# Simulation Based Energy Use Assessment of old housing stock ibadan, oyo state , Nigeria

Edward Adeshola Oladigbolu [1], Afolabi Oladele [2] , Abiodun Kushimo[3]

[1]*Department of Architecture, Bells University of Technology, Ota*
[3]*Department of Architecture, University of lagos*

[1]eddiecreativity@gmail.com , [2]foleabzy@gmail.com, [3]environkush@gmail.com

**Abstract**

Over the years, the housing typology has undergone a variety of paradigm shifts, influenced by regulatory changes, developments in technology and materials, changes in architectural thinking and economic issues. However, the traditional houses in Western Nigeria, typically the ibadan, oyo state mud houses has lasted over generations and experienced varying climatic conditions. Moreso, inspite of the increase in heat within the climatic region, the traditional houses built with mud and adobe building material has lasted the test of time. Heat experienced in this structure cannot be compared to the modern sandcrete blocks construction in order to achieve thermal comfort. Couple of these traditional houses are being retrofitted while most are being demolished outrightly. This research tends to use a simulation approach to examine the energy use to maintain an appropriate indoor condition for thermal comfort and energy use. Revit and insight 360 are being used to smulation the model afterits being drafted in autocad and position appropriately on google map. This enables us identify the impact of the building material envelop on its energy use intensity.However, the Energy use intensity result of 454kwh/m2/yr. was gotten which is high compared to the benchmark of 286kwh/m2/yr accepted for the building. Moreso, , in order to achieve the benchmark as stipulated, other areas have to be looked into like the Operational schedule, lighting efficiency etc

***Keywords***: building envelope, traditional housing, energy use, simulation

**Background to Case Study**

The building in this study was selected randomly. Located in Balogun Geeru village in Akinyele Local Government area of Ibadan, Oyo State, Nigeria. Access to this village can be either through Arola-Aiyegun-Oleyo road in Apete area of Ido local Government area (also in Ibadan Oyo state) or through Ajibode-Laaniba road behind University of Ibadan. Ibadan itself, the state capital has coordinates 7˚ 23′ N and 3˚ 54′ E (Adekola, 2017). It was founded in the 1820's and was an important administrative centre all through the colonial era. In terms of land mass, Ibadan has (between 1982 and 1991) gone from 130.5 square kilometres to 240 square kilometres. By the year 2000, it expanded covering an area of about $400km^2$. By virtue of location, it is well favoured for educational, socio-political, commercial and industrial activities. Mean annual temperature stands at $21^0C$ and mean annual rainfall at about 1,205 mm lasting approximately 109days (Egbinola & Amobichukwu, 2013).

From oral interviews conducted with the residents of this building, its age is estimated to be over 120 years. The woman of the house mentioned that her late father in-law was born in the house and his oldest living sibling is now over 85 years. There are currently 8 people living in the house i.e. both adults and children. The ratio of adults to children was not stated. The house is one of two buildings of the same size, design and construction materials and the building studied being the only habitable one. It is bounded on the southern and western sides by the old residence of the Baale (village head) and another building of the same type (and possibly same age) respectively.

Mode of Construction

A closer examination reveals that there are definite lines on the earthen walls indicating that the walls were raised using layers of earth. These lines upon measurement, indicate that each layer is 460mm high and the thickness 250mm. From the interview conducted, the earthen walls underwent a modified pre-construction process, a combination of two traditional techniques of earth construction. The earth was dug up from trenches nearby and mixed to a state of plasticity by pulverizing it while in the trenches with the feet (Yasemin Ebril, 2018). Sand, consisting of aggregates between 5mm and 13mm diameter was added to stabilize.

Ordinarily, this mix should have been poured into wooden molds or rolled into balls and placed in layers to raise the walls (based on the adobe or cob techniques) instead, it was placed in between form work previously erected (Baglioni E et al, 2016) The height and width of the formwork (previously stated) gave the wall its distinctive lines and thickness. The windows are made of timber and have four panels each with an operable fan light (also in timber). The main entrance door is also of the same material and configuration. The roofing material is corrugated zinc and has evidently undergone corrosion over the years. The rafters and struts are also of timber however they are roughly circular in cross section rather than rectangular.

Fig 1- photograph showing building under study with the damaged kitchen wall at the rear and the small high level windows
Source: Author's field work

Fig 2- photograph showing building under study on the right with the "uninhabited twin" on the left.
Source: Author's field work

## Spatial Configuration

There are basically 8 rooms within the building. These are laid out in two parallel rows with a lobby separating both. Each room opens outward into the lobby space reminiscent of the Afro-Brazilian style of design. The space used for the kitchen is the room at the right rear end of the building. Part of the original walls on the western and the northern sides are broken down. The wall on the southern side has been replaced by conventional sandcrete blocks (150mm thick) while the other wall has been left in the damaged state.

The building under study is one of two buildings erected side by side with a corridor space of 1.25m in between them and is the only habitable one of the two. Each building is separately roofed and done in the same design style.

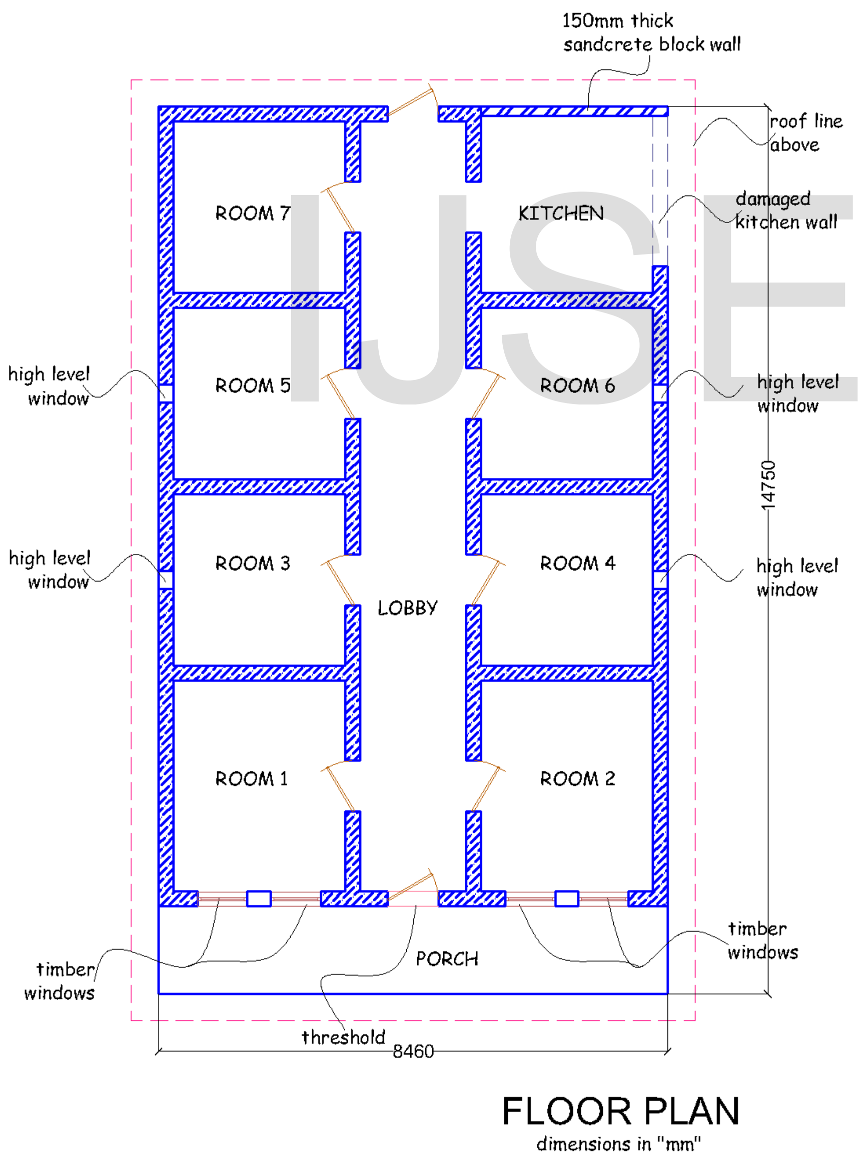


Fig 3: Floor plan of building

Source: Authors' Field work


Fig 4; Aerial view of Case Study- Source Google Earth (01/04/22)



## Methodology

Initial site inventory of facility is aimed at cataloguing and documenting the building characteristics which is needed for simulation. Thus, it becomes a significant repository of graphical and alphanumeric information useful to make several analyses and generate innumerable output mutually consistent (Ugliotti, Dellosta et al. 2016).

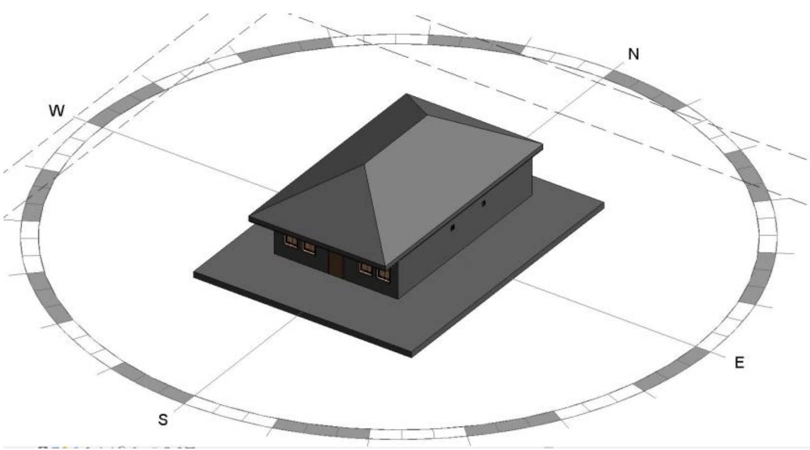


Fig 5; Model of subject as orientated on site( source: authors field work)

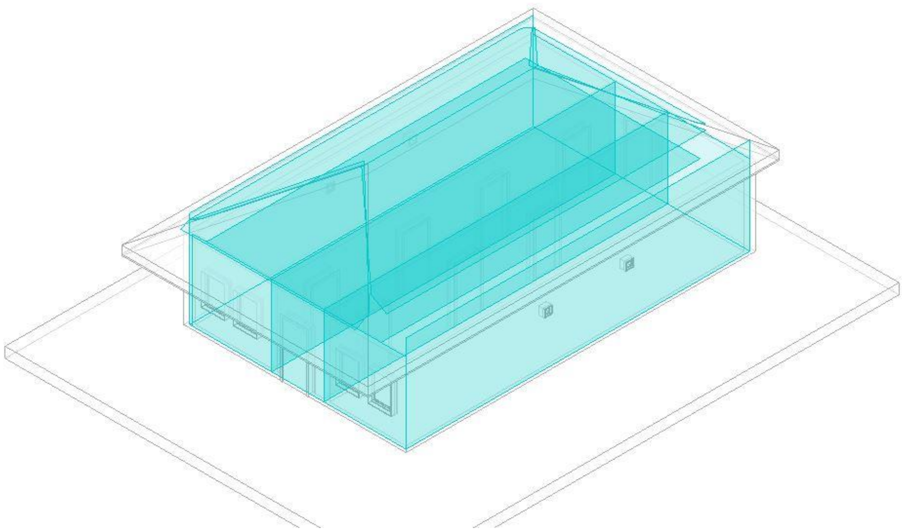

Fig 6; Massing assessment in Revit for energy simulation (source: authors field work)

Building information as extracted are well documented in the table below.

**Table 1 General data**

| | |
|---|---|
| **Use class** | **Residential** |
| **Building Operating Schedule** | All year round |
| **Latitude/Longitude** | 7º28'46.3'N, 3 $^{0}$52'28.7" E |
| **Climatic zone** | Tropical region |

**Table2 Thermal transmittance of opaque elements**

| **Material** | **Thermal transmittance U(W/m2k)** |
|---|---|
| **External wall** | Laterite mud (U=0.8108) |
| **Internal Wall** | Laterite mud (U=0.8108) |
| **Roof** | Metal roof, R-19 batt insulation, (U=0.2490) |

| | |
|---|---|
| **Windows** | wood |

**Result**

Several online simulation soft wares such as passivehaus, ener-habitat, ecotect, etc. are being used to analyze the building performance in terms of energy use intensity and lighting analysis. Insight 360 which is a cloud based energy assessment software developed by Autodesk has been guaranteed to give 95% accuracy in terms of energy use based on the LEED benchmark requirement, so far the weather station based on their climatic conditions and location are being accessed. First and foremost, the model was sent to the insight 360 cloud and a confirmation is sent to the email.

Based on the simulated results there are several key indicators that can be controlled to achieve a sustainable target or energy goal. The indicators are as listed below;

i) Wall construction
ii) HVAC
iii) Western wall
iv) Operating schedule
v) Eastern walls
vi) Southern walls
vii) Plug load efficiency
viii) Lighting efficiency
ix) Infiltration
x) Northern walls
xi) Window Glass- west
xii) Window Glass- east
xiii) Window Glass- South
xiv) Window Glass – North
xv) Roof construction
xvi) Window shades – south
xvii) Window shade – west xviii) Window shade – east xix) Daylighting and occupancy controls

xx) Building orientation

xxi) Window shades – North

xxii) PV –panel efficiency xxiii) PV-payback limit

xxiv) PV –Surface coverage

## Findings and Discussions

Building energy regulatory policy in many countries is moving towards levels approximating net zero energy or net zero carbon(Berry, Whaley, Saman, & Davidson, 2014). Further more, berry et all stated that the concept of combining passive solar design strategies with energy efficient devices and renewable energy technologies is not particularly new. Case studies demonstrating the potential for extremely low energy homes have appeared in many countries and many climates, and recently the International Energy Agency's "Towards Net Zero Energy Solar Buildings" project mapped almost 300 net zero energy and energy-plus buildings worldwide. However, through simulation process, passive strategies deployed in building typology can easily be indentified abd theri impact calculateed numerically.

Figure 7 shows the energy use per year in the facility under the condition in which the building is , with its current building envelope characteristic and parameters. However, the energy use didnt meet up to the 2030 sustainable development goal(SDG) as suggested by the application. Furthermore, table 3 shows all the simulation results and options of its characteristics that can be altered in order to achieve the SDG goals and enhance passive strategies deployment in the building.

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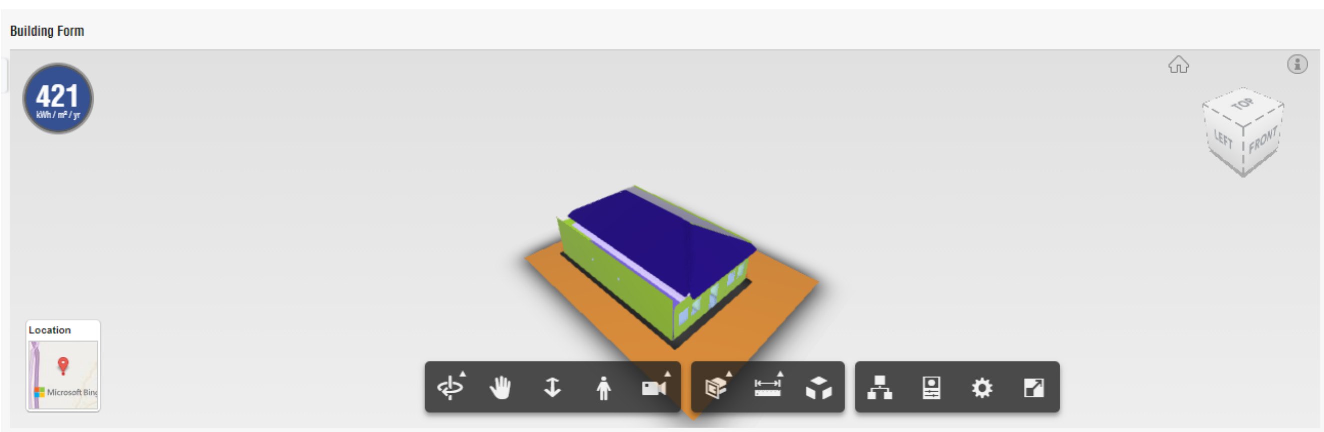


Fig7; simulation result from insight 360

**Table 3 Simulation result from insight 360**.(authors field work)

| Building characteristics | Properties of BC | Energy Use intensity | Benchmark |
|---|---|---|---|
| **Orientation** | 225 | **+3.35** | |
| | 135 | **+2.77** | |
| | 90 | **+1.6** | |
| | BIM | **421kwh/m2/yr** | |
| | 270 | **-0.12** | |
| **WWR-South wall** | 95% | **+15.13** | |
| | 80% | **+12.64** | |
| | 40% | **+4.75** | |
| | BIM(18%) | **421kwh/m2/yr** | |
| | 15% | **-0.67** | |
| **WWR-North wall** | 95% | | |
| | 80% | | |
| | 40% | | |
| | BIM(16%) | **421kwh/m2/yr** | |
| | 15% | | |
| **WWR-West wall** | 95% | **+224kwh/m2/yr** | |
| | 80% | **+191kwh/m2/yr** | |
| | 40% | **+99kwh/m2/yr** | |
| | BIM(15%) | **421kwh/m2/yr** | |
| **WWR-East wall** | 95% | **+197kwh/m2/yr** | |
| | 80% | **+164kwh/m2/yr** | |
| | 40% | **+84kwh/m2/yr** | |
| | BIM(14%) | **421kwh/m2/yr** | |

| | | | | |
|---|---|---|---|---|
| **Window south** | **Shades-** | BIM | **421kwh/m2/yr** | |
| | | 1/6 Win-height | | |
| | | ¼ Win-height | | |
| | | ½ Win-height | | |
| | | 2/3 Win-height | | |
| **Window North** | **Shades-** | BIM | **421kwh/m2/yr** | |
| | | 1/6 Win-height | | |
| | | ¼ Win-height | | |
| | | ½ Win-height | | |
| | | 2/3 Win-height | | |
| **Window West** | **Shades-** | BIM | **421kwh/m2/yr** | |
| | | 1/6 Win-height | | |
| | | ¼ Win-height | | |
| | | ½ Win-height | | |
| | | 2/3 Win-height | | |
| **Window East** | **Shades-** | BIM | **421kwh/m2/yr** | |
| | | 1/6 Win-height | | |
| | | ¼ Win-height | | |
| | | ½ Win-height | | |
| | | 2/3 Win-height | | |
| **Window south** | **Glass-** | Sgl-Clr | | **286kwh/m2/yr** |
| | | Dbl-LoE | | |
| | | Dbl-Clr | | |
| | | BIM | **421kwh/m2/yr** | |
| **Window North** | **Glass-** | Sgl-Clr | | |
| | | Dbl-LoE | | |
| | | Dbl-Clr | | |

| | | |
|---|---|---|
| | BIM | **421kwh/m2/yr** |
| **Window Glass-West** | Sgl-Clr | |
| | Dbl-LoE | |
| | Dbl-Clr | |
| | BIM | **421kwh/m2/yr** |
| **Window Glass-East** | Sgl-Clr | |
| | Dbl-LoE | |
| | Dbl-Clr | |
| | BIM | **421kwh/m2/yr** |
| **Wall construction** | Uninsulated | |
| | R 2 CMV | |
| | R13 Metal | |
| | BIM | **421kwh/m2/yr** |
| | 14inch ICF | |
| **Roof construction** | Uninsulated | |
| | R10 | |
| | R19 | |
| | R60 | |
| | BIM | **421kwh/m2/yr** |
| **Infiltration** | 2.0 ACH | |
| | 1.6 ACH | |
| | 0.8 ACH | |
| | BIM | **421kwh/m2/yr** |
| | 0.17 ACH | |

| | | | |
|---|---|---|---|
| **Lighting efficiency** | 20.45 W/M2 | **+64kwh/m2/yr** | |
| | 11.84W/M2 | **+6.5kwh/m2/yr** | |
| | BIM | **421kwh/m2/yr** | |
| | 3.23W/M2 | **-36.9kwh/m2/yr** | |
| **Daylighting and occupancy controls** | BIM | **421kwh/m2/yr** | |
| | Daylighting controls | | |
| | Occupancy controls | | |
| | D and O controls | | |
| **Plug load efficiency** | 27.99W/m2 | | |
| | 17.22W/m2 | | |
| | 10.76W/m2 | | |
| | BIM | | |
| | 6.45w.m2 | | |
| **HVAC** | ASHRAE Heat Pump | | |
| | ASHRAE Package system | | |
| | BIM | **421kwh/m2/yr** | |
| | High efficiency Heat pump | | |
| **Operating schedule** | 24/7 | **+64kwh/m2/yr** | **286kwh/m2/yr** |
| | BIM | **421kwh/m2/yr** | |
| | 12/7 | **-26kwh/m2/yr** | |
| | 12/6 | **-50kwh/m2/yr** | |
| | 12/5 | **-78kwh/m2/yr** | |
| **PV- panel efficiency** | 16% | | |
| | 18.6% | | |
| | 20.4% | | |

| | |
|---|---|
| **PV- payback limit** | 10 years<br>20 years<br>30 years |
| **PV- surface coverage** | 0<br>60%<br>75%<br>90% |

**-36.9**

**Discussion of findings**

The simulation result has been explicitly written out in table 3 above. From the table, all the twenty (24) variables were adequately tested through the simulation experiment and we could identify the most important element in the building envelope and its impact on energy use intensity (EUI). The building envelop has high thermal mass with attributes of a phase change material (PCM) which tends to maintain the indoor environmental quality through varying climates. However, the Energy use intensity result of 421kwh/m2/yr is high compared to the benchmark of 286kwh/m2/yr accepted for the building. Moreso, from the table we could see that any other variant of building envelope will increase the energy demand. Furthermore, in order to achieve the benchmark as stipulated, other areas have to be looked into like the Operational schedule, lighting efficiency etc



**Conclusion**

With increasing need of energy for cooling and heating in residential buildings in nigeria, its very paramount to deploy passive strategies to reduce the energy demand as best as possible. Energy consumption is on the rise for everyday use but with very low energy supply from the grid alternative strrategies are necessary in order to achieve thermal comfort within the building facility.Using simulation made us to numerically identify the impact of each building characteristics and enable decipher where action is neccessary to be taken inorder to achieve a net zero energy building and also properly scrutinize the impact of the passive strategies deployed in the building in reducing the demand for energy all year round.

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