north of the tollgate on the Lagos-Abeokuta Expressway, it is also home to a sizable market and a crucial road intersection. The Winners' Chapel megachurch's Canaan land estate, and the Africa Leadership Forum, Olusegun Obasanjo, the former president of Nigeria, is also well known for being a resident of Ota. The Olota of Ota is the group's traditional leader. Historically, Ota is the capital of the Awori Yoruba tribe. The first private university of Technology in Nigeria, Bells University of Technology Ota is also located in Ota. The coordinates of Ota are 6°40'29.57"N and 3°11'52.99"E.

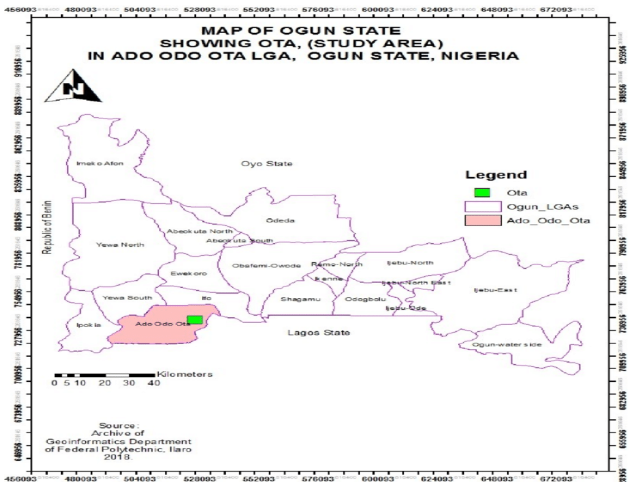


**Figure 1: Map of Ota, Ogun State, Nigeria (Ajala, 2019)**

### 2.2 Study Population

The Bells University of Technology's Architecture, Engineering, and Construction students and professionals served as the study's target population.

### 2.3 Building Simulation Analysis

The analysis of a building's energy performance using computer modelling methods is known as building energy simulation. Bells University Metal laboratory was analysed using the simulation technique. For the simulation, Insight 360 software was used as a building energy performance tool to generate a model. Insight 360 is a validated tool and has furnished architects and integrated teams with centralized access to perform data and an advanced analysis engine for the calculation of energy utilization. The exact building and weather conditions were utilized for making the simulation model.

## III. RESULT AND DISCUSSION

### 3.1 Simulation Analysis

The simulation analysis was carried out on the Metal Laboratory Analysis located in Bells University of Technology, Ota, Ogun State and yielded the below result. After setting all parameters, the insight 360 software utilised the metal lab. Model (fig. 2). The simulation analysis was for a one-year report to give details of the energy analysis.

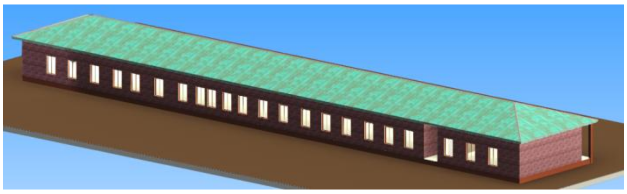

**Figure 2: Rearview Model of the Metal Laboratory**

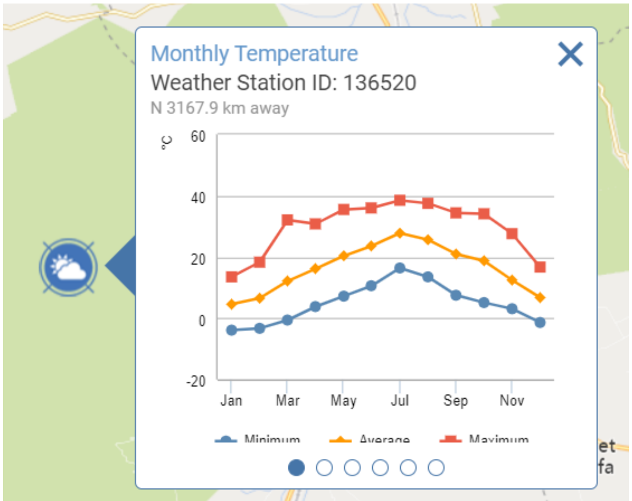


**Figure 3: Weather Chat Analysis of the Metal Lab.**

The weather station above which is showing the weather station of Bells University of technology, in Benja village, off idiroko road. This shows the temperature rises to a maximum high of 38°C to 39°C between May to September and as low as 20°C to 15°C during cold periods. As seen via the chat this is the maximum temperature reading for the entire month.

 

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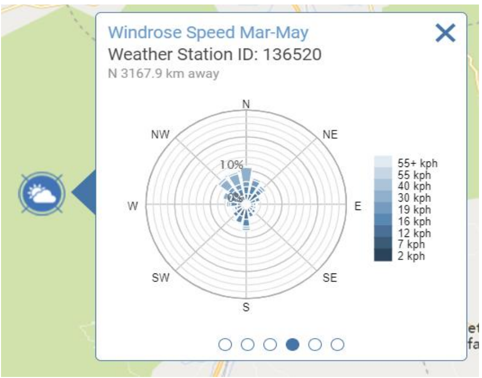


**Figure 4: Windrose Speed (March to May)**

Windrose speed annual weather station ID: 136520 shows that the wind is fastest on the 55kph and the northern hemisphere, a little windier in the north-west with each reading nearing 10% precipitation level, between March to May.

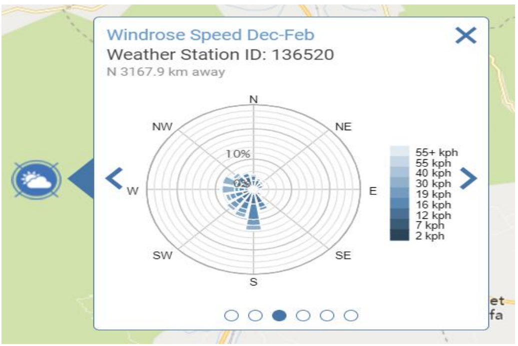


**Figure 5: Windrose Speed (December to February)**

Windrose speed annual weather station ID: 136520 shows that the wind is fastest on the 55kph and the southern hemisphere between December to February.

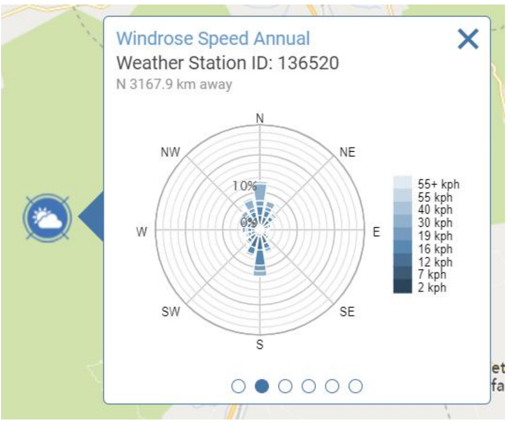


**Figure 6: Windrose Speed Annual**

Windrose speeds annual weather station ID: 136520 shows the wind is fastest on the northern parts of the site at 55kph and the south pole.

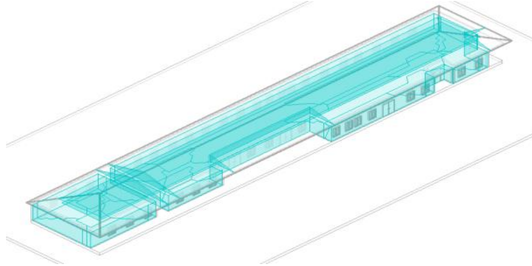

**Figure 7: Energy Analytical Model of the Metal Laboratory**

Fig. 7 shows the various areas covered in green which will be analysed. Table 1 shows the observation of the calculated area of the spaces partitioned with a schedule of analytical surfaces to be perused. This is because the type of materials used in the construction of this building has been considered. A steel door will have its ratings for insulation, as will a wooden door. A single sheet of glass will have its ratings against a triple-sheeted or reinforced glass. Also, the material used for the roof and ceiling, and walls be analysed for the optimal benefit of the metal laboratory. The study of this model/ building will shape the reason why some elements should be replaced, removed, or added to have an energy-efficient building.

**Table 1: Analytical Surface Area of Metal Lab**

<Analytical Surfaces>

| A | B | C | D |
|---|---|---|---|
| Area | Count | Opening Type | Surface Type |
| 32 m² | 8 | Non-sliding Door | |
| 72 m² | 43 | Operable Window | |
| 365 m² | 28 | | Exterior Wall |
| 359 m² | 13 | | Interior Floor |
| 48 m² | 7 | | Interior Wall |
| 659 m² | 16 | | Raised Floor |
| 455 m² | 11 | | Roof |
| 2612 m² | 7 | | Shade |
| 4601 m² | | | |

**Table 2: Analytical Spaces of Metal Lab**

<Analytical Spaces>

| A | B | C | D |
|---|---|---|---|
| Area | Count | Room Name | Volume |
| 264 m² | 1 | Analytical Space 15 | 576.51 m³ |
| 31 m² | 1 | Analytical Space 18 | 64.49 m³ |
| 22 m² | 1 | Analytical Space 10 | 41.85 m³ |
| 26 m² | 1 | Analytical Space 11 | 51.69 m³ |
| 22 m² | 1 | Analytical Space 9 | 41.85 m³ |
| 33 m² | 1 | Analytical Space 17 | 62.53 m³ |
| 51 m² | 1 | Analytical Space 16 | 96.00 m³ |
| 1 m² | 1 | Analytical Space 5 | 0.98 m³ |
| 307 m² | 1 | Analytical Space 3 | 267.97 m³ |
| 20 m² | 1 | Analytical Space 4 | 18.24 m³ |
| 27 m² | 1 | Analytical Space 14 | 52.19 m³ |
| 13 m² | 1 | Analytical Space 2 | 9.20 m³ |
| 51 m² | 1 | Analytical Space 1 | 39.09 m³ |
| 22 m² | 1 | Analytical Space 13 | 41.36 m³ |
| 28 m² | 1 | Analytical Space 12 | 62.03 m³ |
| 79 m² | 1 | Analytical Space 8 | 183.64 m³ |
| 9 m² | 1 | Analytical Space 6 | 19.69 m³ |
| 12 m² | 1 | Analytical Space 7 | 27.08 m³ |
| 1017 m² | | | 1656.38 m³ |

 

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**Table 3: Price of Electricity in Nigeria**

## Nigeria electricity prices

| Nigeria electricity prices | Household, kWh | Business, kWh |
|---|---|---|
| Nigerian Naira | 23.592 | 38.530 |
| U.S. Dollar | 0.057 | 0.093 |

**Source: GlobalPetrolPrices.Com**

In Nigeria, the price of electricity is 0.057 USD per KWh for households and 0.93 USD for businesses which includes all components of the electricity bill such as the cost of power, distribution, and taxes. For comparison, the average price of electricity in the world for that period is 0.135 USD per Kwh for households and 0.126 USD for businesses.

Calculations were based on several data points at various levels of electricity consumption for both households and businesses but the chart in fig. 8, only shows two data points. Since this analysis will check the consumption of electricity as well as petroleum in a private business franchise the rates above will apply on an annual consumption base.

**Pv-payback limit:** Use the payback period to determine which surfaces will be used for the PV system. Surfaces with shading or poor solar orientation may be excluded with the current setting at 20 years to 30 years duration for the payback. This would give the occupant enough time to fund the repayment for PV Panels installed.

**Pv-surface coverage:** With the current setting at 75% to 90% to be covered by the PV-Surface.

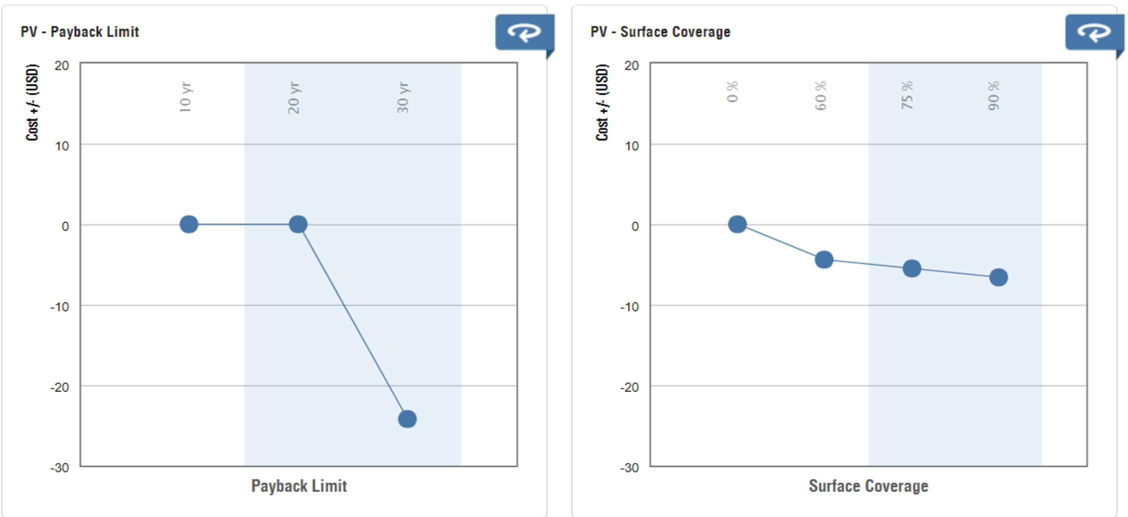


**Figure 8: Analysis of PV-Panel of Metal Lab**

**HVAC:** Represents a range of HVAC systems efficiency which will vary based on location and building size. with the current setting for the building information model (BIM) is high-efficiency terminal AC.

**Schedule:** The typical hours of use by building occupants' current setting: 12/7 – BIM.

**Pv – panel efficiency: t**he percentage of the sun's energy will be converted to AC energy. Higher efficiency panels same surface area. Current setting 18.6% - 20.4%.

 

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**Figure 9: HVAC, Operating Schedule and Panel Efficiency of Metal Lab**

**Lighting efficiency:** Represents the average internal heat gain and power consumption of electric lighting per unit floor area. Current setting: 20.45 W/m² - 7.53 W/m²

**Daylighting and occupancy control:** Represents typical daylighting dimming and occupancy sensor systems. Current setting: Daylighting controls – Occupancy controls.

**Plug load efficiency:** The power used by equipment i.e. Computers and small appliances excludes lighting or heating and cooling equipment. Current setting BIM -6.46 W/m²

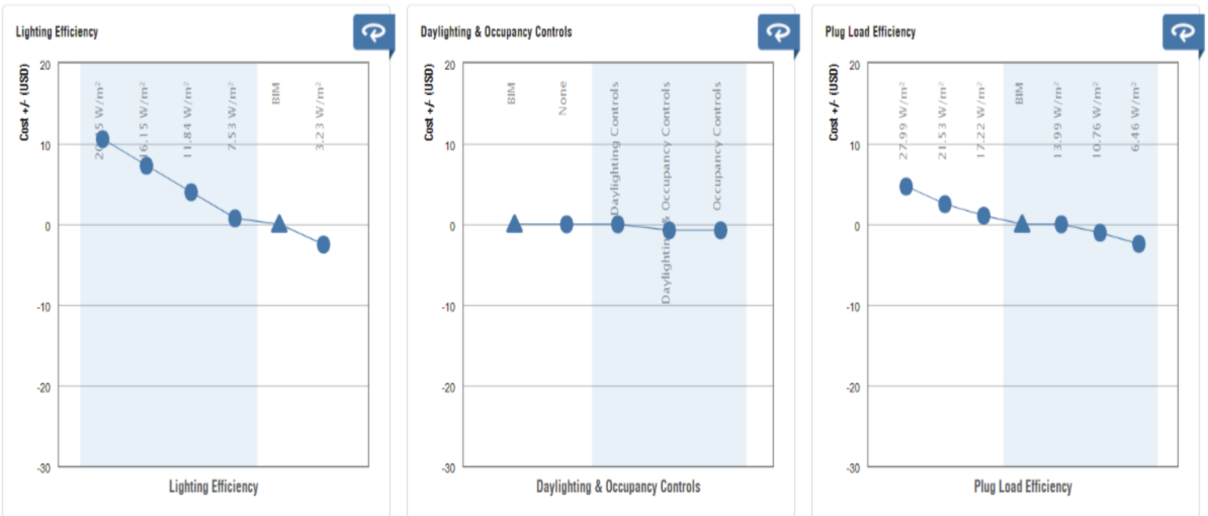


**Figure 10: Lighting Efficiency, Daylighting Occupancy Control and Plug Load Efficiency of Metal Lab**

**Wall construction:** Represents the overall ability of wall constructions to resist heat losses and gains. Current setting: BIM – R38 Wood.

**Roof construction:** This represents the overall ability of roof construction to resist heat losses and gains. Current setting: R15 – R38

**Infiltration:** The unintentional leaking of air into or out of conditioned spaces; is often due to gaps in the building envelope. Current setting: 0.4 ACH – 0.17 ACH

 

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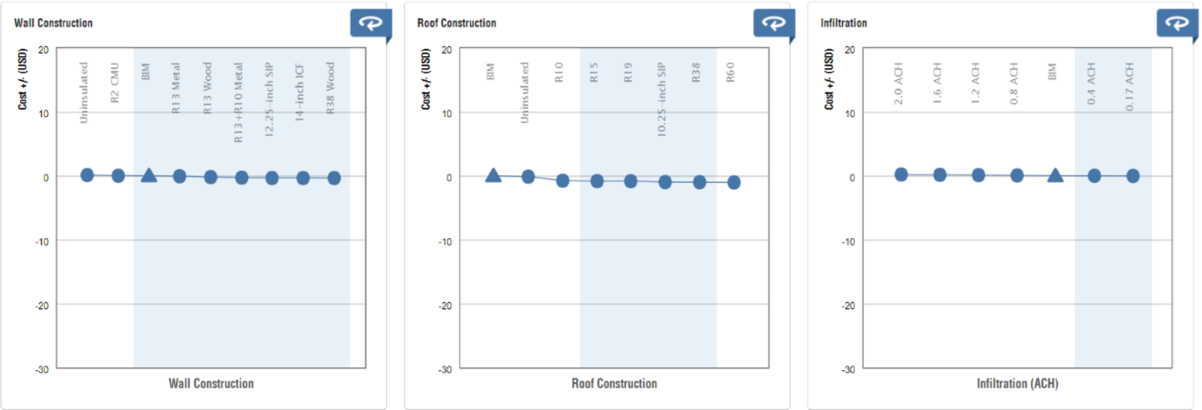


**Figure 11: Wall Construction, Roof Construction and Infiltration of Meta Lab**

**Wwr – eastern walls:** Window-Wall-Ratio (Glazing area/gross wall area) interacts with window properties to impact daylighting, heating, and cooling. Current setting: 40% to BIM (29%).

**Window shades – east:** Shades can reduce HVAC energy use. The impact depends on other factors. Such as window size and solar heat gain properties.  Current setting: 1/3 Window (Win.) height to 2/3 Window Height.

**Window glass – east:** Glass properties control the amount of daylight, heat transfer, and solar heat gain into the building along with other factors. Current setting: BIM to Trp LoE

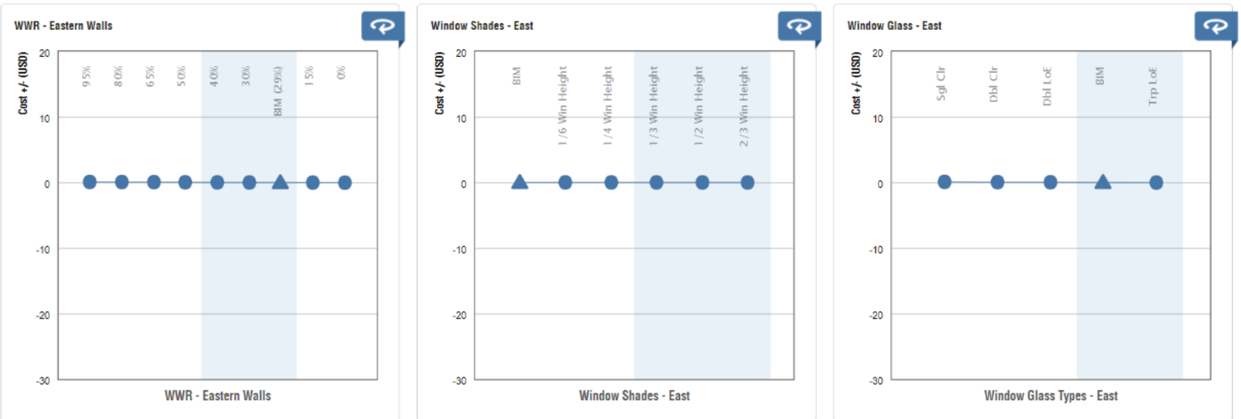


**Figure 12: Eastern Wall, Window Shade and Glass of Metal Lab**

**Wwr – western walls:** Window-Wall Ratio (glazing area/ gross wall area) interacts with window properties to impact daylight, heating, and cooling. Current setting: BIM (23%)

**Window shades – west:** Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties. Current setting: 1/3 Window Height to 2/3 window height.

**Window glass – west:** Glass properties control the amount of daylight, and the heat gained into the building along with other factors. Current settings: Trp LoE – BIM.

 

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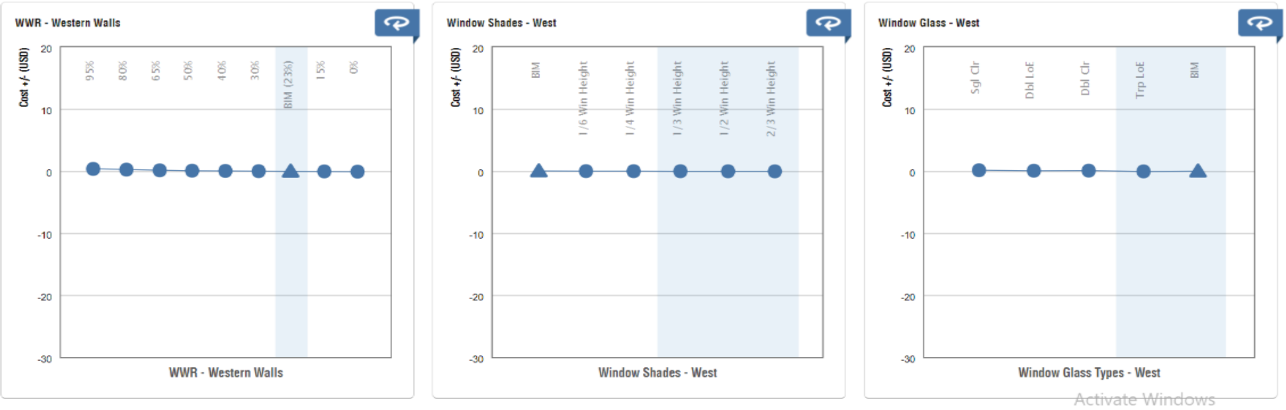


**Figure 13: Western Wall, Window Glass and Shade of Metal Lab**

**Wwr – northern walls:** Window-Wall Ratio (glazing area/ gross wall area) interacts with window properties to impact daylight, heating, and cooling. Current setting: 40% - BIM (16%).

**Window shades – north:** Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties. Current setting: 1/6 Window Height to 1/3 window height.

**Glass – north:** Glass properties control the amount of daylight, and heat gains into the building along with other factors. Current settings: Trp LoE – BIM.

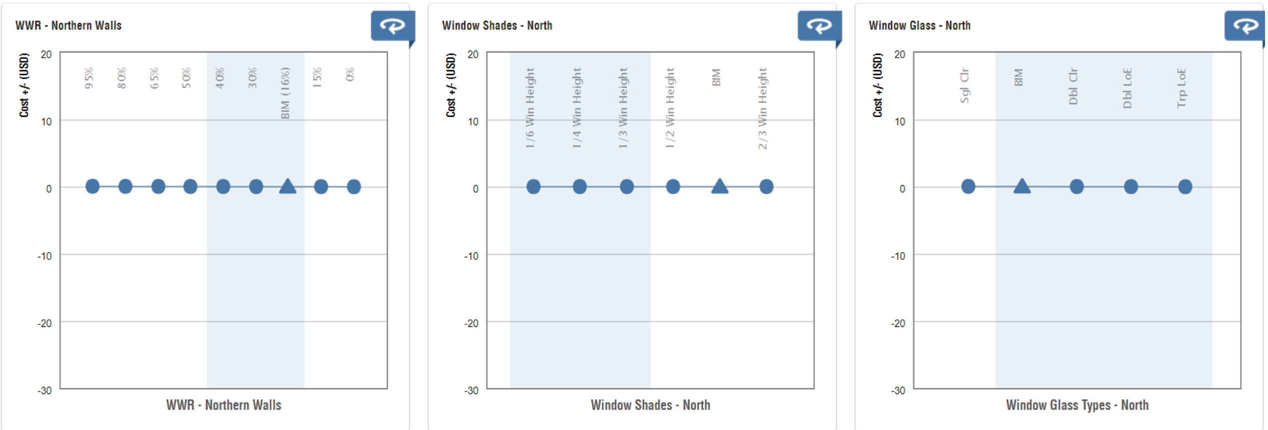


**Figure 14: Northern Walls, Window Shade and Glass of Metal Lab**

**Wwr – southern walls:** Window-Wall Ratio (glazing area/ gross wall area) interacts with window properties to impact daylight, heating, and cooling. Current setting: BIM (6%) to 40%.

**Window shades – south:** Shades can reduce HVAC energy use. The impact depends on other factors, such as window size and solar heat gain properties. Current setting: 2/3 Window Height to 1/3 window height.

**Window glass – south:** Glass properties control the amount of daylight, and the heat gained into the building along with other factors. Current settings: BIM – Sgl Clr.

 

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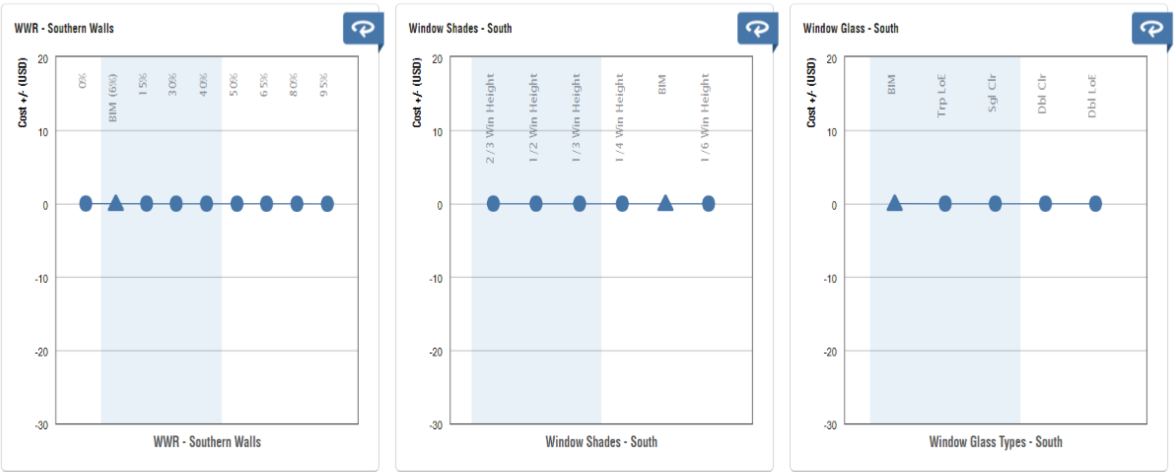


**Figure 15: Southern Walls, Window Shades and Glass of Metal Lab**

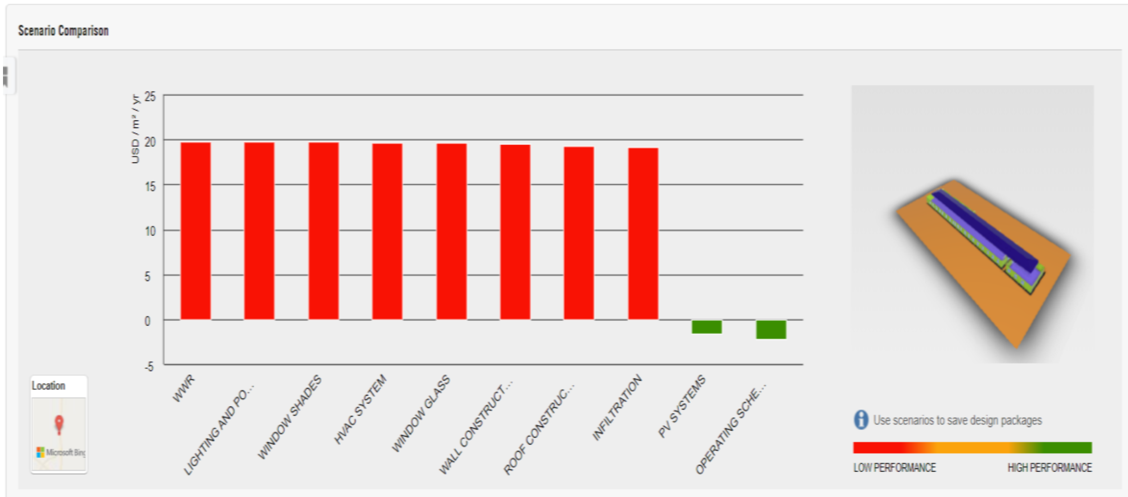


**Figure 16: Comparison of Energy Efficient Parameters of Metal Lab**

The current exchange rate of Dollars to Naira= ₦580.0 black market values

\$13.9 / sqm in a year which is ₦8062.0/m²

672.35 m x 11.4m = area of the building

766.08m².

Therefore, the total area of the building by cost per square meter is equal to the cost of energy consumption per year.

766.08m x ₦8062.0

= ₦6,176,136.96

Therefore, at this rate, this will be what this building will consume if the building is in use every single day.

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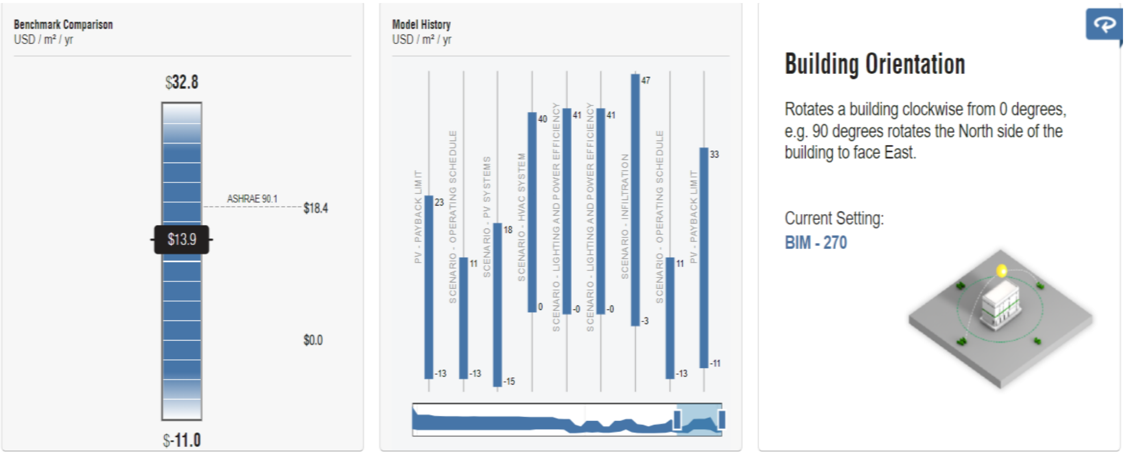


**Figure 17: Benchmark Comparison of Energy Efficiency of Metal Lab**

The above analysis provided shows that just before construction; a building can be planned such that you maximize the potential of the elements around the environment to achieve maximum energy efficiency. The initial cost from the benchmark comparison was 32.8$ per sqm in a year. In naira that will translate to ₦19, 024.00 which is expensive when considered.

Now, by providing and tweaking things up and down in the building all that was reduced to the rate of 13.9$ which translates to ₦8,062.00 at this rate almost double that amount has been saved so far. The various key elements discussed and rearranged have affected the productivity of the building positively, this building has been programmed to not only provide efficient energy but also save some funds literally.

### 3.2 Questionnaire Analysis

#### *3.2.1 Characteristics of Respondents*

The questionnaire was responded to among students and staff in the built profession (architecture, engineering and construction) within the Bells University of Technology, and a total of 103 responses was gathered via the random sampling technique. Table 4 shows the socio-demographic pattern of the respondents. The questionnaire was mostly answered by males (73.8%) while the female response was 26.2%. The highest age group of the respondent was between 20 – 30 years. Marital status, education, ethnicity and religion had a mix of all the groups. The occupational role of the respondents shows that 56.3% of the respondents were other which are students within the institution, 35% were academic staff and 8.7% were the administrative staff. 61.2% of them have been using the facility for over one year (fig. 18) which implies they would be able to give sufficient information about the building.

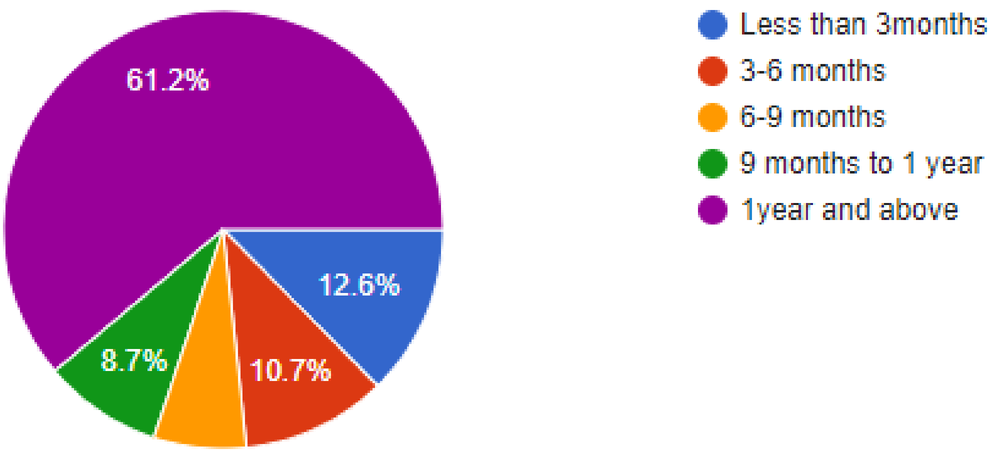


**Figure 18: Length of Facility Usage**

 

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**Table 4: Respondent's Socio-Demographic Characteristics**

| S/N | Socio-Demographic Characteristics | Category | Frequency n=103 | Percentage %=100 |
|---|---|---|---|---|
| 1 | Gender | Male<br>Female | 76<br>27 | 73.8<br>26.2 |
| 2 | Age grouping (years) | Below 20<br>20-30 years<br>30-40years<br>40-50 years<br>50 and above | 9<br>42<br>18<br>29<br>5 | 8.7<br>40.8<br>17.5<br>28.2<br>4.9 |
| 3 | Marital Status | Married<br>Single<br>Divorced/Separated<br>Widowed | 36<br>58<br>7<br>2 | 35<br>56.3<br>6.8<br>1.9 |
| 4 | Educational attainment | Diploma<br>B.Sc./HND<br>Postgraduate | 15<br>45<br>43 | 14.6<br>43.7<br>41.7 |
| 5 | Occupational role | Admin staff<br>Academic staff<br>Technical staff<br>Others | 9<br>36<br>0<br>58 | 8.7<br>35.0<br>0<br>56.3 |
| 6 | Religion | Christian<br>Muslim<br>Others | 70<br>23<br>10 | 68<br>22.3<br>9.7 |
| 7 | Ethnicity | Igbo<br>Yoruba<br>Hausa<br>Others | 22<br>52<br>7<br>22 | 21.4<br>50.5<br>6.8<br>21.4 |

### *3.2.2 Energy Savings, Consumption and Efficiency*

Observation and questionnaire analysis shows that the majority of the respondent has sufficient knowledge about energy efficiency within the institution. Some of their definition of energy efficiency includes; energy efficiency is the use of less energy to perform a particular task, energy-efficient buildings utilize less energy for heating, cooling and running of appliances. Energy efficiency is the capacity of a building or equipment to use minimal energy to function and operate. Energy efficiency also means saving and maximizing energy utilization.

Energy saving within the institution includes; using natural lightning within interior spaces, use of low energy lighting equipment, switching off equipment when not in use and space positioning for effective natural lightning utilization. Table 5 shows the respondent's frequency on the adequacy of energy-efficient design considerations. The response rate to all the indicators shows they are adequate. Fig. 18 shows the summary of the implementation of energy efficiency indicators in the building design. The descriptive statistics show that energy efficiency indicators and strategies are adequately implemented (41.54%) in the design of the institutional building. 36.23% of the respondents say that the energy efficiency indicators have been fairly utilized in the building design and just a few (2.81%) respondents don't agree with the utilization of energy efficiency indicators.

This gives a clear indication that the buildings being utilized in the institution are energy efficient and this may be a result of utilizing professionals in the construction of such buildings. The result of this study shows that built professionals know what energy efficiency is and it has been utilized in the design and construction of the institution building which aligns with what Erebor et al., (2021) documented on the appraisal of awareness and implementation levels of energy efficient design strategies. The result of some other studies says that awareness and implementation of energy efficiency among professionals in the construction industry in Nigeria are low (Atanda & Olukoya, 2019). This aligns with studies in China (Ding & Zhou, 2020), Malaysia (Azizi, Wilkinson, & Fassman, 2015) New York (Trencher & Van der Heijden, 2019).

 

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**Table 5: Response Rate on Adequacy of Energy Efficient Design Considerations in Institutional Buildings**

| Design Considerations | Very Adequate | Adequate | Fair | Inadequate | Very Inadequate |
|---|---|---|---|---|---|
| Space Capacity | 16 | 46 | 37 | 2 | 2 |
| Amount of Natural lighting impact on building | 22 | 47 | 28 | 6 | 0 |
| Amount of Artificial lighting impact on building | 12 | 51 | 31 | 4 | 5 |
| Space Utilization rate | 15 | 43 | 39 | 4 | 2 |
| Energy consumption | 7 | 43 | 40 | 10 | 3 |
| Energy consumption per work output | 8 | 39 | 48 | 7 | 1 |
| Operating schedule | 8 | 49 | 40 | 3 | 3 |
| Occupancy control during the day | 10 | 45 | 41 | 4 | 3 |
| Occupancy control at night | 13 | 37 | 42 | 5 | 6 |
| Impact of natural airflow | 13 | 42 | 35 | 9 | 4 |
| Impact of artificial airflow | 9 | 38 | 39 | 12 | 5 |
| Space temperature | 21 | 33 | 33 | 13 | 3 |
| Size of fenestration | 8 | 53 | 31 | 9 | 2 |
| Natural light efficiency | 11 | 52 | 33 | 6 | 1 |
| Distance to trees/natural shed | 8 | 38 | 33 | 19 | 5 |
| Wind direction | 7 | 38 | 36 | 20 | 2 |
| Building orientation | 10 | 35 | 39 | 15 | 4 |
| Building height | 11 | 43 | 38 | 10 | 1 |
| Building configuration | 8 | 41 | 46 | 5 | 3 |

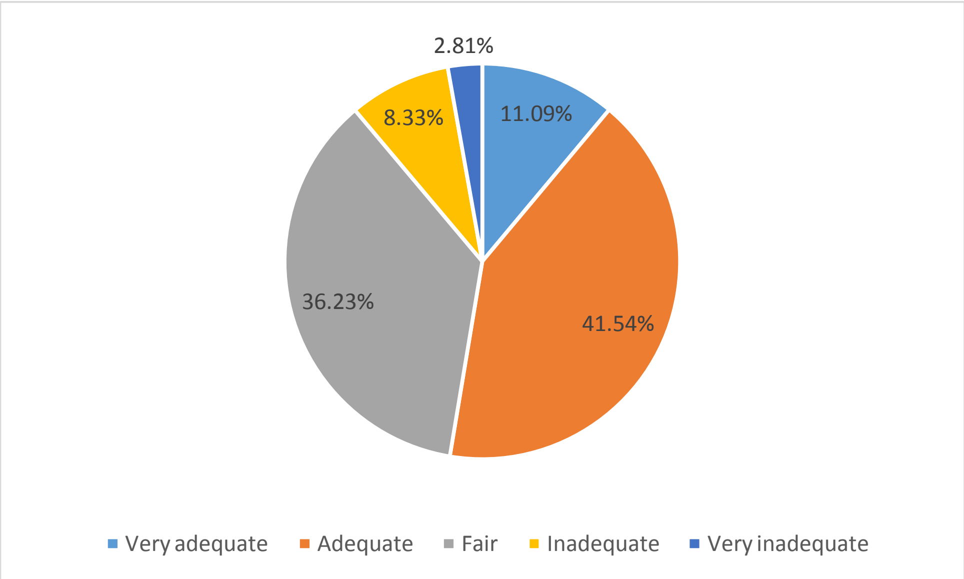


**Figure 18: Summary of the Adequacy Level of Energy Efficiency Design Strategies and Indicators in Institutional Buildings**

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## IV. CONCLUSION

According to the research and assessments, a number of factors affect how much energy is used in the structure, including; building orientation, window shades, window-to-wall ratio, window glass, wall construction, roof construction and lighting efficiency. By utilizing the right technology for building envelope design, which has a significant impact on energy consumption in the building, these energy consumption variables can be minimized. The simulation results indicate, in contrast to the roof structure, that there are fewer energy gains from using shading devices and window glass properly for reducing energy consumption. An important issue to take into account when constructing a building is how the building envelope will affect how much energy will be required to heat and cool it. As a result, the building envelope must be optimized to reduce heating and cooling loads. One of the most important factors to take into account when designing a building is the nature of the building envelope because it determines the amount of energy required to heat and cools a building. As a result, the building envelope needs to be optimized to keep heating and cooling loads to a minimum.

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