DEVELOPMENT OF THE NATIONAL BUILDING ENERGY EFFICIENCY CODE (BEEC)

Technical Study

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Maps

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0 Executive Summary

This document provides a description of a set of new minimum energy efficiency requirements for Nigeria and the process of identifying them. These minimum energy efficiency requirements have been used to form a National Building Energy Efficiency Code (BEEC). Research was conducted primarily in the Federal Capital Territory of Abuja but the requirements can be adopted by any state in Nigeria. In addition, the process of developing a labelling and incentive scheme, procedures for Control and Enforcement of the minimum energy efficiency requirements, and finally recommendations on calculation and compliance tools are also described. Each of these topics is dealt with in a specific chapter as follows:

Chapter 1: Minimum energy efficiency requirements

Chapter 2: Building energy labels and energy efficiency incentives

Chapter 3: Control and enforcement

Chapter 4: Calculation methods and tools

0.1 Minimum Energy Efficiency Requirements

The scope of such minimum requirements is at this initial stage covering two building categories namely, residential and business/office buildings. Based on the Nigerian Building Energy Efficiency Guideline (BEEG), through case study analysis of design documentation for planned building projects and expert opinions, common design and construction practices have been identified. Through modelling and simulations of a defined "standard" building (Business As Usual – or BAU model) the expected energy performance have been determined. Further, through review of international references as well as simulation variations of the BAU model, the minimum efficient requirements have been identified. The simulations take into account the various climatic conditions found in Nigeria.

A benchmark building which includes energy efficiency interventions that lead to a minimum of 40% energy savings over current building practices was then developed.

The interventions include:

- Overall Window to Wall Ratio not exceeding 20%
- Requirement for shading when Window to Wall Ratio exceeds 20%
- Reduction of installed lighting power density
- Minimum requirements for roof insulation
- Minimum performance of AC equipment specified
- Installation of non-inverter split units to be restricted

Table 1: BEEC Minimum Requirements

Building element	Description	Value
Roof	Add layer of insulation	1.25 m²K/W
WWR	Window to Wall Ratio (or shading)	20%
Lighting – Residential	Maximum lighting power density	6 W/m²
Lighting – Office	Maximum lighting power density	8 W/m²
Air-conditioning split units	Minimum performance	Minimum COP/EER 2.8
Air-conditioning split units	Type of compressor	Inverter compressors only

Two compliance methods are possible:

- Prescriptive: For this option, projects must adhere to all the requirements as a checklist, no energy calculations are required.
- Performance: This looks at a whole building analysis using energy simulation software. Project teams may deviate from the prescriptive requirements, provided that the theoretical energy use of the building is less than or equal to that of the same building with all the prescriptive requirements included.

These minimum energy efficiency requirements are to be voluntary for up to a maximum of two years to allow an individual state an adoption and inception phase, after this period the state can then make the requirements mandatory.

The minimum energy efficiency requirements will also apply to the Ministry of Power, Works and Housing's own buildings. The two-year period to allow the adoption and inception phase as a preparation to make the requirements mandatory will also apply.

0.2 Building Energy Labels and Energy Efficiency Incentives

A comparative building label that rates a building depending on how many of the proposed BEEC initiatives have been implemented in the building has been developed. Since it is recommended that the programme starts off as voluntary, this is a way of encouraging building owners by giving them an official "stamp of approval" or "badge of honour".

The label adopted is in line with that already being developed for household appliances by the Standards Organisation of Nigeria. The higher the rating the more efficient the building, i.e.: a 4-star rated building is more efficient than a 1, 2, or 3 star. Each state would provide its logo as an endorsement of the label as they adopt the BEEC (see Figure 1).

After a voluntary period of two years maximum, the competent authority should make all requirements mandatory, and the label will be revised to be used for communicating building energy efficiency on the market.

Table 2 below shows the level of performance awarded to implementing the different initiatives. These will only be in place for the initial two-year inception phase. After this, the code should be mandatory and should be no option for doing only some of the requirements.

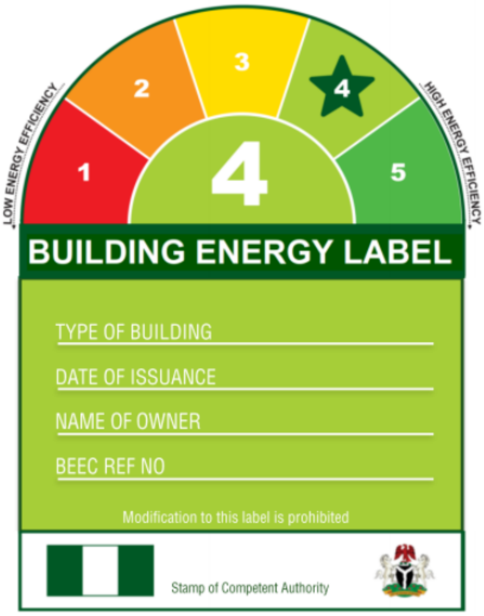


Figure 1: Proposed Building Label

Table 2: Star Rating for Energy Efficiency Label

Rating	Intervention	Minimum Specification
1 star	• Window to Wall Ratio and/or shading	• 20% and/or shading as per BEEC Calculator
2 star	• Window to Wall Ratio and/or shading • Lighting – Residential • Lighting – Office	• 20% maximum and/or shading as per BEEC Calculator • Maximum lighting power density 6 W/m² • Maximum lighting power density 8 W/m²
3 star	• Window to Wall Ratio and/or shading • Lighting – Residential • Lighting – Office • Roof insulation	• 20% maximum and/or shading as per BEEC Calculator • Maximum lighting power density 6 W/m² • Maximum lighting power density 8 W/m² • Minimum R-value 1.25 m²K/W
4 star	• Window to Wall Ratio and/or shading • Lighting – Residential • Lighting – Office • Roof insulation • Air-conditioning minimum performance (only if air-conditioning is necessary)	• 20% maximum and /or shading as per BEEC Calculator • Maximum lighting power density 6 W/m² • Maximum lighting power density 8 W/m² • Minimum R-value 1.25 m²K/W • Minimum EER/COP 2.8 and Inverter Compressor
5 star	On application only. This allows for taking into account renewable energy systems (Photovoltaic, Solar water heating) which are currently outside the BEEC minimum requirements.	

Appropriate options for energy efficiency incentives were presented and included external (conditions to be met) and internal (generated by the occupants) approaches. The development of a comprehensive and relevant incentive scheme is subject to the policy decisions taken by the Federal Government, and should not be pre-emptive. For example, will funds be prioritized and committed to support a financial incentive and will they be regular and stable? Based on the analysis it has been recommended that the non-financial incentive of expedited permitting is offered to new building applications which target a 2 star (or higher). The effectiveness of this incentive should be reviewed, and adjusted as appropriate, within two years. In this period, the BEEC is to be voluntary, once the period is over then the requirements can be made mandatory for all new applications.

Concessionary financing has been deemed to be inappropriate. Primarily because it is very difficult to separate or quantify energy savings ex ante. In the event that financiers were even willing to consider discounted funding, they would require accurate meter readings. This would add cost and complexity to a programme that has been designed to, in its first phase, be simple and straightforward.

0.3 Control and Enforcement

Training has been identified as the most important enabler to effective control and enforcement of the BEEC. A survey was done to determine the capability of staff responsible for building permit approvals in assessing submissions related to energy efficiency in general and a BEEC in particular. From the survey, it was clear that not many of the staff have had previous exposure to the building physics elements that are important to a BEEC. Training that focuses not only on the procedural requirements of a BEEC but also on the background knowledge of energy efficiency in general has been recommended.

The training will cover all aspects of the BEEC including but not limited to:

- Understanding building physics
- How to use BEEC calculation sheets
- Recognising correct details pertaining to BEEC on drawings
- Spot checks for all items
- Recognising different types of equipment (i.e. how to tell if a unit is an inverter type or not)
- How to use new forms and procedures to process applications, track progress and keep a database
- Understanding the performance route to compliance

It has also been suggested that this training serves as a minimum qualification for staff that will process building permit approvals as well as for professionals in the construction industry. Therefore, the training will include tests or exams that must be passed.

0.4 Calculation Methods and Tools

The identification of Calculation Methods and Tools has been carried out. The aim was to find a tool for the calculation of building energy performance that is applicable for the mass market and also drives energy efficiency by promoting integrated design.

Three software packages have been recommended as per the list below:

- OpenStudio
- Equest
- Matchbox

Cost was deemed to be a major factor in selection of the software package. For adoption by the mass market, the software either needs to be free (OpenStudio and Equest) or possible to be administered via a country licence purchased by the Government or a donor (Matchbox).

All packages use similar simulation engines with varying levels of accuracy. However, the comparative analysis showed that all the packages were able to report similar energy savings for the interventions required by the BEEC. It should be noted that all software packages pass international standards like BESTEST and ASHRAE 140-2014 which are used to ensure the capabilities of different packages. Therefore, the issue comes down to cost and user-friendliness rather than accuracy since they all pass a minimum standard.

A standardized reporting mechanism and modelling protocol guide has also been developed. This ensures that whatever software package is used, the same process is followed by all projects.

Table of Content

1 Development of Minimum Energy Efficiency Requirements

This chapter contains the following parts:

- Description of the objectives and the procedure of developing minimum energy efficiency criteria.
- Detailed review of the Nigerian building sector and the available climate data. This explains the basis for the type of information used to derive the energy consumption baseline and the energy efficiency targets.
- A presentation of the development of BAU and benchmark models as the basis for developing minimum energy efficiency targets.
- Recommendations on minimum energy efficiency requirements and to what type of buildings they apply.
- A short presentation on Integrated Design as a method to achieve energy efficient buildings in practice and provides an outlook on future developments of minimum energy efficiency requirements.

1.1 Objectives and Procedure

1.1.1 Description of Objectives

The development of minimum energy efficiency requirements for new residential and office buildings in Nigeria proposes recommendations to the effective use of energy in new buildings. The overall aim was to propose recommendations, that:

- Take into account bioclimatic aspects;
- Encourage the design of new buildings in a manner that reduces the use of energy without constraining creativity in design, building function and the comfort or productivity of the occupants;
- Optimize passive cooling strategies;
- Are dealing with cost considerations and market access to construction materials and building fabrics;
- Deal with the absolute minimum requirements for energy efficiency in such a way that they can be applied anywhere in the country.

In addition, requirements should be defined in such a way that the building designer can choose from two ways of showing compliance with the proposed minimum energy efficiency requirements:

- Compliance method 1: Demonstrating compliance with minimum prescriptive requirements
- Compliance method 2: Whole building energy performance requirement, based on a reference building that complies with prescriptive minimum requirements

The energy consumption for the following shall not be included in the performance calculations:

- Appliances for office and households
- Energy consumption related to industrial or other processes
- Energy consumption for hot water heating

1.1.2 Description of Procedure

Based on information for residential buildings provided by the Building Energy Efficiency Guideline (BEEG), analysis of case studies provided by responsible authorities, and additional information collected from stakeholders, the business as usual (BAU) scenario of inputs for both building types was determined.

Business-As-Usual or BAU is defined as a building with a design and electrical installations that can be described as currently and commonly found in buildings (with a specific function, such as residential or office) in Nigeria. Thus, BAU scenarios represent the baseline of building energy efficiency in Nigeria.

A series of simulations of different buildings were then conducted to determine which items were to be included in a benchmark model. This benchmark model makes up the baseline for the recommended energy efficiency requirements.

Benchmark model refers to a building with a design and with electrical installations that in terms of energy efficiency is in compliance with exactly the defined minimum energy efficiency requirements.

Table 3 and Table 4 below show a summary of inputs used to develop the BAU and benchmark models for various building elements.

Table 3: Summary of Inputs for Residential Buildings

Building Element	Business-As-Usual Input	Benchmark Input
Roof Construction	Aluminium roof – no insulation	Aluminium roof – with insulation to R-1.25m²K/W
External Wall Construction	Concrete block	Concrete block
Floor Construction	Concrete slab	Concrete slab
Window Type	Single glazed clear	Single glazed clear
Window to Wall Ratio	30%	20%
Shading	No shading	No shading
Lighting	13 W/m²	6 W/m²
Air-conditioning System	Non-inverter split units	Inverter type split units

Based on simulations and the concluding analysis, recommended minimum prescriptive requirements have been developed for the following areas:

- Fenestrations and shading
- Lighting
- Roof
- Air-conditioning (AC)

The same methodology was taken in developing the benchmark model for offices. However, from the initial studies of building projects it was clear that the same minimum requirements would apply to offices as for residential, except for lighting where higher densities can be expected.

Table 4: Summary of Inputs for Office Buildings

Building Element	Business As Usual Input	Benchmark Input
Roof Construction	Aluminium roof – no insulation	Aluminium roof - with insulation to R-1.25m²K/W
External Wall Construction	Concrete block	Concrete block
Floor Construction	Concrete slab	Concrete slab
Window Type	Single glazed clear	Single glazed clear
Window to Wall Ratio	40%	20%
Shading	No shading	No shading
Lighting	10 W/m²	8 W/m²
Air-conditioning System	Non-inverter split units	Inverter type split units

1.1.3 Method Applied: Parametric Study

Parametric modelling looks at investigating the impact of various building elements on energy by changing one parameter at a time and comparing the results. This method was applied for developing the benchmark models.

Parametric simulations were undertaken for one office building and two residential building types; a bungalow duplex unit and a multi-unit apartment.

The tables below show the various elements investigated.

From this list of items, the ones that had the largest impact on energy efficiency and were straightforward to implement were selected for regulation.

The business as usual input for each item is shown in grey.

Table 5: Parametric Simulation Variations 1

Simulation Variations			
Construction	**Name**	**Description**	**U-value (W/m²K)**
External walls	Concrete block 1	Aerated concrete block	0.71
	Concrete block 2	Concrete block - Heavy	3.00
	Concrete block 3	Concrete block - Medium	1.36
	Concrete block 4	Concrete block - Light	0.58
	Brick 1	Double skin brick wall	2.20
	Brick 2	Double skin brick wall with air cavity	1.57
Roof	Roof 1	Metal roof tile - no insulation	7.28
	Roof 2	Metal roof tile - 25mm insulation	1.31
	Roof 3	Metal roof tile - 50mm insulation	0.72
	Roof 4	Metal roof tile - 75mm insulation	0.50
	Roof 5	Metal roof tile - 100mm insulation	0.38
	Roof 6	Metal roof tile - 125mm insulation	0.31
Ground floor (duplex bungalow)	Ground 1	150mm concrete slab (lightweight)	1.80
	Ground 2	150mm concrete slab (dense)	3.72
	Ground 3	100mm concreate slab (dense)	4.28
Ground floor (multi-unit apartments)	Ground 1	150mm concrete slab (dense)	3.72
	Ground 2	100mm concrete slab (lightweight)	2.35
	Ground 3	100mm concreate slab (dense)	4.28

Table 6: Parametric Simulation Variations 2

Simulation Variations		
Construction	**Name**	**Property**
Infiltration	Infiltration 1	0 air changes an hour
	Infiltration 2	0.25 air changes an hour
	Infiltration 3	0.50 air changes an hour
	Infiltration 4	0.75 air changes an hour
Glass type	Single glazed clear	SHGC – 0.8; U-value 6.9
Shading	No shading	-
	Shading	0.5 m overhang
		1.0 m overhang
		1.5 m overhang

Window to Wall Ratio	WW Ratio 1	20 %
	WW Ratio 2	30 %
	WW Ratio 3	40 %
	WW Ratio 4	50 %
Lighting	LPD 1	3 W/m²
	LPD 2	6 W/m²
	LPD 3	13 W/m²
	LPD 4	9 W/m²

The graphs in Annex 1 illustrate the impact of regulated items on energy efficiency. By changing various building elements one at a time, it was possible to see what impact each item had on overall bulldogging performance. The interventions that had the highest impact on energy efficiency are the ones that were selected for regulation via a Building Energy Efficiency Code.

The graphs are colour-coded to show items that were selected for regulation with their corresponding impact on overall energy efficiency and the cumulative impact of these interventions.

1.2 Review of the Existing Building Sector in Nigeria

1.2.1 Documents and Reports Reviewed

The following background material has been made available and studied:

- Building Energy Efficiency Guideline for Nigeria (BEEG); Federal Ministry of Power, Works and Housing (Housing); June 2016
- Nigerian National Building Code 2006
- Report on Energy Efficiency in Buildings (EEB) in Selected Sub-Sectors of the Nigerian Building Sector: Development of recommendations for interventions to promote energy efficiency in buildings incl. appendices; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; December 2013
- Institutional and Policy Mapping of the Renewable Energy, Energy Efficiency and Rural Electrification Sub-Sectors in Nigeria; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; November 2013
- National Renewable Energy and Energy Efficiency Policy (NREEEP); Ministry of Power, Federal Republic of Nigeria; 2015.04.20
- Drawings, load plans and other building information from randomly selected residential projects provided by Department of Development Control FCT Abuja
- Drawings, load plans and other building information from randomly selected office projects provided by Department of Development Control FCT Abuja

1.2.2 Current Energy Performance of the Existing Building Stock

This section is based on the documents mentioned above. In particular three sources form the main input:

Drawings, load plans and other building information from randomly selected dwelling and office projects constructed in recent times

Building Energy Efficiency Guideline for Nigeria (BEEG)

Report on Energy Efficiency in Buildings (EEB) in Selected Sub-Sectors of the Nigerian Building Sector

<u>Residential buildings</u>

Building projects

Based on studies of building projects, three representative building typologies have been identified:

- Multi-unit apartments
- Bungalows duplexes
- Bungalows

The three types are defined as below based on the geometry of the building.

Table 7 shows a summary of documents received from Department of Development Control

Table 7: Summary of Documents Received

	Bungalow	Bungalow duplex	Multi-unit apartment
Number of projects	4	2	13
Apartments in building	1	2-4	3-12
Total area	148-1288 m^2	313-386 m^2	49-377 m^2
Number of bedroom	4-12	3-4	1-4
Number of stories	1-3	2-3	1-4

The building type "Bungalow" – i.e. a single house for a single family, is not seen as a representative type of the future building mass of new buildings in Nigeria, and is therefore not further commented on.

Figure 2 below shows the dispersion of the size of all the building projects.

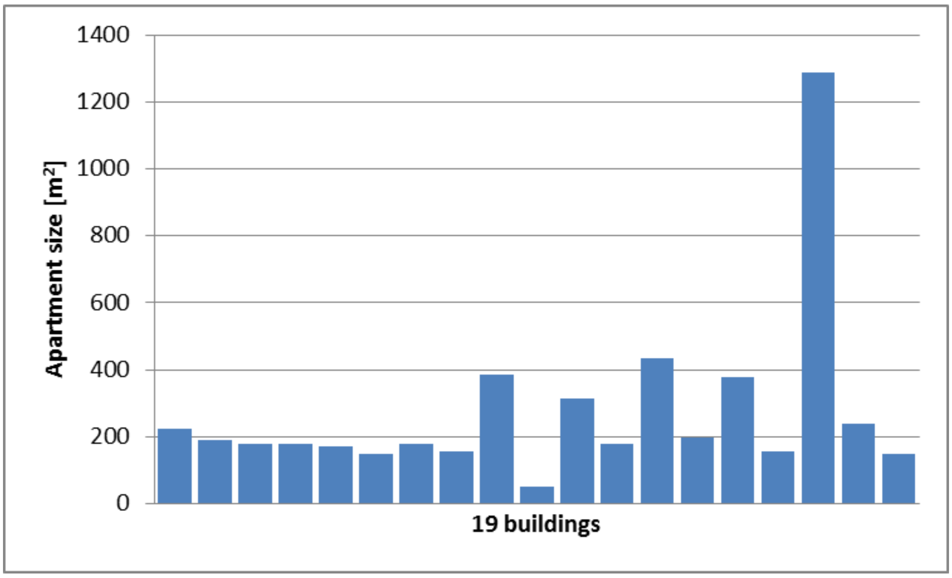


Figure 2: Dispersion of the size of the building projects analysed

A study done by GIZ in 2013 covering 51 households, groups the analysed buildings after income ("low", "medium" and "high income")1.

Comparing this study with the 19 building projects made available for this report suggests that all 19 are in the "medium" and "high income" category.

Energy use

The typical energy consumption in the two identified building types – multi-unit apartments and duplex bungalows, is estimated based on energy calculations performed for the studied building projects.

The energy consumption is divided into three categories: lighting, cooling and water heating.

The preliminary study shows that a few additional groups make up part of the total energy use as well. These energy consumptions come from TV, computers, refrigeration etc. The studies show that these consumptions make up approximately 45 – 55 % of the total energy use.

[1] Geissler, Dr Susanne & Macharm, Ene Sandra "Energy Efficiency in Buildings (EEB) in Selected Sub-Sectors of the Nigerian Building Sector: Development of recommendations for interventions to promote energy efficiency in buildings", 2013

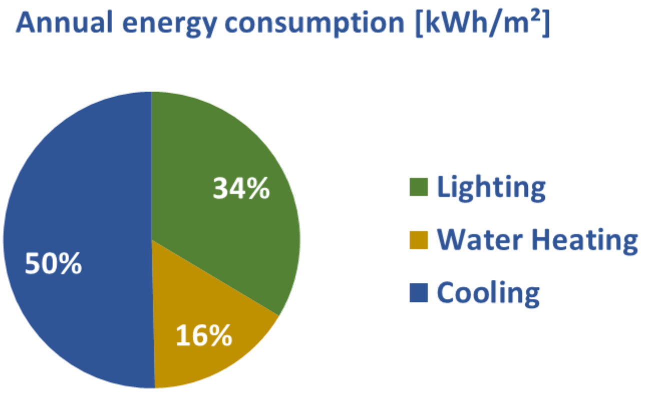


Figure 3: Estimated average consumption of the analysed buildings - duplex bungalow. -

Total 144 KWh/m²/year

Table 8: Estimated average consumption of the analysed buildings - duplex bungalow

Estimated Energy Consumption (150 m² duplex bungalow)					
Equipment	**Average power [W/m²]**	**h/day**	**days/year**	**h/year**	**Annual energy use [kWh/m²]**
Lighting	16	8	365	2920	48
Cooling	74	3	365	1095	72
Water heating	32	2	365	730	24
Total					*144*

Note: The usage is based on the Report on Energy Efficiency in Buildings (EEB)[2]

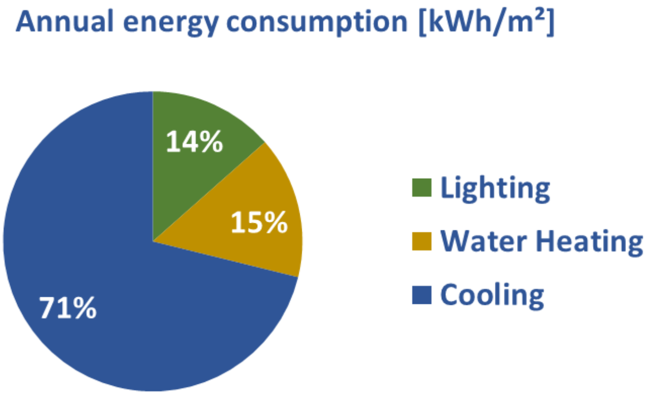


Figure 4: Estimated average consumption of the analysed buildings – multi-unit apartment –

Total 163KWh/m²/year

[2] Geissler, Dr Susanne & Macharm, Ene Sandra "Energy Efficiency in Buildings (EEB) in Selected Sub-Sectors of the Nigerian Building Sector: Development of recommendations for interventions to promote energy efficiency in buildings", 2013

Table 9: Estimated average consumption in the analysed buildings – multi-unit apartment

Estimated energy consumptions (1200 m² multi-unit apartment)					
Equipment	**Average power [W/m²]**	**h/day**	**days/year**	**h/year**	**Annual energy use [kWh/m²]**
Lighting	13	8	365	2920	22
Cooling	30	3	365	1095	116
Water heating	35	2	365	730	25
Total					*163*

Note: The usage is based on the Report on Energy Efficiency in Buildings (EEB)[2]

Offices

Building projects

Data from the studies of building projects are shown in Table 10 below. All the analyzed buildings were fairly similar in terms of materials, so only one office type has been identified.

Table 10: Summary of documents from Department of Development Control

	Offices
Number of projects	10
Total area	1150 - 12000 m²
Number of stories	3 – 9

Several of the offices were part of a bigger multi-purpose building. Only data from the office part of the building has been included in the above numbers.

Figure 5 below shows the dispersion of the size of all the building projects

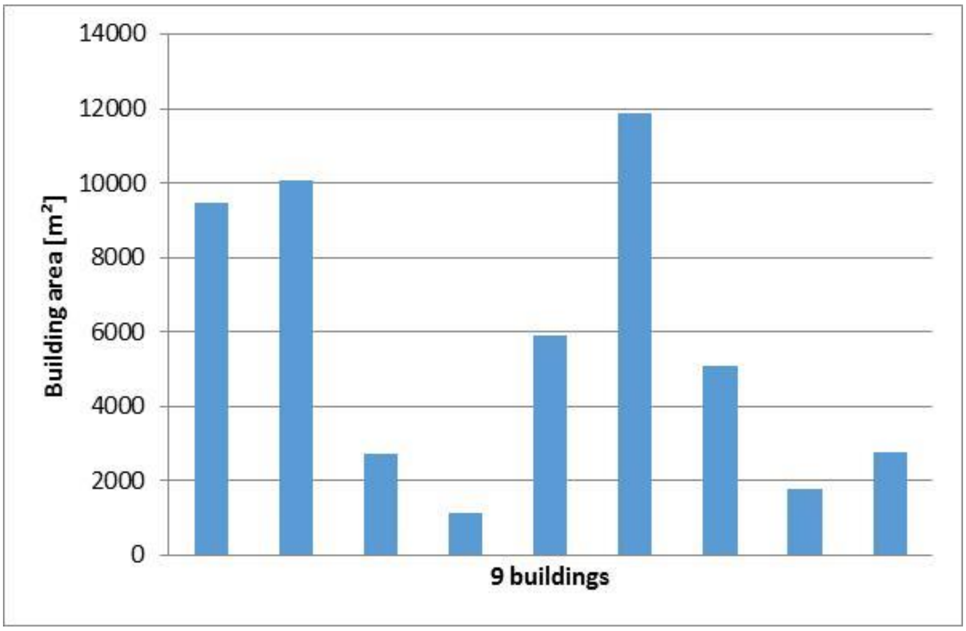


Figure 5: Dispersion of the size of building projects analysed

Energy use

The typical energy consumption in a Nigerian office building is estimated based on energy calculations performed for the studied building projects.

The same three parameters as with the dwellings have been analysed: lighting, cooling and water heating.

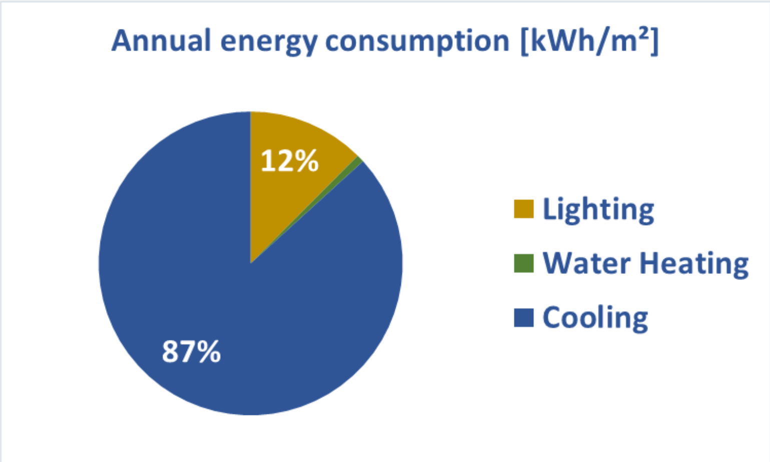


Figure 6: Annual energy consumption - Office Building

Total 249 KWh/m2/year

Table 11: Estimated average consumption of the analysed buildings – office building

Estimated energy consumptions (4000 m² office building)					
Equipment	**Average power [W/m²]**	**h/day**	**days/year**	**h/year**	**Annual energy use [kWh/m²]**
Lighting	10	12	250	3000	31
Cooling	86	10	250	2500	216
Water heating	3	2	250	500	2
Total					*249*

Note: The usage is based on the Report on Energy Efficiency in Buildings (EEB)[3]

[3] Geissler, Dr Susanne & Macharm, Ene Sandra "Energy Efficiency in Buildings (EEB) in Selected Sub-Sectors of the Nigerian Building Sector: Development of recommendations for interventions to promote energy efficiency in buildings", 2013

1.3 Climatic Data

1.3.1 Weather Data Source

Climatic data for analysis was purchased from Meteonorm. This is the most comprehensive meteorological reference available worldwide. It provides access to a catalogue of meteorological data for solar applications and system design at any desired location in the world. It is based on more than 25 years of experience in the development of meteorological databases for energy applications.

Meteonorm is considered to be the meteorological reference for the following applications: solar energy, building design, heating and cooling systems, education, renewable energy system design, agriculture and forestry, environmental research and many more.

Numerous global and regional databases have been combined and checked for their reliability. Most of the data is taken from the GEBA (Global Energy Balance Archive), from the World Meteorological Organization (WMO/OMM) Climatological Normals 1961–1990 and from the Swiss database compiled by MeteoSwiss.

The periods 1961–1990 and 2000–2009 are available for temperature, humidity, wind speed and precipitation; the periods 1981–1990 and 1991–2010 for solar radiation.

Monthly climatological (long term) means are available for the following eight parameters:

- Global radiation
- Ambient air temperature
- Humidity
- Precipitation
- Days with precipitation
- Wind speed
- Wind direction
- Sunshine duration

The station data is supplemented by surface data from five geostationary satellites. This data is available on a global grid with a horizontal resolution of 8 km (3 km in Europe and Northern Africa).

This data for various cities in Nigeria was used to test the implications of the minimum energy efficiency requirements on similar buildings in different climatic areas of the country.

The following sections give an example of weather data outputs for Abuja, similar outputs for several cities in Nigeria are also provided.

1.3.2 Exemplary Weather Data

The following graphs summarize climatic data as provided by the weather files.

The figure below shows the percentage of hours between certain temperature bands (annual average). In 23% of hours temperature is between 30-34 °C.

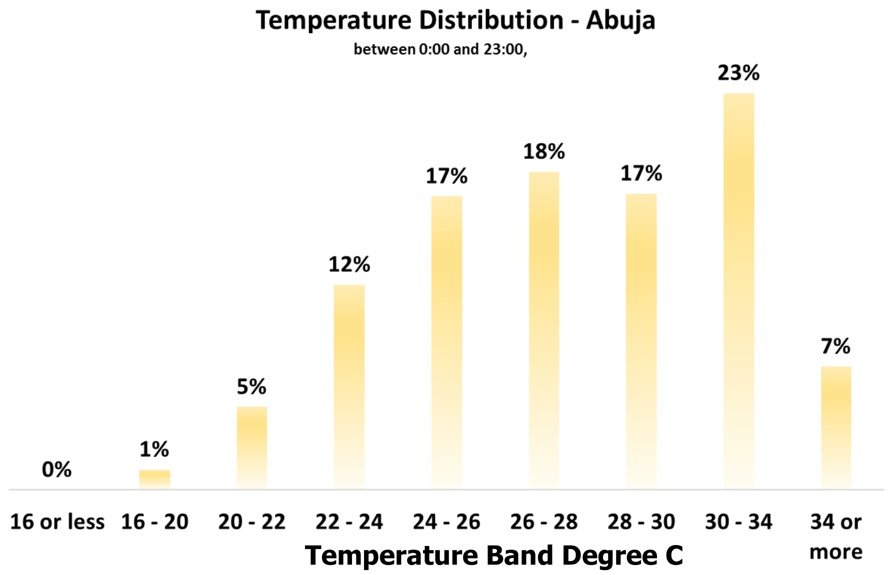


Figure 7: Annual Temperature distribution (between 0:00 and 23:00)

The figure below shows the percentage of hours between certain humidity bands (relative humidity, annual average). In 37% of hours humidity is above 70%.

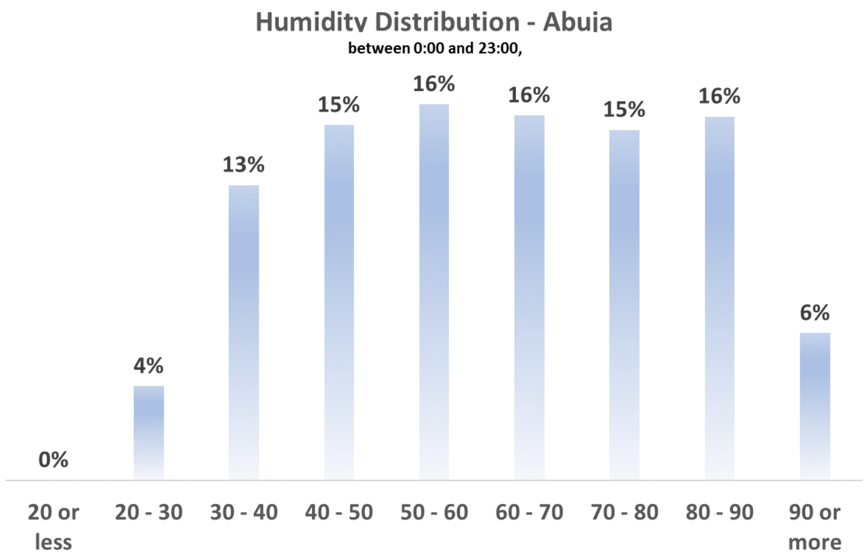


Figure 8: Annual humidity distribution (between 0:00 and 23:00)

The graph below shows the daily maximum and minimum temperature swing.

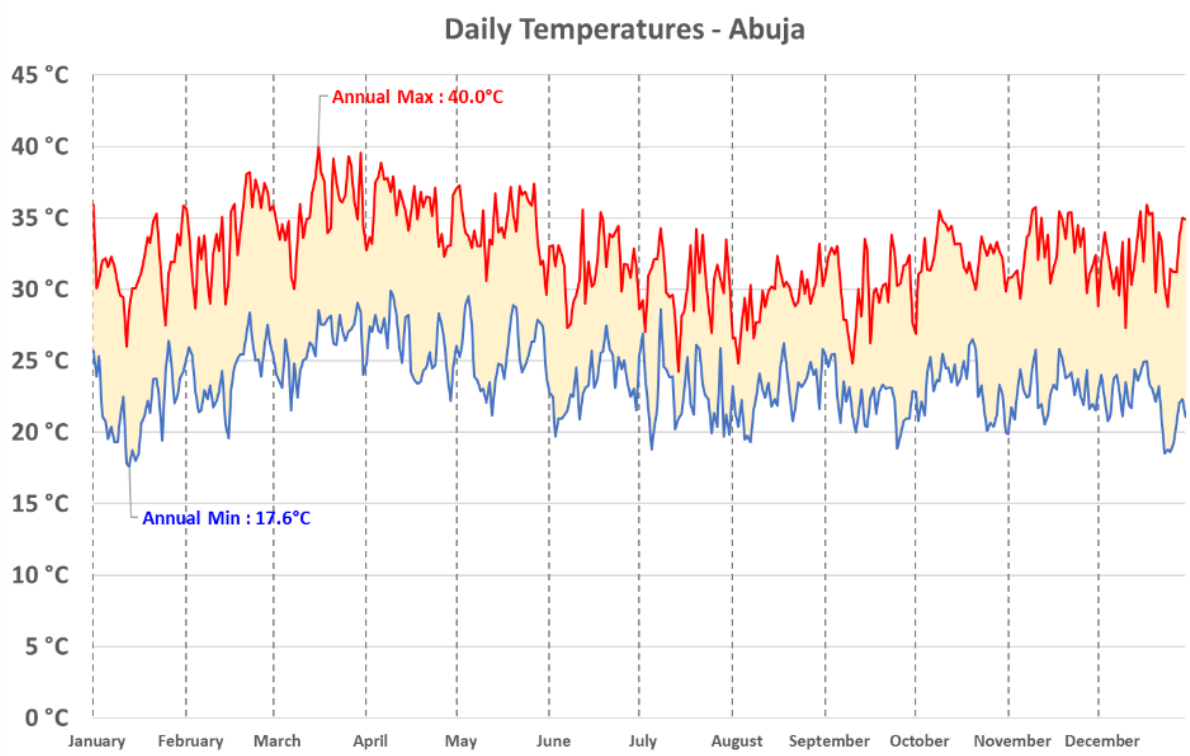


Figure 9: Daily temperature swing

The graph below shows the solar radiation incident on vertical surfaces. This shows that for South facing facades, there is still a large amount of solar radiation in late parts of the year (November/December) and early parts of the year (January/February).

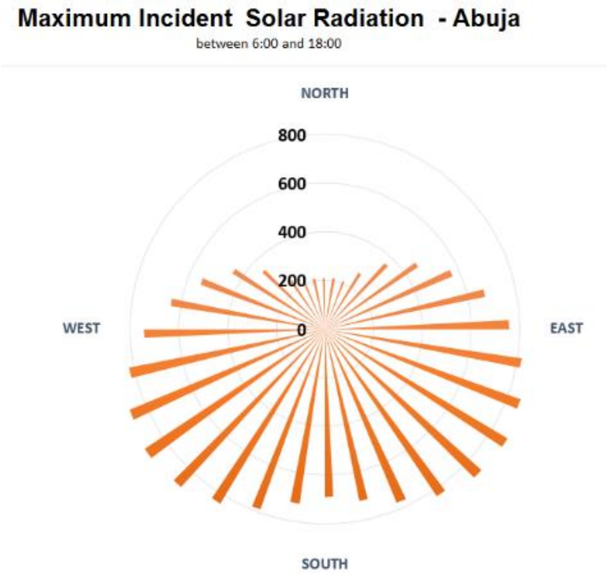


Figure 10: Maximum solar radiation - January

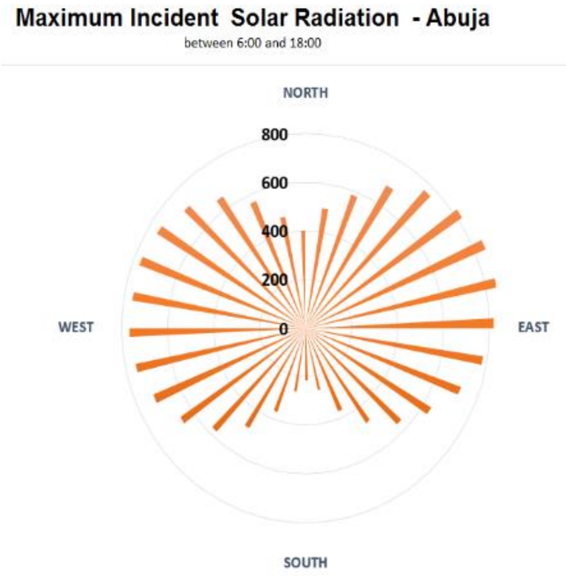


Figure 11: Maximum Solar Radiation - June

A comparison between the climate in Abuja and the rest of the country was conducted. Even though there are three distinct climate zones in Nigeria, the measures adopted for the BEEC are the minimum that will make a difference in all states in the country. Therefore, this BEEC can be used by any state in the country.

The graph below shows a comparison of annual temperatures for different locations in Nigeria.

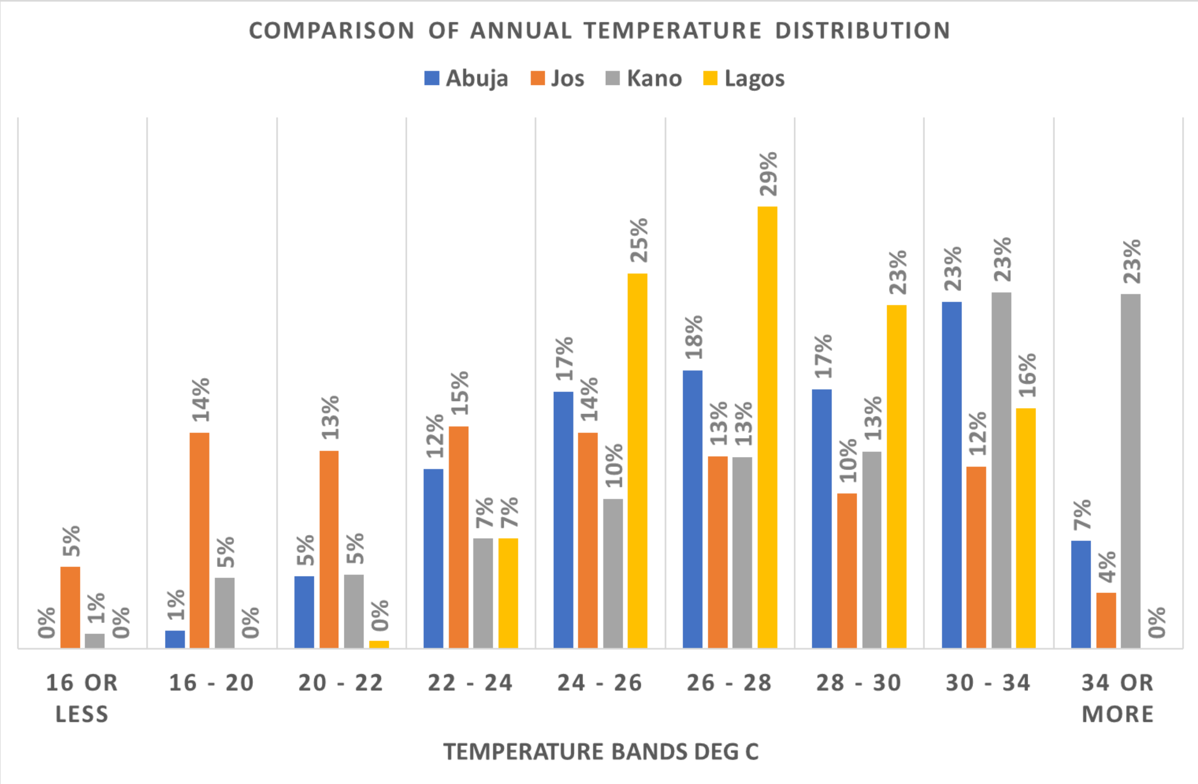


Figure 12: Annual temperature comparison for various cities

Whilst there is a significant difference between climates in different part of the country, this would not affect the results of this technical study significantly. This is because the simulation models did not include a provision for fresh air, infiltration is however accounted for. This study looks only at the passive design elements of building design along with the efficiency of cooling and lighting systems.

For the latitudes that Nigeria falls between, the solar gains are very similar, the same minimum efficiency requirements have therefore been provided for all states.

The graphs below show the difference in solar radiation for Kano in the North and Lagos in the South, as can be seen, there is very little difference in solar radiation, not enough to justify different requirements.

Since the solar gains have the most impact on buildings and there is very little difference in solar gains across the country, it follows that different requirements in different parts of the country would not be justified.

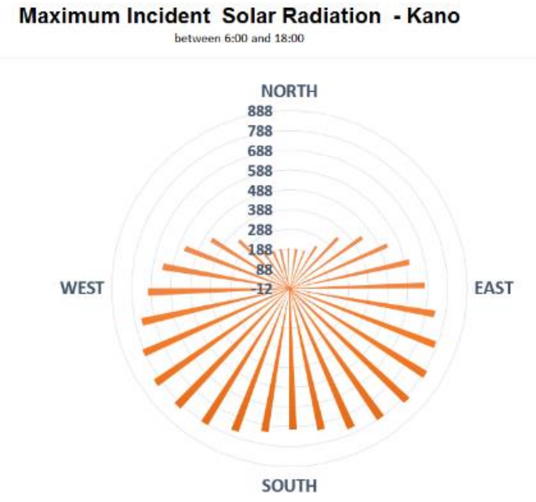


Figure 14: Solar Radiation Kano

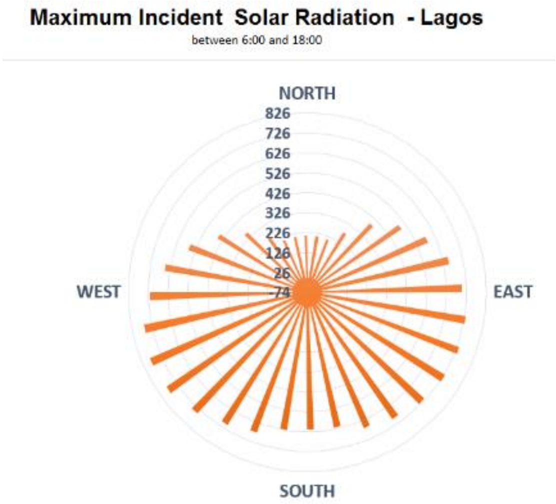


Figure 13: Solar Radiation Lagos

The figure below shows the results of simulating the same building in different parts of the country. It shows that with the exception of Jos, which lies on a plateau and is at a much higher altitude than the rest of the country, differences due to local climate are marginal.

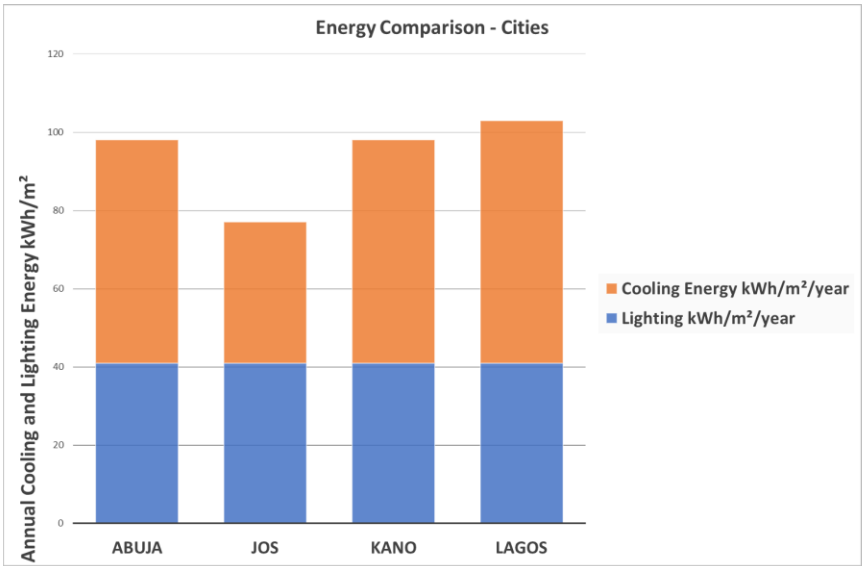


Figure 15: Energy Comparison - Different Climates

1.4 Applicability of Minimum Energy Efficiency Requirements

The energy efficiency requirements to be developed are expected to include all new developments of buildings classified as Group B (Business and Professional) and Group R (Residential) as defined in the National Building Code of Nigeria section 4 (Building Design Classifications).

1.4.1 New Residential Buildings

For Group R (Residential) building types (according to classification of the National Building Code 2006) it is recommended to identify a limit in terms of total gross floor area for residential building that are not required to comply with the proposed energy efficiency requirements. Such exemptions can be justified by the fact that minimum requirements normally are targeting larger end-users and because stringent energy efficiency requirements may in some cases result in increased prices of smaller residential building types.

The initial study and on site review of the existing residential building sector shows quite a mix of residential buildings from the low, middle and high-income building segment supplemented with multilevel residential blocks accommodating more apartments.

Based on our initial study we recommend a minimum threshold of 85 m^2 gross floor area being envisaged for the code. This is to apply to a standalone building only.

1.4.2 New Office Buildings

Group B (Business & Professional) building types (according to classification of the National Building Code 2006) which typically are larger than residential buildings would normally benefit in terms of operational costs by complying with minimum efficiency design and hence no exemptions are proposed for this class of buildings.

1.5 Development of Building Models and Determination of Energy Saving Potential

Minimum prescriptive and performance requirements have been developed through the study of reference documents, actual building projects, and simulations models. The studies of the simulation models are further described in the following sections.

A set of Business-As-Usual (BAU) simulation models of different representative building types have been developed. These models make up the base point in the simulations. The output of the study is a clear indication of the important factors influencing the energy consumption, and the reasonable level of minimum requirements.

The following building types have been identified:

- Residential building
  - Bungalow duplex
  - Multi-unit apartment
- Office building

Based on the knowledge gained from the study of the models, a benchmark model for each building type has then been developed (BEEC-Model). The benchmark model forms the basis of both the minimum prescriptive and minimum performance requirements.

1.5.1 Business-As-Usual (BAU) Models

Bungalow duplex building

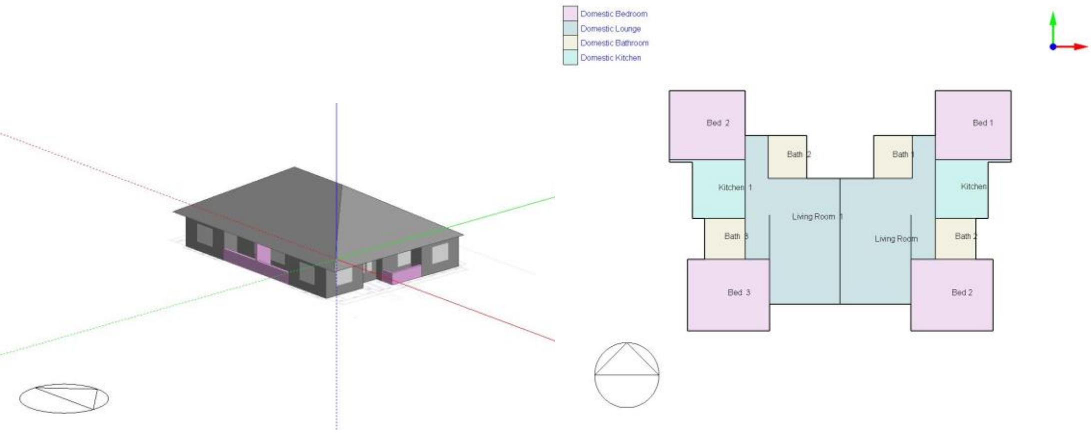


Figure 16: Bungalow duplex building model image

Table 12: Typical bungalow duplex building

Basics	**Description**	**Property**
Dwellings	Number of dwellings in building	2
Area	Gross floor area per dwelling	75 m²

Multi-unit apartment building

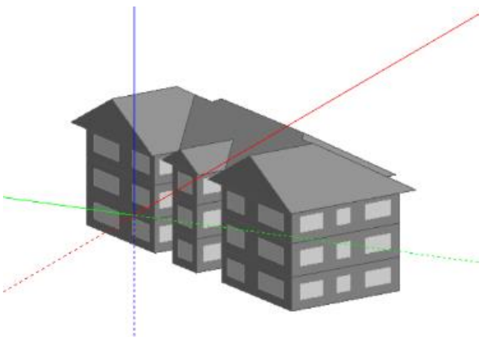


Figure 17: Multi-unit apartment building model image

Table 13: Typical multi-unit apartment building

Basics	**Description**	**Property**
Dwellings	Number of dwellings in building	6
Area	Gross floor area per dwelling	200 m²

Office building

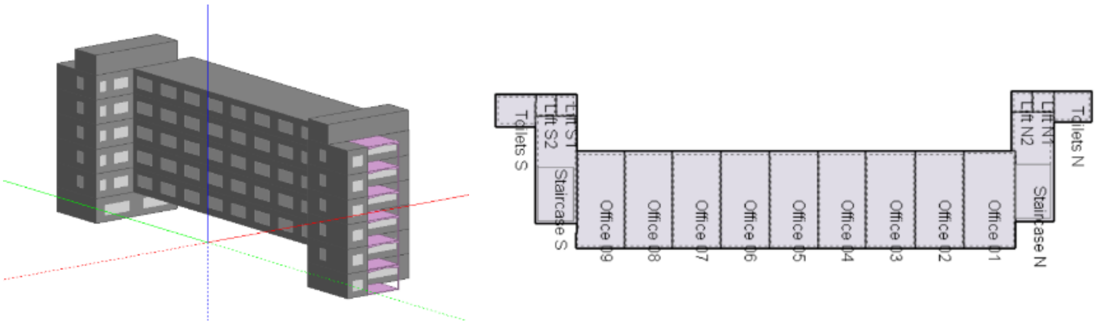


Figure 18: Office building model image

Table 14: Typical Office Building

Basics	Description	Property
Stories	-	5
Area	Gross floor area per story	800 m²

1.5.2 BAU Energy Performances

The energy consumptions of the BAU models are divided into the following groups:

- Cooling
- Interior lighting

As discussed, a few additional groups of energy consumptions make up 45 – 55 % of the total energy consumption; this part includes energy for cooking, refrigeration, TV, computers, etc.. These uses are not regulated by the code but are included in some figures to give an indication of the estimated total savings.

Bungalow duplex building

The figure below shows the distribution of energy consumption when all energy use (i.e. regulated and non-regulated loads) is included.

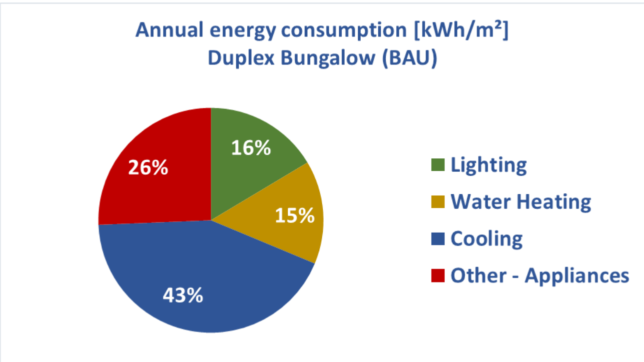


Figure 19: Distribution of total energy consumption – bungalow duplex (BAU)

Total 195 kWh/m²/year

The figure below shows the distribution of the energy consumptions for loads regulated by the BEEC only.

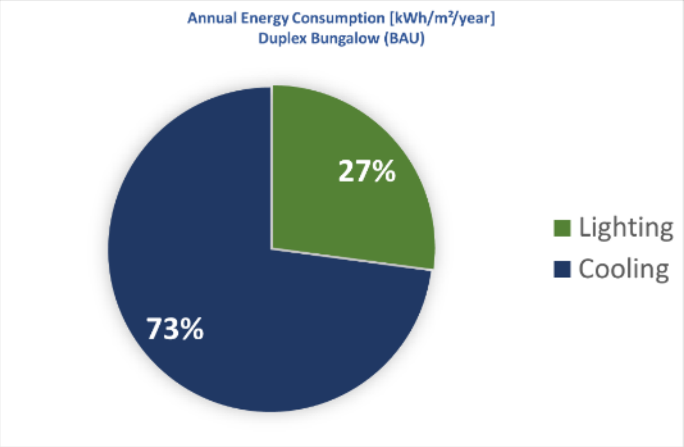


Figure 20: Distribution of energy consumption for regulated components – bungalow duplex (BAU)

Total: 145 kWh/m²/year

Multi-unit apartment building

The figure below shows the distribution of energy consumption when all energy use (i.e. regulated and non-regulated loads) is included.

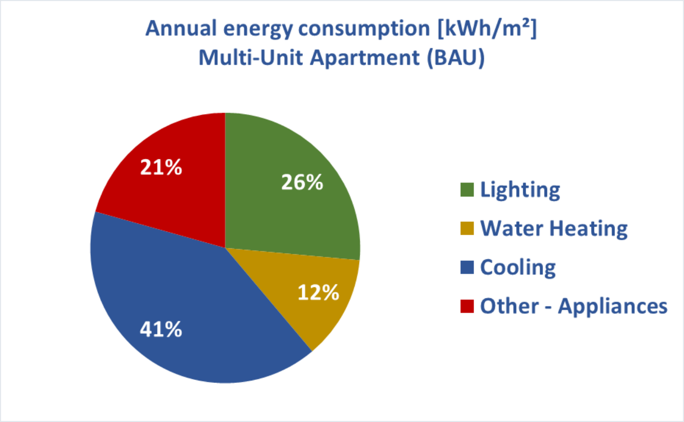


Figure 21: Distribution of total energy consumption – multi-unit apartment (BAU)

Total: 121 kWh/m²/year

The figure below shows the distribution of the energy consumptions for loads regulated by the BEEC only.

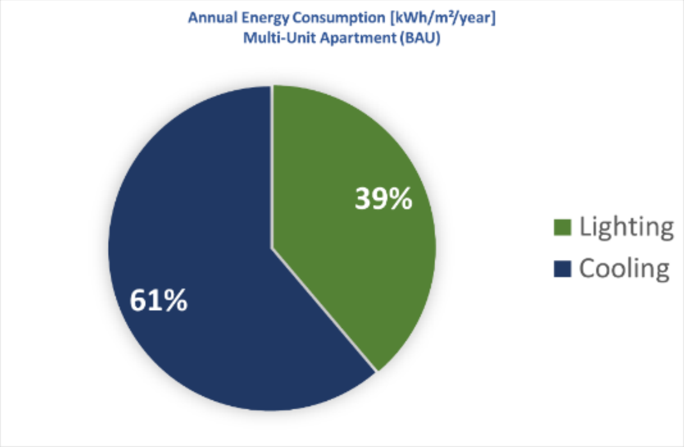


Figure 22: Distribution of energy consumption for regulated components – multi-unit apartment (BAU)

Total: 96 kWh/m²/year

Office building

The figure below shows the distribution of energy consumption when all energy use (i.e. regulated and non-regulated loads) is included.

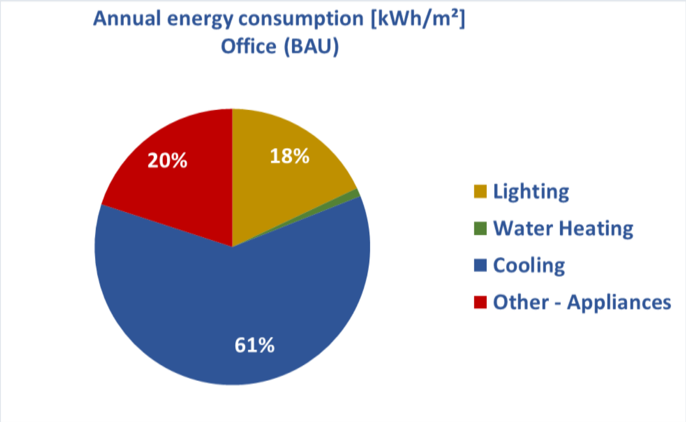


Figure 23: Distribution of total energy consumption – office building (BAU)

Total: 290 kWh/m²/year

The figure below shows the distribution of the energy consumptions for loads regulated by the BEEC only.

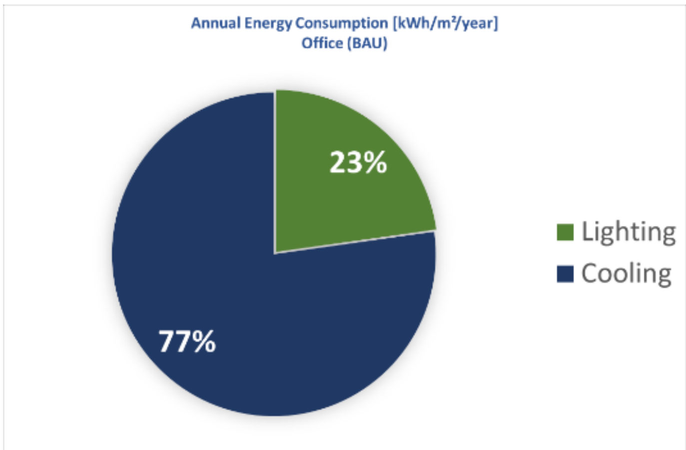


Figure 24: Distribution of energy consumption for regulated components – office building (BAU)

Total: 178 kWh/m²/year

1.5.3 Benchmark Models (BEEC Model)

Based on the simulation models, a set of minimum prescriptive requirements have been developed. The BAU models are then improved with these prescriptive requirements, i.e. better roof insulation.

These improved models make up the benchmark models, setting the baseline for the minimum performance requirements.

The benchmark model forms the basis of both the minimum prescriptive and minimum performance requirements and is therefore called BEEC model.

The input data to the benchmark models that differs from the BAU models are shown in the table below. The rest of the input data are the same as for the BAU models.

<u>Residential and office building</u>

Table 15: Input data to the benchmark model that differs from the BAU input data

Construction	Property
Roof	Aluminium roof tile – Insulation to R-1.25m²K/W
WWR	20 % or shaded as per shading calculator
Lighting – Residential	6 W/m²
Lighting – Offices	8 W/m²
Cooling unit	Inverter unit

1.5.4 Benchmark Energy Performances

The figures below show the energy performance of the benchmark models, this was based on simulation results conducted for the relevant building.

The diagrams show that the energy consumption of non-regulated items make up an increased percentage of the total building energy as the building is made more efficient.

Bungalow duplex building

The figure below shows the distribution of energy consumption for the benchmark building when all energy use (i.e. regulated and non-regulated loads) is included.

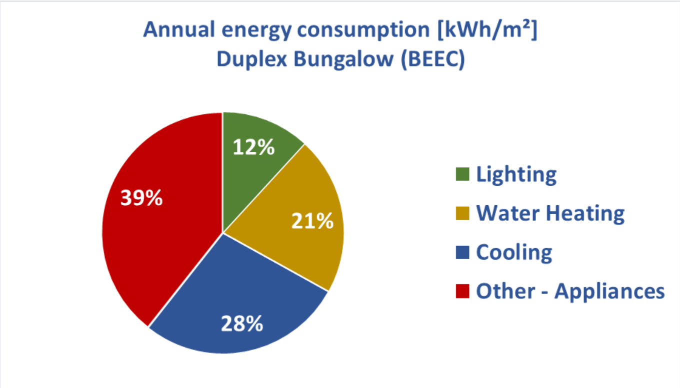


Figure 25: Distribution of total energy consumption – duplex bungalow benchmark

Total: 127 kWh/m²/year

The figure below shows the distribution of the energy consumptions for the benchmark building for loads regulated by the BEEC only.

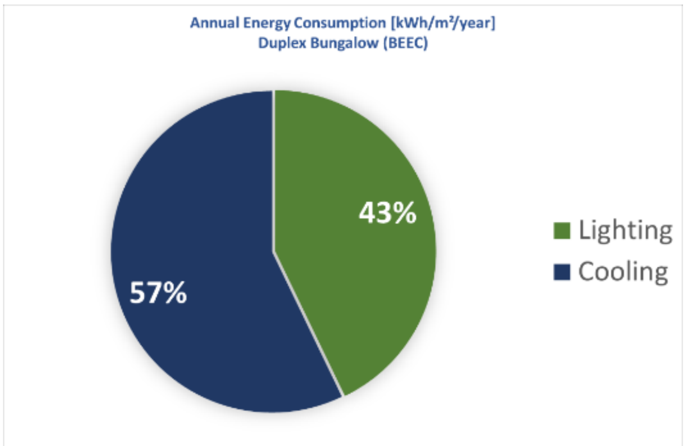


Figure 26: Distribution of energy consumption for regulated components - duplex bungalow benchmark

Total: 77 kWh/m²/year

Multi-unit apartment building

The figure below shows the distribution of energy consumption for the benchmark building when all energy use (i.e. regulated and non-regulated loads) is included.

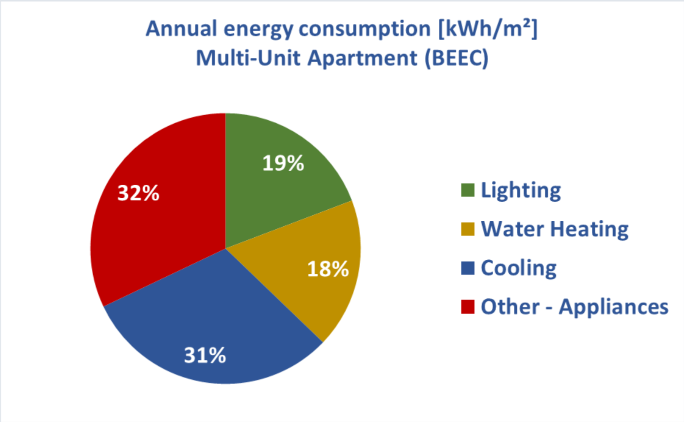


Figure 27: Distribution of total energy consumption – multi-unit apartment benchmark

Total: 78 kWh/m²/year

The figure below shows the distribution of the energy consumptions for the benchmark building for loads regulated by the BEEC only.

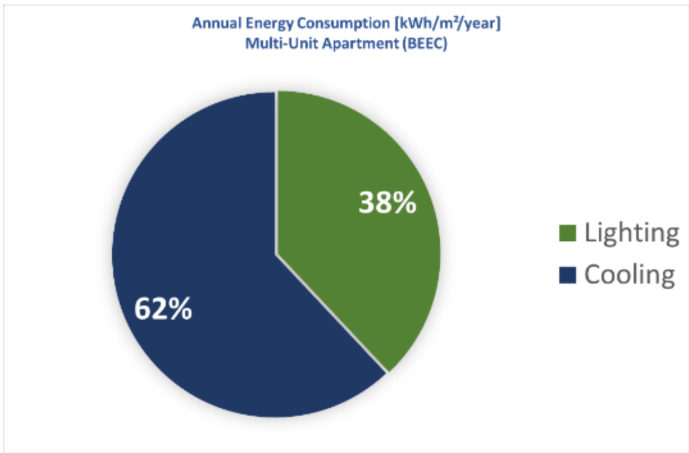


Figure 28: Distribution of energy consumption for regulated components - multi-unit apartment benchmark

Total: 53 kWh/m²/year

Office building

The figure below shows the distribution of energy consumption for the benchmark building when all energy use (i.e. regulated and non-regulated loads) is included.

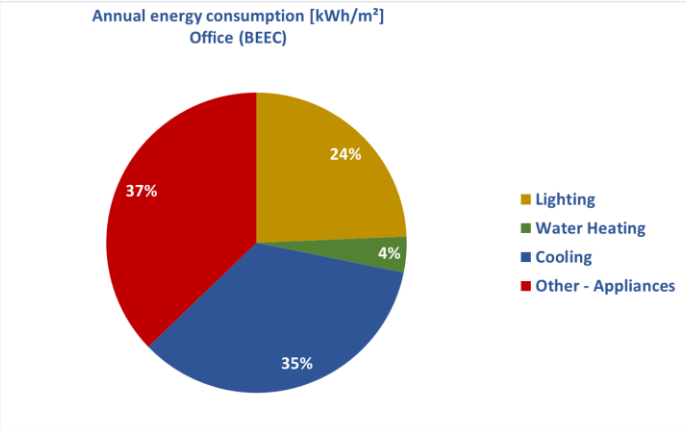


Figure 29: Distribution of total energy consumption – office building benchmark

Total: 156 kWh/m²/year

The figure below shows the distribution of the energy consumptions for the benchmark building for loads regulated by the BEEC only.

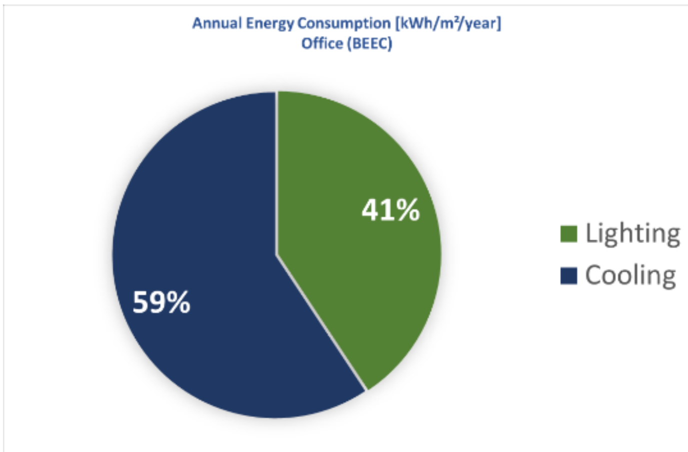


Figure 30: Distribution of energy consumption for regulated components – office building benchmark

Total: 96 kWh/m²/year

1.5.5 Energy Saving Potential

The figures below compare the estimated energy consumption of the BAU models with the benchmark models. Only energy consumption for regulated loads is shown.

The diagram shows that significant energy savings can be expected, namely savings of 45 to 55% over the regulated loads.

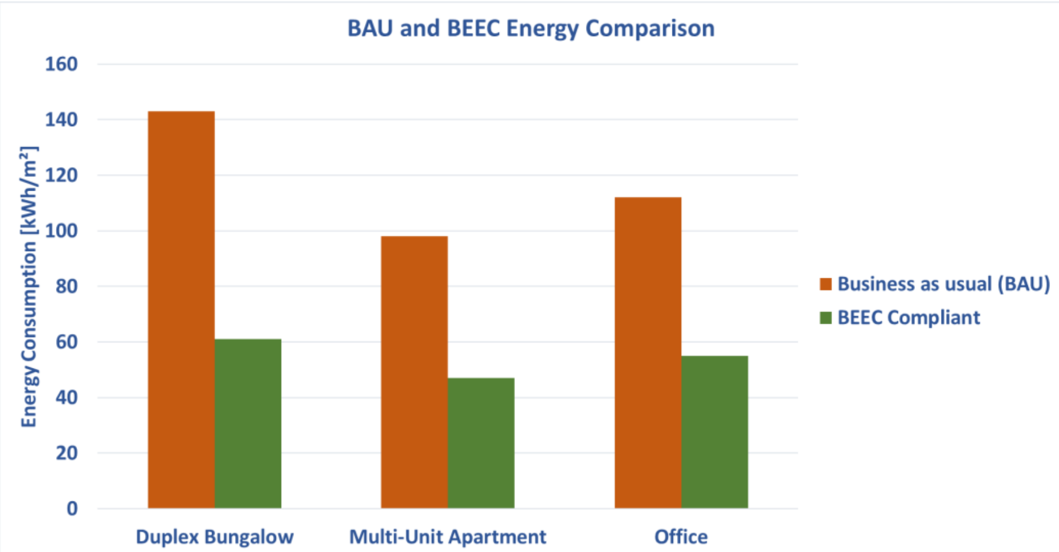


Figure 31: Estimated energy savings on energy related to the operation of the building components only

1.6 Prescriptive Minimum Energy Efficiency Requirements

Based on the analysis described in the previous chapters, this chapter provides recommendations on prescriptive minimum energy efficiency requirements for residential and office buildings, also referred to as Compliance Method 1.

Recommended minimum requirements have been developed for the following areas:

- Fenestrations and shading
- Roof
- Lighting
- Air-conditioning (AC)

For each of the requirements, the following is discussed:

- Recommended energy efficiency requirements. Specifies the recommended prescriptive requirement.
- Applicability. Specifies which buildings the requirements are applicable to.
- Method of verification. Specifies the method of calculation and documentation to be submitted to verify evidence of compliance with prescriptive requirements in both the design stage and the as-built stage.

The requirements presented below are valid for all climates found in Nigeria.

1.6.1 Fenestrations and Shading

Maximum Window to Wall Ratio per orientation, per floor is 20%. This is calculated using the BEEC Calculator tool. For buildings that exceed this allowance, shading must be added as per the BEEC Shading Calculator provided with this report (electronic Annex 2).

Table 16: Recommended EE requirement - WWR and shading

Building element	Minimum requirement
Window to Wall Ratio	Not to exceed 20% for each orientation per floor
Horizontal shading	Where Window to Wall Ratio exceeds 20%, horizontal shading as per BEEC Shading Calculator to be provided

Applicability

This requirement applies to all buildings within the scope of the code.

Method of verification

Design stage

- Architectural plan layouts and elevation drawings of façade and fenestration
- Fenestration schedules or drawings showing the areas of fenestration
- Calculation showing the Window to Wall Ratio
- Completed BEEC Calculator for Window to Wall Ratio or shading

As-built stage

- Material from design stage updated to "as-built"
- Comparison of physically built situation with submitted documents

1.6.2 Roof

Of all the building elements, the roof is most exposed to climatic sources of heat gain. Throughout the day the roof is exposed to direct solar radiation, which is potentially the most significant source of heat gain. The most important strategy is to manage the transfer of heat through the roof structure. A layer of insulation is therefore required to be provided within the roof. The R-value of the insulation must be calculated using the tool provided with this report (BEEC Calculator).

Table 17: Recommended EE requirement - Roof

Building element	Minimum requirement
Roof	Minimum R-value of added insulation 1.25 m^2K/W

Applicability

This requirement applies to all buildings within the scope of the code.

Method of verification

Design stage

- Plan layout and sectional details of the different roof types
- Detailed sectional drawings showing the roof composition including the position of the insulation
- Technical product information showing k-value of insulation
- Completed BEEC Calculator for insulation

As-built stage

- Material from design stage updated to "as-built"
- Comparison of physically built-in products with submitted documents

1.6.3 Lighting

Installed power and energy consumption of artificial lighting should be minimized by the use of more efficient lamp/ballast systems and luminaires. The requirements below include ballast losses.

Table 18: Recommended EE requirement - Lighting

Type of usage	**Maximum lighting power density [W/m²]**
Building interiors – Residential	6 W/m^2
Building interiors – Office	8 W/m^2

To achieve the lighting requirements, designers are encouraged not to exceed the design Lux levels for various spaces in the table below.

Table 19: Recommended lux levels

Type of usage	Recommended maximum illuminance [lux]
Living rooms	300 lux
Kitchen	300 lux
Bedroom	200 lux
Toilets and bathrooms	150 lux
Stairs/stairwells/corridors	150 lux
Offices	400 lux

Applicability

This requirement applies to all buildings within the scope of the code.

Exemptions are Emergency lighting and Outdoor recreational facilities.

Method of verification

Design stage

- Lighting layout plan
- Lighting schedules showing the numbers, locations and types of lighting luminaries used
- Technical product information of the lighting luminaries used
- Completed BEEC Calculator for lighting

As-built stage

- Material from design stage updated to "as-built"
- Comparison of physically built-in products with submitted documents

1.6.4 Air-conditioning (AC)

Only air-conditioners with inverters are accepted for installation in buildings. Air-conditioning is to have a minimum cooling EER/COP of 2.8.

Buildings that will be provided with no AC must show that the electrical supply has been sized to not include AC. Sizing calculations must clearly show that only lighting and equipment have been allowed for.

Applicability

This requirement applies to all buildings within the scope of the code.

Method of verification

Design stage

- Schedule of air-conditioners showing numbers and types
- Product technical data showing inputs required for BEEC Calculator
- Completed BEEC Calculator for air-conditioners

As-built stage

- Material from design stage updated to "as-built"

- Comparison of physically built-in products with submitted documents

1.7 Overall Minimum Energy Performance Requirements

For buildings seeking an alternative to the prescriptive route to compliance, a performance route is also available.

In the performance route, buildings shall have an overall energy performance, determined by a competent person using an approved energy simulation program, less than or equal to that of a reference building designed in accordance with the prescriptive requirements for building elements and services defined in the BEEC.

Therefore, for this compliance method, the building energy simulation should be performed twice: once for a building as it has been designed (referred to as the design building), and the second simulation for the reference building. The reference building shall meet all the minimum prescriptive requirements specified in the BEEC. The calculated energy consumption of the design building must not exceed the calculated energy consumption of the reference building.

All inputs to the software must be documented using the BEEC Calculator (electronic Annex 2) and also indicated on drawings as per the prescriptive route to compliance.

1.8 Improving Energy Efficiency: Recommendations on Integrated Energy Design

Building Energy Efficiency Codes can be described as a set of minimum efficiency requirements of building design components. The aim is hence to ensure that, certain design aspects that have direct impacts on the consumption of energy in the buildings, are complying with some minimum standards.

There are components of the building that require energy to achieve the expected conditions in a building. These design components are often referred to as Active Design and include lighting and airconditioning. Other design components of a building such as the building envelope – including external wall, windows and roofs –also have an impact on the overall efficiency of a building. These design components do not consuming energy directly but serve as a shield to prevent either heat gain or heat loss, depending on the ambient climate and outdoor environment. Such components are often referred to as Passive Design.

There is a direct correlation between the Passive and the Active Design for how much energy is needed to control the indoor climate of a building.

For a building that is located in a hot climate and where solar heat gains require an active design – an air-conditioner – the passive design of the building, such as orientation, shading and insulations in roof or walls is important to consider in order to determine the correct sizing of an air-conditioning system, and thereby the energy consumption and cost of installation. Collaboration between building designers of various building components is therefore important as a starting point when designing a new building.

In the energy efficiency business sector this fact is already well known and hence a concept called "Integrated Energy Design" has been generally recognized, and is gaining increased acceptance.

The Integrated Energy Design (IED) can best be described by having a closer look at the process it involves:

Step 1: Make the commitment (this also involves the developer or investor, who needs to explain and disseminate the intentions of developing an energy efficient building)

Step 2: Identify potential energy design strategies

Step 3: Set goals for energy-efficient design

Step 4: Identify and coordinate interactions with disciplines

Step 5: Use whole-buildings analysis

Step 6: Base decisions on life-cycle economics

Step 7: Follow-through

As it appears from the 7 steps described above, when designing, planning and constructing a building, the energy aspect must play a central role in all phases of the development project, and therefore a design team is often engaged throughout the whole process from the programming until completion of the building. This is different from a conventional building project where specialists step in at different stages and withdraw after completion of their tasks.

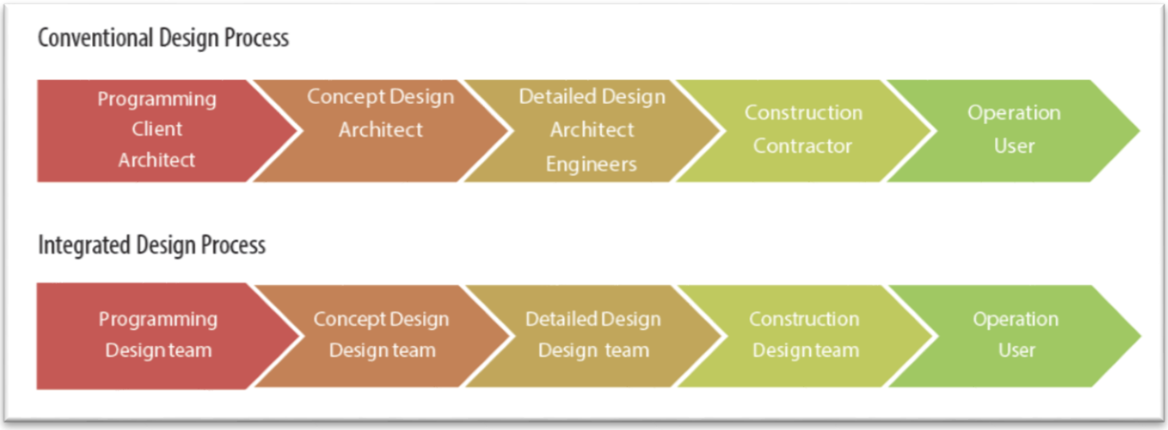


Figure 32: Conventional – or Integrated Design Process

1.9 Outlook for Future BEEC Targets

This chapter places the preceding chapters in perspective by comparing the proposed minimum requirements with international BEECs and looks at possibilities for future reviews.

1.9.1 Comparison to International Best Practice

The BEEC proposed has been benchmarked against two international minimum energy efficiency standards:

- SANS 10400-XA (South Africa)
- ASHRAE 90.1 (USA)

This gives good context for the code as it can be seen what is being done elsewhere on the continent and internationally. The table below displays the differences between the different codes by showing the respective requirements in a comparative way.

Table 20: Building energy code comparison

	Nigeria BEEC	South Africa SANS	USA ASHRAE
Roof insulation R-value	1.25	3.7	4.2
External walls	Concrete block	Brickwork	Highly insulated light weight construction
Glass type	Single clear SHGC – 0.78 U-value – 5.8	Single clear SHGC – 0.78 U-value – 5.8	Single low-performance glass SHGC – 0.4 U-value – 3.4
Window to Wall Ratio	20%	Varies per orientation Average 30%	As per design building or 40%, whichever is lower
Hot water	Not regulated	50% from non-electrical resistive heating	Electrical resistive heating
Lighting W/m² Residential	8	17	9.6
Lighting W/m² Office	6	5	9.6
Air-conditioning	Inverter Split unit COP 2.8	Split unit COP 2.5	Varies according to size of the building

1.9.2 Roof Insulation

Levels of insulation required for BEEC are lower than those for other codes. This is seen as an area where the BEEC can improve on in the future.

Recommendation for future BEEC: Increase insulation to an R-value of 2.5 m²-K/W.

1.9.3 External Walls

BEEC has the least amount of thermal insulation to walls of the three codes. This is an area where, legislating a change would have a significant impact on the local industry. Guidance can be taken from countries like Mauritius where insulated concrete blocks have been introduced slowly over time.

Recommendation for future BEEC: Add insulation requirement for external walls.

1.9.4 Glass Type and Window Ratios

Both of the two other codes studied have recommendations for changing Window to Wall Ratio requirements based on the glass specification. This has not currently been allowed for in the BEEC.

Since there is little use of performance glass in the country, the first iteration of the code would provide the same guidance irrespective of the glass type. Should solar performance glass and associated data sheets become more commonly used, the requirements can be updated to include performance glass types.

Recommendation for future BEEC: Window to Wall Ratio and shading requirements to be updated and include performance glass.

1.9.5 Hot Water

This is not currently legislated. For residential homes in particular, there will need to be a move to regulate hot water energy use. Interesting to note that because of the high use of gas in America, they still allow resistive heating for hot water, whilst South Africa requires non-resistive heating for 50% of the hot water heating.

Recommendation for future BEEC: Solar hot water heating to become mandatory.

1.9.6 Lighting

The BEEC represents the most stringent lighting requirements of the three codes in general. With the rapid advances in lighting technology, this is not seen as being too ambitious. The codes in question were last updated in 2011 (SANS) and 2010 (ASHRAE), hence for lighting, a code developed in 2017 should have more stringent requirements. There is however, no requirement for lighting control and this is seen as a future improvement on the BEEC.

Recommendation for future BEEC: Occupancy sensors for areas with transient occupancy (toilets, meeting rooms, store rooms, break rooms etc.) to be required.

1.9.7 Air-conditioning

The current recommendation for the BEEC only addresses one type of equipment and only looks at performance. Since the current norm in Nigeria is split units this is seen as being adequate for the time being. More developed codes like the ASHRAE code stipulate different systems for different sized buildings, this is a direction the BEEC needs to move in.

Recommendation for future BEEC: Develop AC requirements based on size of buildings and their usage (i.e. office or residential).

1.9.8 Air Leakage

The building envelope should provide adequate barrier to prevent uncontrolled mixing of outside air with air-conditioned space. The energy required to remove moisture from uncontrolled leakages of outside air into the building (the AC) is one of the highest energy load contributed by the external environment into a building in the hot and humid climate.

In a leaky building, the energy used to remove moisture would be higher than the energy used to remove heat contributed by solar radiation. In air-conditioned buildings, the building envelope should act as a barrier to prevent uncontrolled entry of outside air into an air-conditioned space.

Recommendation for future BEEC: It is recommended that the following areas of the building envelope be sealed, caulked, gasket, or weather-stripped to minimize air leakage:

- **a) Joints around fenestration and door frames;**
- **b) Junctions between walls and foundations, between walls at building corners, between walls and structural floors or roofs, and between walls and roof or wall panels;**
- **c) Openings at penetrations of utility services through roofs, walls and floors;**
- **d) Site-built fenestration and doors;**
- **e) Building assemblies used as ducts or plenums;**
- **f) Joints, seams, and penetrations of vapor retarders; and**
- **g) All other openings in the building envelope surrounding conditioned space.**

Ducts that provide a connection between conditioned spaces to outside air should have a damper in between to prevent air leakages into conditioned space when the duct is not in operation.

Note: Negative impact on indoor air quality must be avoided. Fresh air supply must be ensured.

1.9.9 Ceiling Fans

Ceiling fans in comparison to air-conditioning have a very small electrical energy requirement compared to an air-conditioning system. The current code excludes fans on the basis of trying to make the biggest initial impact with the smallest number of regulated items.

Recommendation for future BEEC: Celling fans must meet or exceed the minimum requirements when operating in a downward-blowing direction as per the ENERGY STAR® Program Requirements for Residential Ceiling Fans displayed in the table below.

Table 21: Air flow efficiency requirements

Fan speed	Minimum air flow [m^3/s]	Minimum efficiency [$m^3/s/W$]
Low	0.6	0.07
Medium	1.3	0.05
High	2.4	0.04

1.9.10 Monitoring

A unique problem in Nigeria is that of estimated energy bills. Although this is currently being addressed by the government, the BEEC can help this process by requiring the installation of electrical meters.

Recommendation for future BEEC: Electrical meters for the monitoring of energy consumption should be provided to all incoming power supply in any building.

In multi-unit apartment buildings, each individual apartment unit shall be equipped with an electrical sub-meter.

2 Building Energy Labels and Energy Efficiency Incentives

Labels are a form of energy declaration of products, services, and also buildings. They serve to inform the public in general and specifically customers about the environmental or energy-related impact of the labelled object, and can be combined with incentives in order to boost the application of energy efficiency minimum requirements.

This chapter provides an overview about energy labels, it analyses the role of labels in building energy efficiency codes, and presents recommendations how to make use of labelling when implementing the energy efficiency minimum requirements of the BEEC.

2.1 Options for Energy Declaration - Labels

2.1.1 Impact of Buildings on the Environment

Buildings have extensive direct and indirect impacts on the environment. These can be characterized into four discrete phases:

- **Impact prior and during construction**: This includes items such as the selection of the site; building practices and disposal of materials construction.
- **Impact of building materials used**: The type of materials selected. For example, are products locally sourced; use of recycled materials; and the extent to which high impact materials (which may be cheaper) are eliminated.
- **Impact of operations during occupancy**: With the expected lifespan of buildings (commercial and residential) more than 35 years, this is where the bulk of the environmental impacts emanates from as buildings use energy, water, raw materials, general waste and some also emit harmful atmospheric emissions.
- **Renovation or demolition after useful life**: The way the building is dismantled and the materials are disposed.

Governments can influence the environmental4 impact of buildings through mandatory and voluntary programmes. The two are not mutually exclusive and the most effective approach is a combination of the two. As all citizens are required to comply with legislation it needs to strike the balance between actual environmental performance improvements and ensuring that the industry and lower income groups are not adversely affected. In other words, the requirements must be realistic and achievable. However, it is necessary to ensure that the opportunity for additional improvement is not only available but defined. This falls under a voluntary rating scheme. The figure below depicts the three tools used to achieve these objectives.

The first is the mandatory building code; the second is a certification system which is represented by a label; and the third takes the form of incentives (financial and non-financial). Energy savings are maximised when tools are used in combination, as the impact of the three is

[4] The National BEEC project limits its requirements to energy. Although the principle is relevant to all environmental aspects of a buildings (energy, water, waste etc), henceforth this report will only refer to energy to align with the outputs of the other chapters.

larger than the sum of the individual expected impact. However, it is vital that the programme follows an overall and coordinated strategy as too many signals and instruments may also confuse the market.

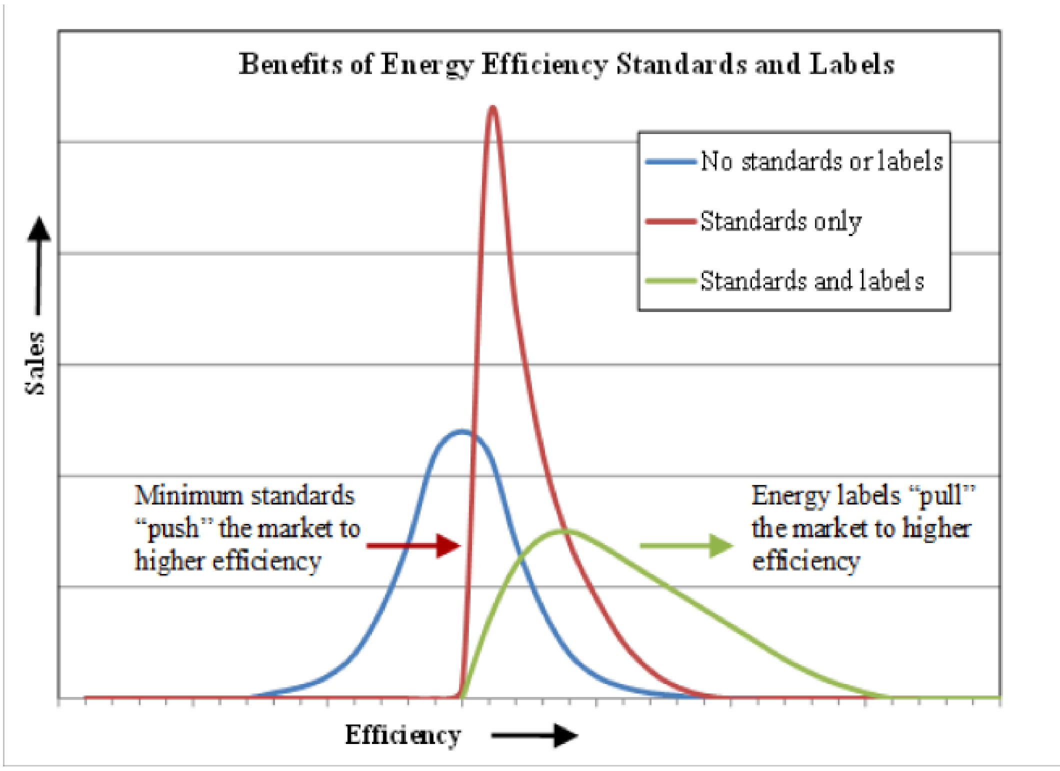


Figure 33: The impact of policy tools in shifting the market towards higher efficiency building

2.1.2 Types of Energy Labels

Appliance energy labels have been used successfully in many countries to overcome market barriers and increase awareness and for this reason they have been extended and developed for buildings.

As with appliance labels, building labels are affixed to buildings and provide details about its energy performance. Two types exist:

- Endorsement provide no information and purely serve as a 'seal of approval', generally signifying that a minimum standard has been achieved.
- Comparative labels rank additional efficiency achievements by applying an easily understandable system. Four conventions exist internationally: Stars, Numbers, Alphabet and Symbols.

Endorsement labels are inherently voluntary whereas comparative labels can be mandatory or voluntary (see Figure 34). Countries using the comparative label tend to implement mandatory programmes to increase compliance. Examples of comparative labels for energy and green buildings is shown below (see Figure 35).

Figure 34: Examples of building endorsement labels

Figure 35: Example of a green building comparative label

Figure 36 shows comparative labels, from different regions, which only consider a building's energy usage.

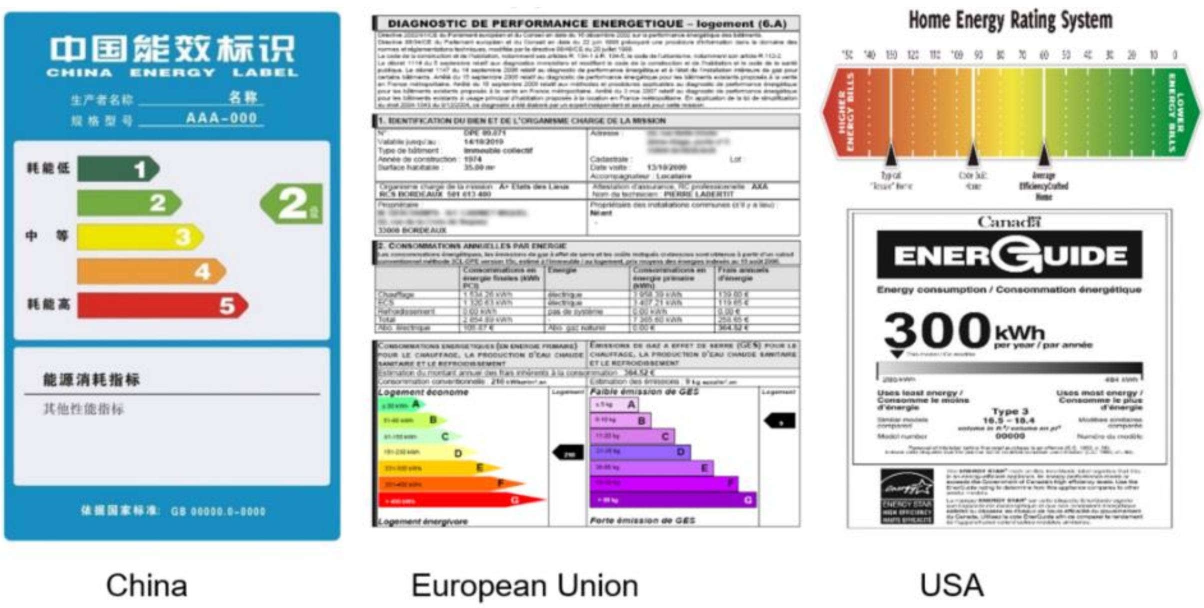


Figure 36: Example of comparative labels – energy only

What is immediately evident from the figures above are the varying levels of complexity, which is governed by two items. The first, are the number of requirements needed to achieve the different levels, and the second is how the information is communicated to the end consumer. It is not necessarily the case that a demanding and comprehensive rating system is communicated with a detailed label. For example, LEED which is a holistic certification and not limited to energy is very detailed but is represented in a simplistic form. Conversely, the Building Energy Rating and Home Energy Rating System (EU and USA) only consider energy, but the labels provide the consumer with detailed explanations. The second item, deals with the design of the label. Both require a more detailed analysis.

2.1.3 Taxonomy of Building Rating System

Figure 37 provides a simplistic taxonomy of building rating systems. The base of the pyramid considers all aspects and is therefore not applicable to this project. Tier 2 recognises that to maximise energy savings during the operational phase the major energy consuming appliances must be included, at a minimum this would include heating and cooling; lighting load; hot water and miscellaneous equipment load (basic but necessary appliances such as refrigerators, cooking and washing machines). Tier 3 would only consider the design and building fabric of the house.

The presence of two labelling schemes, one for green buildings and one for building energy efficiency, creates confusion among consumers as has been the case in China. It is therefore important that awareness programmes educate consumers about the meaning of multiple labels, if they exist. In Nigeria, the Green Building Council has indicated its intent to introduce its own (Tier 1) label.

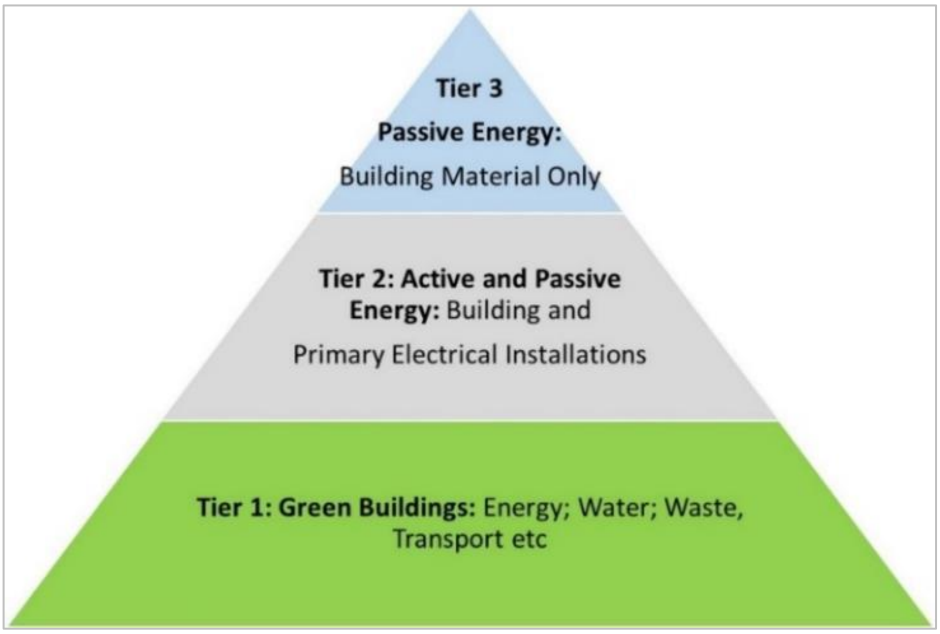


Figure 37: Taxonomy of building rating systems

2.1.4 Label Design Options

As noted, the most striking difference between the three labels in Figure 36 is the level of detail, which increases from left to right. The primary aim of a building label should be to provide appropriate and effective information to consumers allowing them to make informed decisions. Research has shown that each country and culture has specific connotations to words, letters, numbers, symbols and colours. Appropriate handling of these subtleties and careful framing of energy information can enable better delivery of messages or, if ignored, impede effective interpretation of intended messaging.

The most significant aspects for label cognition are:

- **Simplicity**: A label that is simple to understand
- **Single message**: To be effective, an energy label should have a large logo, or large, bold font conveying one primary message
- **Compartmentalisation of details**: Rather than dumb down the label, structure the label with the detailed, technical, building information in separate compartments for those who want to interrogate the specifics
- **Good formatting**: It is important to structure the label around a central message, good scale and contrast in scale, "white space" and size of typography that corresponds with importance of the label element
- **Value for money**: Consumers indicated that cost comparisons (indicative operational costs), rather than comparisons of energy units are preferred

2.2 Selecting a Label Design for Nigerian BEEC

The Standards Organisation of Nigeria (SON) is in the process of implementing a Standards and Labelling programme for appliances. The label chosen for buildings is closely linked to that already developed for appliances. As depicted, the energy label presents five different energy classes, ranging from 1 to 5, each displayed as a number with a different background colour. A star is used to define which level of rating the building actually achieves. The lowest energy efficiency class is awarded with one star, while the highest efficiency class is awarded with five stars, and all buildings are rated accordingly. The higher the rating the more efficient the building, i.e.: a 4 star rated building is more efficient than a 1, 2, or 3 star.

Each state would provide its logo as an endorsement of the label as they adopt the BEEC.

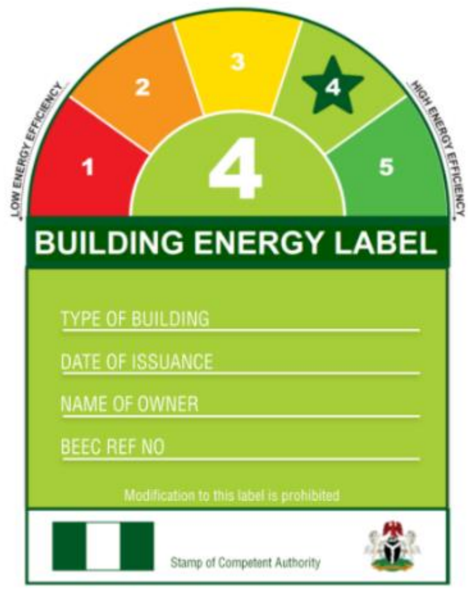


Figure 38: Proposed Nigerian energy label for buildings

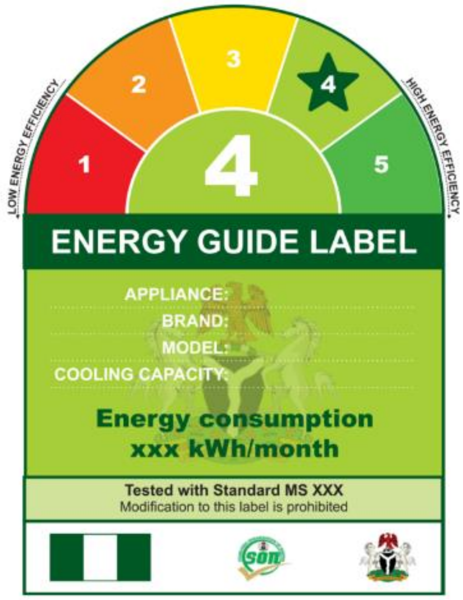


Figure 39: Example of appliances label

The design of the label by the Standards Organisation of Nigeria is a result of extensive local research in line with international best practise. Key features include a local design and government endorsement (national colours, Nigerian coat of arms and flag); the star system aligns with the regional efforts of Ghana which adopted this approach; and the label ascribes to simple format, single message and compartmentalisation of details. An example of the label for appliances is shown below.

The advantages and disadvantages of adopting the appliances label for the BEEC are considered in the table below.

Table 22: Suitability of residential appliances label for the BEEC

Advantages	Disadvantages
• Label in place, reducing time and cost • Label is a result of local research, additional research may yield minimal new information • Introducing a new label design is likely to create confusion and dilute effectiveness of both programmes • Opportunity for programmes to leverage off each other	• Some customisation will be necessary, which may create design and message constraints • Cooperation with appliance labelling team may introduce complexity

The benefits outweigh the disadvantages, and it is proposed that the appliance label is adopted for BEEC. As the Nigerian residential appliance label is a comparative label and that it provides the flexibility required by the BEEC, no further analysis is necessary.

2.3 Rating of the National BEEC Label

For the two identified building types (residential and office buildings), Chapter 1 identifies appropriate Window to Wall Ratios, and requirements for insulation, lighting, and AC units.

Provided that the minimum energy efficiency requirements will be voluntary prior to imposing them as mandatory, the BEEC label will award those buildings having BEEC requirements implemented.

By applying different minimum energy efficiency requirements in an incremental manner, different star ratings will be achieved for the building. A four star building represents a fully BEEC compliant building.

The BEEC rating is described below, once for the prescriptive route to compliance, and once for the performance route to compliance.

Prescriptive Route: The complexity with this approach is working out how to score a combination of measures. The approach detailed in Table 23 is recommended.

Performance Route: This approach is suited to the modelling software approach. Table 24 shows that projects can be rewarded for partial adherence to the minimum energy requirements and this is mirrored for the modelled approach. This means that for a 1 star building, its energy use is greater than that of a BEEC compliant building but not exceeding it by more than 40%. When a building is in complete adherence with the BEEC, it will have energy use that is equal to or less than that of a BEEC compliant building. Table 24 therefore shows the allowance by which a building is allowed to exceed the BEEC compliant buildings energy use by.

Table 23: Reference table of interventions to determine rating (prescriptive route)

Rating	Intervention	Minimum Specification
1 star	Window to Wall Ratio or shading	20% maximum and/or shading as per BEEC Calculator
2 star	Window to Wall Ratio or shading Lighting – Residential Lighting - Office	20% maximum and/or shading as per BEEC Calculator Maximum lighting power density 6 W/m² Maximum lighting power density 8 W/m²
3 star	Window to Wall Ratio or shading Lighting – Residential Lighting – Office Roof insulation	20% maximum or shading as per BEEC Calculator Maximum lighting power density 6 W/m² Maximum lighting power density 8 W/m² Minimum R-value 1.25m²K/W
4 star	Window to Wall Ratio or shading Lighting – Residential Lighting – Office Roof insulation Air-conditioning minimum performance (only if air-conditioning is necessary)	20% maximum and/or shading as per BEEC Calculator Maximum lighting power density 6 W/m² Maximum lighting power density 8 W/m² Minimum R-value 1.25m²K/W Minimum EER/COP 2.8 and Inverter Compressor

5 star	On application only. This allows for taking into account also renewable energy systems (Photovoltaic, Solar water heating) which are currently outside BEEC.

Table 24: Illustrative example of rating schedule (performance route)

Rating	Allowance for exceeding BEEC compliant building
1 star	40% to 31%
2 star	30% to 21%
3 star	20% to 11%
4 star	10% to 0%[1)]
5 star	Below 0%[2)]

[1)] 0% excess energy consumption compared with the code requirements means that the building is compliant with the BEEC.

[2)] Less energy consumption than compared with code requirements means that the building is better than required by the BEEC.

For both approaches it is vital that a carefully considered compliance mechanism is developed and actively enforced.

The figure below illustrates the table above graphically. It shows that for a 1-star building, its energy use is greater than that of a BEEC compliant building by a maximum of 40%, 30% for a 2-star building and so on. A 4-star building has energy use that is within 10% of a BEEC compliant building. A 5-star building has an energy use that is less than that of a BEEC compliant building.

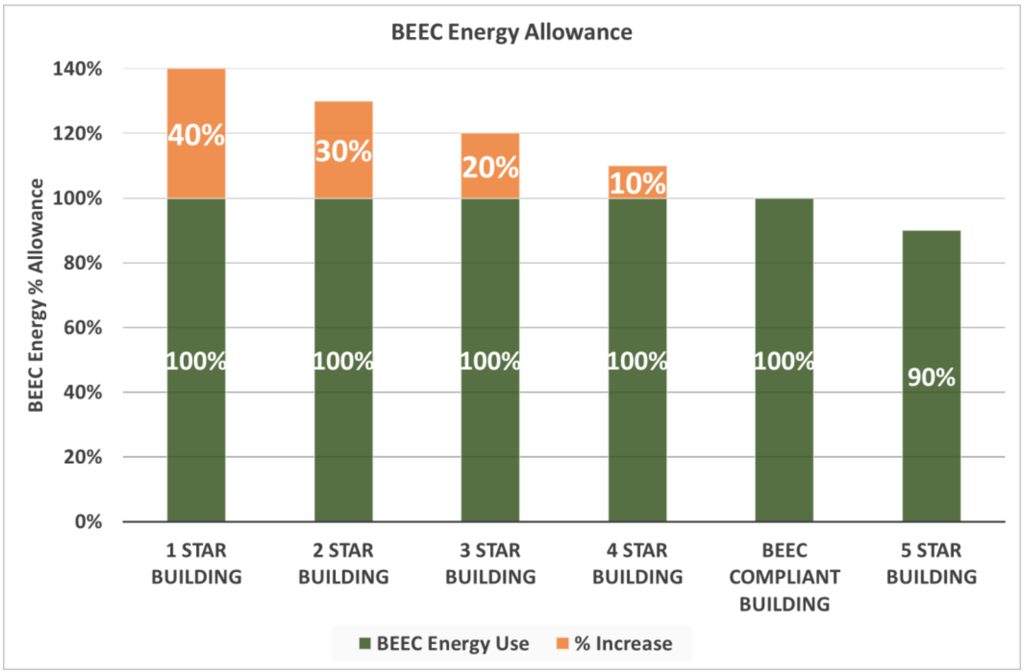


Figure 40: BEEC energy allowance

2.4 Building Energy Efficiency Incentives

2.4.1 Definition and Introduction

Research has found that the effectiveness of building standards varies from country to country, primarily because of difficulties in compliance and enforcement. In developing countries, energy efficiency programmes are ineffective or significantly less effective than predicted - in countries where they do exist they do so on paper only, due to insufficient implementation and enforcement, corruption, capacity resources, funding, technical expertise and other problems. Moreover, they are often initiated by development agencies, but if this support does not extend to the implementation period, the prospects for success are likely to be low.

Market barriers, the commonly used term, seeks to explain why participants fail to respond to government policy or regulation. A failure to address or overcome these barriers, all and not some, will lead to the continued poor performance of programmes.

Research has concluded that although barrier themes are generic and to be found everywhere, the extent to which they apply in every region varies and thus, solutions to these barriers cannot be formulaic or prescribed, but must address the underlying local issues. Barriers to the uptake of ratings and certification programmes can be categorized into three broad groups, or more accurately, perspectives: Economic, behavioural and organizational.

The table below presents an overview of these aspects.

Table 25: Universal barriers encountered by energy efficiency initiatives

Perspectives	Examples	Actors	Sub-Division	Barrier	Description
Economic	Imperfect information; asymmetric information; hidden costs; risk	Individuals and organization conceived of as rational and utility maximizing	Rational behaviour[5]	Heterogeneity	Technology may not be cost effective in a particular instance
				Hidden costs	Technology investment entails extra costs or loss of benefits that are not reflected in engineering models
				Risk	Stringent investment criteria may represent a rational response to risk
				Access to capital	Capital for investment cannot be accessed
			Market or organizational failure	Imperfect information	Agents lack sufficient information to make economically efficient decision
				Adverse selection	Agent cannot transmit or discover beneficial properties of a good (asymmetric information adds transaction costs)
				Split incentives	Agent cannot appropriately benefit of investment: landlord tenant type relationships
				Principal-agent relationships	Principal may impose strict investment criteria to compensate for imperfect information

[5] Rational behaviour implies utility maximizing or routine following

Perspectives	Examples	Actors	Sub-Division	Barrier	Description
Behavioural	Inability to process information; form of information; trust; inertia	Individuals conceived of as boundedly rational with non-financial motives and a variety of social influences	Bounded rationality[6] The human decision	Bounded rationality	Cognitive limitations lead to satisficing[7] rather than optimizing and relying on routines and rules of thumb Organisational routines may systematically neglect efficiency
				Form of information	May be inadequate to stimulate action
				Credibility and trust	Agents may not trust source of information
				Inertia	Agents resist change because they are committed to what they are doing and justify inertia by downgrading contrary information
				Values	Lack of environmental awareness leads to neglect of efficiency opportunities
Organization	Building professionals lack power and influence; organizational culture leads to neglect of environmental issues	Organisations conceived of as social systems influenced by goals, routines, culture, power structures etc.	Contextual factors	Power	Agents lack sufficient power within an organization to initiate action
				Culture	Environmental awareness and efficiency play no part in corporate culture

[6] Bounded rationality is the idea that in decision-making, **rationality** of individuals is limited by the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make a decision.
[7] *Satisficing* is a decision-making strategy that aims for a satisfactory or adequate result, rather than the optimal solution.

2.5 Mandatory versus Voluntary Approach to BEEC

Deciding between a mandatory or voluntary approach is not straightforward, as both can work or fail. It is the local context and ultimately the design, implementation and commitment which will determine success or failure. The differences and the key success factors between the two are summarised in figure 41.

What can be concluded is that a voluntary programme on its own will yield poor results unless it is supported by carefully considered instruments which entice the market to participate. This is intuitively logical - why would project developers change their business as usual approach if they are not required to do so (regulations)? Or there is no perceived tangible benefit in doing so voluntarily?

The main instruments available for voluntary participation, are:

- **Unilateral agreements**: Self-regulatory approach where an industry commits to acting in recognition of their environmental impact and to avoid regulatory controls through a pro-active approach. The implementation experience however has been found to be poor;
- **Negotiated arrangements**: Contracts between industry and public authorities for achieving a defined target per an agreed time schedule. As with unilateral agreements, the non-enforceable nature and low level of monitoring of these agreements has resulted in unsatisfactory outcomes. To correct this, the EU for example, has now attached penalties for non-compliance;
- **Supported voluntary programmes**: Participants agree to comply with standards put forward by public authorities. In so doing, they demonstrate their support for public initiatives and gain recognition for environmental efforts and encouraged/enticed to do so through the provision of a state supplied benefit (incentive).

Based on this research, and discussions held with the stakeholders it is recommended that BEEC is introduced as a supported voluntary programme with the end objective of converting it to a mandatory programme in the future, ideally not later than 2 years.

Since the BEEC programme is recommended to start off as voluntary, labelling is seen as a way of encouraging building owners by giving them an official "stamp of approval" or "badge of honour".

After a voluntary period of two years maximum, the competent authority will make all minimum requirements mandatory, and the label will be revised to be used for communicating building energy efficiency on the market as part of a mandatory scheme.

BEEC

Mandatory

Set of procedures and regulations that prescribe the energy performance of buildings. Implemented with legal and monitoring framework, standards can be a very powerful and effective tool in transforming the market by prohibiting the construction of buildings that do not meet the minimum efficiency level

Key Success Factors

1. Development of regulations and legal instruments for effective implementation i.e: penalties for non-compliance
2. Awareness and training for a sufficiently skilled workforce to oversee the project. Private sector training is also necessary
3. Administration and monitoring become the key components
4. Data collection to allow for systematic and periodic adjustments and tightening of the regulations
5. Cooperation of project developers, manufacturers and product suppliers is necessary
6. Political will to implement programme and dedicated funding needed to succeed

Advantages

1. Impacts the entire market
2. Properly managed programme can yield large energy savings and improve comfort levels
3. Support local industry and create jobs

Disadvantages

1. Expensive and requires dedicated and committed management
2. Inappropriate min standards may disrupt the market and create negative publicity

Voluntary

Provides consumers with information that can promote (but not mandate) more educated and energy-conscious decisions when purchasing or renting. A more flexible approach, which requires a business-driven process, to put forward the most cost-effective options, to allow developers to play a pro-active role in setting quantified criteria

Key Success Factors

1. Market can only respond if it is aware of the programme, thus promotional activities become the major implementation task. A comprehensive campaign which covers multiple mediums must be developed
2. Funding must be sufficient, long term and committed
3. Enticing voluntary participation usually requires an incentive
4. Cooperation of project developers, manufacturers and product suppliers is necessary

Advantages

1. Policy signal to industry to prepare
2. Creates the opportunity for stakeholder engagement and participation
3. Does not create massive disruptions

Disadvantages

1. Performance and energy savings difficult to quantify
2. High probability that market does not respond
3. Difficult to secure and maintain long term funding for communication and awareness campaigns. These are the first to go in a downturn
4. Likely to influence most affluent and educated

Figure 41: Summary of mandatory and voluntary approaches to BEEC

Also the mandatory scheme should include a voluntary component besides the defined minimum requirements, which can be termed 'mandatory'. The voluntary participation caters and recognises additional energy savings measures, such as SWH, higher specification AC and insulation. The 'mandatory' measures have been carefully selected for their high-energy savings making them financially attractive, ease of implementation and straightforward to enforce. Incentives should therefore be limited to the voluntary side of the programme and used as a 'hook' to encourage participation.

2.6 Incentive Types

Government has an important role to play and must lead by example by taking appropriate action to overcome market failures and barriers. An incentive can be defined as an action which influences people to act in a specific way. Several types of incentives exist, as shown below in Figure 42.

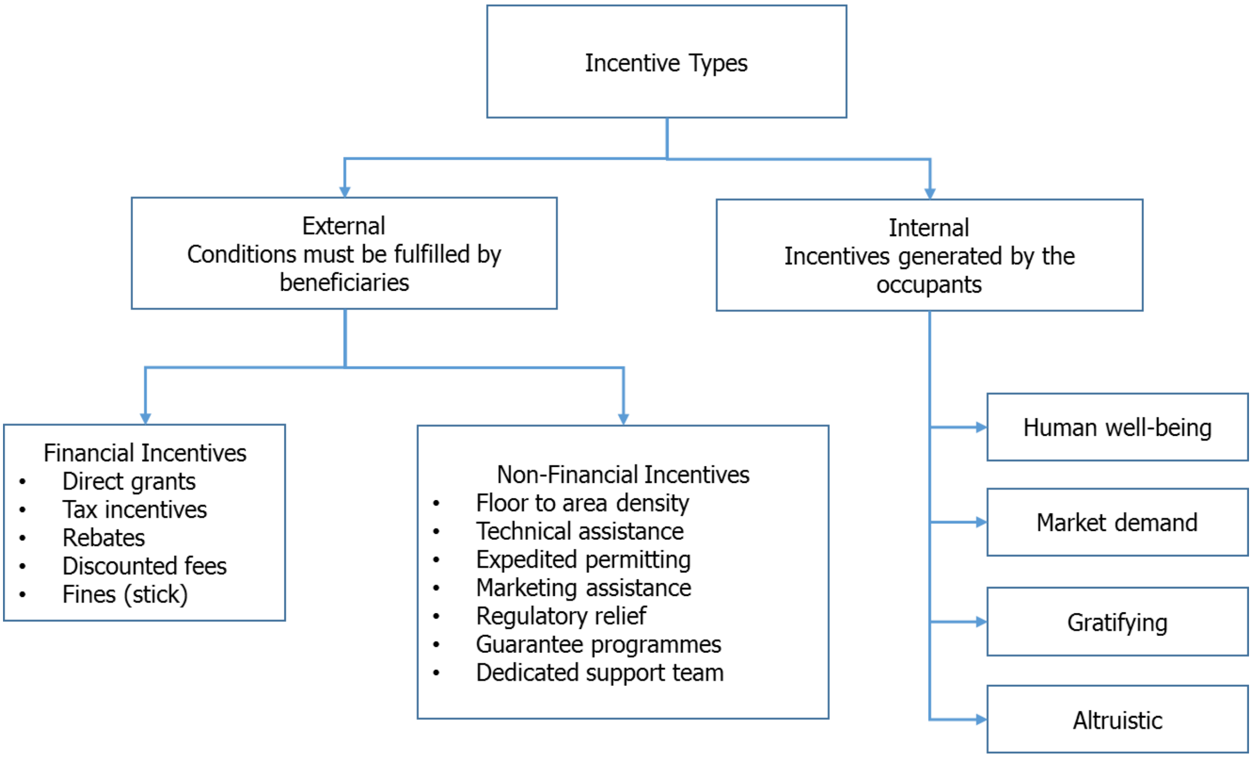


Figure 42: Incentive types

2.7 Internal: Own Volition

Public policy alone cannot bring about the change needed to transform the building sector. The opposite to external incentives, which are either forced or compelling rewards, internal incentives are motivated by an individual's or company's connection to the activity.

Several types exist, and individually or collectively may motivate action:

- **Human well-being**: Given the amount of time people spend in buildings, the highest possible comfort levels should be targeted;

- **Market demand**: Green buildings have a higher market demand and can charge higher rentals;
- **Gratification and market differentiation**: Green awards and general recognition of a building exceeding the norm produces competitive advantages for firms and enhances their image and reputation;
- **Altruistic**: Actions based on personal beliefs and values;
- **Persuasion and Inspiration**: Influenced by demonstration buildings, project developers get a better understanding of what is possible, what can be achieved and the resulting benefits.

2.8 External: Financial Incentives

This is commonly referred to as the 'carrot and stick' approach. Carrots take the form of financial incentives (FI) to overcome economic barriers. However, to be effective the stick is applied when the market fails to comply with regulations or has reneged upon voluntarily, but binding, agreed upon commitments.

Government administered financial aid programmes have the following instruments at their disposal:

- **Internal**: Paid directly by the government in the form of financial incentives (grants / subsidies, funds and preferential loans) or fiscal measures (tax reduction, tax credit, reduced VAT); or
- **External**: FIs provided by utilities or other parties in response to a regulatory mandate.

The major shortcoming of government funded FI programmes is that they tend to rise and fall as governments change and are the first to be sacrificed when public money becomes scarce. This has resulted in many countries seeking alternative and innovative approaches to finance energy efficiency programmes, which have taken the form of using well-regulated non-governmental institutions, such as commercial banks and private utilities for the distribution of incentives. Funding is sourced from levies applied on electricity sales and utility mandates for energy savings. It is unlikely that the Nigerian government will provide financial incentives for developers to build energy efficient buildings due to the high costs and more pressing developmental priorities.

Instinctively, financial incentives are deemed to be the most effective and appropriate measure to alter behaviour and influence decisions. However, several factors must be carefully considered:

- **Unethical behaviour**: Incentives, in the form of cash, can lead to fraud as people look to enrich themselves and gain a competitive advantage. This can occur internally (administrators) or externally (claimants), these two parties may even collude;
- **Funding**: Financial resources must be established and committed, with five years as the recommended duration. FIs be stable and must not be arbitrarily increased or decreased;
- **National standards**: More specifically for technological equipment (solar water heaters, lighting, HVAC etc.), financial benefits linked to expected energy savings must

be supported by credible performance testing. If such mechanisms do not exist it is highly likely that savings will not be achieved and limited financial resources will be wasted;

- **System performance**: Incentive calculations must be designed with system performance in mind to avoid oversized or over-priced systems;
- **Measurement and Verification**: Robust procedure to measure energy.

Best practise dictates that a FI is offered to an operationally functioning energy efficiency programme rather than using a FI to launch the programme.

In lieu of the above, FI is not recommended as a support mechanism.

2.9 External: Non-Financial Incentives

Non-financial incentives include Floor-to-Area density (FAR), technical assistance, expedited permitting, reduced application fees, business planning assistance, marketing assistance, regulatory relief, guarantee programmes, and dedicated green management teams in building and planning departments. Under this approach, the government grants the project developers rights, or additional rights, that are beyond what is normally allowable, when certain conditions are fulfilled. For instance, expedited permitting enables owners who incorporate green building materials into a proposed development to get their plans and permits more quickly from the local authority. The FAR incentive allows the owners to construct more building area than allowed by the usual zoning. Though these are non-financial incentives, owners are often able to recoup some or all of their expenditure on green development through the increased rentable/saleable space or reduced administrative time, which often provides an even greater cost reduction to the project developers. It is thus correct to say that non-financial incentives provide a financial reward. Additionally, non-financial incentives are flexible and can be designed to fit local conditions and have the benefit of limiting direct costs.

Research has shown that non-financial incentives to promote green-building incentives have proven to be more effective than traditional FI's as they are preferred by the industry and most specifically by project developers, the most important protagonist in the value chain. Indeed, these findings were confirmed at the private sector workshop8 held during the country visit to Nigeria.

With regard to incentives it is evident that government not incurring any direct financial costs is not strictly accurate:

- **Reduced fees**: Although not a direct cost, this results in reduced revenue with the net effect being much the same for the administrating body;
- **Assistance (technical, marketing, business)**: These are specialised skills which must be acquired or developed, as they are new and do not exist;
- **Unethical behaviour**: With processing priority given to energy efficient applications, this benefit creates perverse incentives. For example, submissions which have minimal

[8] Private sector workshop held at GIZ offices 01 February 2017

or supposed green components are submitted for fast tracking creating delays, the need for checking etc.

In a nutshell, very few building projects are likely to pursue voluntary measures without receiving some sort of benefit. Based on this research, including the stakeholder consultations in Abuja, it is proposed that expedited permitting is offered to any building seeking a 2 star or better. This process should be relatively straightforward to arrange within the local authority and should not create unacceptably high risks in terms of manipulation, opportunities for fraud and corruption, or onerous additional costs. During the first review of the programme this non-FI must be evaluated to determine: 1) its suitability – market response and 2) if additional non-FIs are necessary.

2.10 Public Education, Awareness and Training

Campaigns to educate the public and prepare key market players are critical to the success of new building labelling and rating schemes. Awareness, as a barrier to their adoption, comprises of the following:

- Lack of sufficient information and understanding on the part of consumers/tenants/building owners to make well-informed consumption and investment decisions;
- Lack of information about the energy performance of buildings;
- Energy information may not be provided or analysed by end-users, energy providers, or other implementing agencies;
- Benchmarks for performance may not exist; and
- Perception that energy efficiency measures make buildings more expensive.

A review of China's experience with the introduction of the energy efficiency building programme, which is typical of new programmes, include: insufficient capacity building, unclear program goals, high transaction costs, and low public awareness. Two major barriers that have limited participation in the programme are scarcity of expertise in building simulation evaluation and subsequent high costs. It is proposed that energy performance modelling is not introduced immediately but phased in. To start it may be offered by application only to ensure that large, high profile demonstration projects are not excluded.

There is little doubt that combining these 'soft' policies are more effective if complemented with incentives, voluntary agreements and regulations, however this more complete package is only as good as its foundation. It is vital that participants of the BEEC programme, who are looking to move beyond the baseline, understand the benefits and opportunities rather than chasing an incentive which they may not fully understand and are only doing so for expediency.

2.11 Concessionary Funding Opportunities

Although green financing and green bonds in principle seem feasible and logical, they are notoriously difficult to set up. The primary obstacles are:

- How to separate or quantify energy savings?

- Will they actually materialise?
- How do you encourage consumer behaviour to maximise savings and avoid the offsetting effects of rebound and backfiring?
- Banks tend to be risk averse and question new technologies, this is made worse by a reluctance to provide secured loans for energy efficient equipment.

These barriers can be addressed by a guarantee provided by climate funds but generally require government or utility participation. For example, Tunisia's successful SWH rollout programme was only possible because the utility provided the security the banks demanded.

Furthermore, the structure of the programme in the first phase is designed:

1) For basic compliance with no or limited additional cost; and
2) Demonstrate that the interventions (insulation and higher specification AC) for 2 star or better rating, will in addition to reducing operational costs, also decrease capital investment as generators sizes can be smaller, AC for heating and cooling can be reduced due to improved insulation etc.

It is suggested that this is reviewed in the second phase of the programme.

2.12 Findings and Recommendations

Education and awareness builds demand for voluntary labels and engages the market. Training of building owners and vendors has a marked impact on participation. A look at the common barriers experienced in the procurement of products and commissioning of energy efficient buildings in the public sector immediately identifies awareness as the starting point. This might not be the singular answer but the starting point which provides the entry point to unlocking the remaining barriers. For example, a better understanding of life cycle costing can start to question stringent policies of lowest initial purchase price requirements for equipment.

Figure 43: Hierarchy of barriers in energy efficiency procurement

In conclusion, it is proposed that the programme is implemented in two phases as shown in the figure below.

Phase 1
(Suggested Duration: 1-2 years)

1. Minimum qualification criteria (roof insulation, WWR and A/C)
2. Introduction of a building label, which aligns with residential appliance S&L design
3. Modelling allowed by application only
4. Comprehensive public education training and awareness
5. Additional EE measures recognized (2 star or >) and supported via non-financial incentive of expedited permitting

Phase 2

1. Programme evaluation, to identify strengths weakness and effectiveness. Decision on converting to mandatory approach
2. Corrective actions (as required) and tightening of minimum EE standards to improve energy savings
3. Consider introducing modelling for specific building types
4. Determine whether additional incentives needed
5. Review training and awareness programme and adjust as required

Figure 44: Proposed project phases

3 Enforcement and Control

3.1 Introduction and Organizational Arrangements

Based on discussions and resolutions made at inception meetings in Abuja with stakeholders (November 2016) it was agreed that Enforcement and Control as part of a Building Energy Efficiency Code (BEEC) should be dealt with by analysing case studies and by analysing the example of the Department of Development Control of the Federal Capital Territory of Abuja.

This should be seen as a 'proof of concept', which if successful, increases the probability that it will be adopted by other states and cities.

Its voluntary status means that building applications are not subject to its requirements except if decided by the state or local Authorities. To encourage participation several measures are outlined in other sections of this report, namely a label, non-financial incentives, public awareness and training.

When the BEEC becomes mandatory, the legitimacy and credibility of the programme relies on ensuring that all certified buildings actually comply with the BEEC code, and this can only be achieved if there is a practical yet robust control and enforcement mechanism in place.

Figure 45 identifies the main stakeholders involved in the introduction and implementation of the BEEC. The figure shows the structure for FCT Abuja but is assumed that other states will have similar structures.

3.2 Assumptions and Implications of Introducing a BEEC

Considerations of introducing a BEEC are based on the following assumptions and implications:

- The approach for introducing a BEEC requires that the implementing authority has a certain level of expertise.
- From discussions held during country visits, the control and enforcement function is structured according to the following assumptions and additional activities shown with the example of Department of Development Control (DoDC) in the FCT representing the authority responsible for conducting the compliance check as well as carrying out inspections of completed buildings before the permit of habitation is issued.
- The competent authority does appraisals and site checks of completed buildings in-house and this task will not be outsourced.
- Energy efficiency is a technical discipline, which has not been a requirement in the local authority and will need to be developed. This will require additional training of existing resources.
- The BEEC will result in a new and additional work load for the department. The local authority should understand that this implies increased work load for existing staff and / or the hiring of new staff.

Table 26: Public sector stakeholders across tiers of Government (Abuja example)

National	**Ministry of Power Works and Housing** Carries the highest authority with regards to formulation and preparation of policy tools and regulations. In the context of the new BEEC it is important to ensure the Ministry's full commitment and support in promoting awareness and implementation of the minimum energy efficiency requirements
Federal/State	**Federal Capital Development Authority** Highest administration body dealing with construction and building development. Their mandate is to oversee Planning, Design and Construction of the FCT, and ensure that developments conform to and surpass the set standards
Local Government	**Abuja Metropolitan Management Council (AMMC)** Responsible for the coordination and supervision of, amongst others, Development Control. The AMMC is responsible for the granting of permits for public/private developments, and the monitoring/enforcement of physical development activities in line with the provision of the Abuja Master Plan and other Development Control guidelines
	Department of Developmental Control (DoDC) The responsible entity for carrying the compliance check of the existing building codes for building designs that are submitted as part of the application for obtaining the required construction permit. The DODC also conducts inspections of newly constructed buildings and issues permits of use when full compliance has been confirmed
Civil Society	**Green Building Committees** Abuja Administration has formed Green Building Committees that evaluate applications for certification and issuing Green Building Certificates. A 5-year roadmap has been formulated laying out plans for further institutionalization and implementation of the Green Building concept. During the first year – 2015 – references and benchmark as well as checklists have been developed. These checklists have also been incorporated into the Development Control Manual of the Department

3.3 Existing Building Code in Nigeria

The National Building Code for Nigeria sets minimum standards on Building Pre-design, Design, Construction and Post-construction stages with a view to ensuring quality, safety and proficiency. The Code defines 10 different classifications of buildings of which two main classes are relevant to this present project, namely: Group B – Business and Professional and Group R – Residential. Under Group R there are 4 sub-classifications which includes various sizes of residential buildings, which also includes Hotel buildings.9

The Code includes a separate section which provides general recommendations on fundamental principles of green building and sustainable design.

The recommendations under energy and environment consider passive design aspects, such as building orientation and designs to minimizing undesirable solar heat gains by using high performance low-e glazing and shading. General recommendations also make provision for efficient lighting and HVAC systems. All these measures support and align with the BEEC.

3.4 International Experience and Good Practice

Building Energy Efficiency Codes were first developed and implemented over 30 years ago, and during that time have been adopted by many countries (Figure 46), but as would be expected have yielded different results. It is worth evaluating some of these experiences to get an understanding of approaches that have worked and those that have not. The information can also serve as a valuable reference in developing a set of requirements and implementation procedures that are found to be most appropriate and suitable for the Nigerian context.

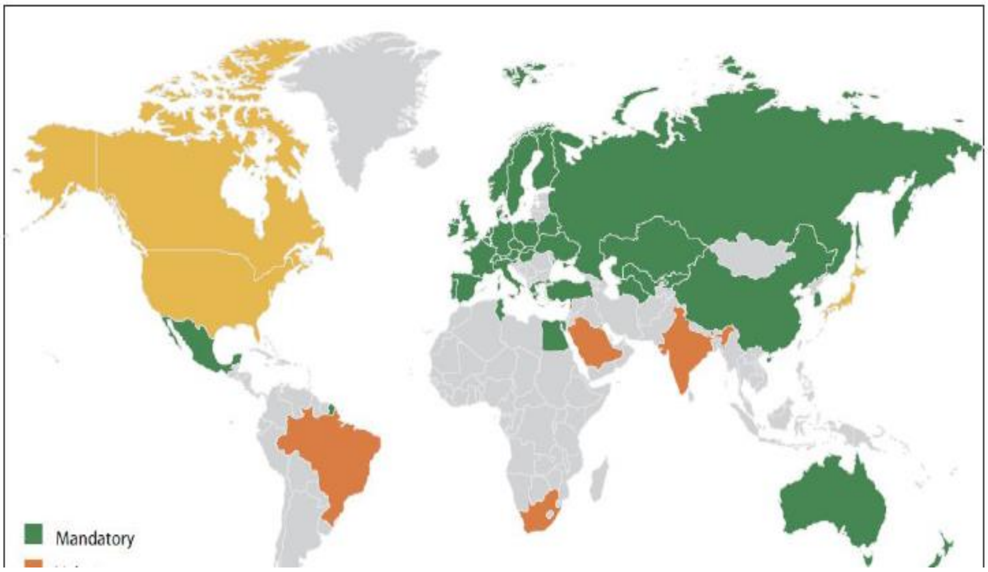


Figure 45: Building energy codes in place for new residential buildings (IEA 2013)

[9] Hotel buildings have not been included as targeted building type in the development of minimum energy efficiency requirement.

3.5 Best Practice Building Codes

A report10 published by the Global Building Performance Network, found enforcement to be the most challenging aspect of code implementation across all jurisdictions. In an assessment of the "quality" of the enforcement standards among countries that have introduced BEEC, Sweden scored the highest rating (5/10), indicating that even in small, highly developed economies, which have a long history in implementing minimum requirements and are perceived to have high levels of energy efficiency, enforcement is problematic.

Thus, effective implementation of a building energy code is one of the most difficult aspects. Policy makers are faced with a myriad of challenges, ranging from disjointed governance structures, under resourced enforcement bodies, to a lack of funding, training and education of stakeholders. The key lesson that can be learnt from the best practice regions is the importance of a well-structured and well-resourced compliance regime that adopts a targeted approach to enforcement and compliance.

If mandatory or stated energy targets are to be achieved, then the actual impact of the policy measures must be individually understood, making monitoring of code compliance a must.

3.5.1 BEEC Case Studies

The countries selected for the case studies have been chosen based on direct experience with the projects, similar climatic conditions, and because they provide a mix of new and established programmes.

Thailand	
Location and Climate	 The Thai economy is the world's 20th largest by GDP at PPP and the 27th largest by nominal GDP. Most of Thailand has a tropical wet and dry or savanna climate type. The south and the eastern tip of the east have a tropical monsoon climate.
Energy Efficiency Building Codes	The first version was introduced in the mid-90s and only applied to existing buildings by providing an energy consumption threshold. The code was expanded (2001-04) to include: 1) buildings in the design stage and a threshold of the total conditioned floor area was defined (> 2000 m2); and 2) new minimum energy efficiency requirements for the building envelope (roof, walls and windows), air-conditioning, lighting and hot service water supply.
Control and Enforcement	Compliance to the code can be achieved by prescribing (meet specified requirements) or by proving performance. For the latter, a public tool was developed by the Ministry of Energy. The updated building codes became compulsory (>2000 m^2) in 2009 and enforcement lies with the technical departments of local authorities. However, the actual compliance is considered weak as the capacity within the local authorities are limited due to a lack of training, resource shortages, and a lack of clear and concise instructions and guidance from the central administration and involved ministries.
Vietnam	

[10] Global Buildings Performance Network (GBPN): Designing and Implementing Best Practice Building Codes: Insights from Policy Makers, July 2014

Location and Climate

The Vietnamese economy controlled by central government five year plans is one of the fastest growing in the world.

The country has a hot sub-tropical climate but with three distinct regions. In the north, which has differences in latitude it does get cold in places but has an average humidity of 84% throughout the year. The central region experiences hot and dry winters, and the south remains hot and humid throughout the year.

Energy Efficiency Building Codes

Voluntary building energy efficiency codes were introduced in 2006. These were updated in 2013 and became compulsory for buildings under design with a total floor area greater than 2500 m². The code sets prescriptive requirements for the building envelope (OTTV or WWR, U-values), air-conditioning, lighting, other electrical installations (pumps, lift, escalators etc.) and hot service water supply. The local Department of Construction, during the permit application process, is required to assess compliance.

Control and Enforcement

Enforcement has been poor due to limited capacity of human resources and a lack of clear and concise instructions from the central administration and related ministries. This is being addressed by the Ministry of Construction in Vietnam which has started conducting comprehensive training activities for practitioners and local government staff. Resource shortages have also been acknowledged and will be addressed by allowing accredited private sector companies to assess compliance.

Denmark

Location and Climate

A high income mixed economy, it is the 18th biggest economy in the world.

Denmark has a temperate climate, characterised by mild winters, with mean temperatures in January of 1.5 °C, and cool summers, with a mean temperature in August of 17.2 °C. Because of the country's northern location, there are large seasonal variations in daylight.

Energy Efficiency Building Codes

Prescriptive building energy efficiency requirements were introduced in 1961, and in 1982 the first performance compliance option was included. In 2005 the code was updated to be an overall performance regulation. The latest code and supporting policy encompasses many progressive and dynamic aspects including mandatory computer modelling, air-tightness testing for all buildings, bioclimatic design considerations, renewable energy included in the calculation, boiler and HVAC testing systems, voluntary low energy classes for buildings (which form the basis of stricter future mandatory requirements) and a national target of 75% less energy to be used in buildings by 2020.

Control and Enforcement

The code is mandatory for residential, commercial and public buildings. Enforcement is undertaken at the local and central level, supported by accredited third-party inspectors. On-site inspections may take place during construction, post completion and even occupancy. Penalties for non-compliance include refusal of permission to occupy or construct.

In 2009, it was decided that governmental energy consumption should be reduced by at least 10% by 2011, compared with the consumption in 2006. Since then, the certificate of public buildings must be put on physical display in the building itself.

South Africa

Location and Climate

A middle-income energy intensive economy, it is the 31st biggest economy in the world.

South African climate is influenced by altitude and surrounding oceans. On the whole, it has a temperate climate with dry winters in the interior and wet summers. The south west has a Mediterranean climate, whereas the east coast enjoys a tropical climate. South Africa is a water scarce country.

Energy Efficiency Building Codes

The 1977 National Building Regulation identifies three routes to compliance: prescriptive, performance and reference building. In 2011, mandatory energy usage for all new buildings were introduced, allowing developers to use one of the three routes to compliance. Under the prescriptive approach the following are targeted (mandatory): roof insulation, 50% of hot water from non-electrical resistance heating (solar water heater, gas etc.), fenestration, shading and walls.

A performance route is also allowed where buildings can simulate performance and pass the regulations based on their theoretical energy savings.

Control and Enforcement

Compliance is monitored by local government's building control officials (BCO's), who are required to ensure that building applications meet the 10400-XA requirements. They are also expected to undertake inspections of completed buildings.

The programme has suffered from the following. First, BCO's were not adequately made aware of the regulations and then not trained. This was corrected post implementation but meant that many buildings were erroneously granted building permits. The second, is that the prescriptive requirements are unreasonably onerous and expensive, while the modelled approach (performance and reference building) set generous maximum values which do not align with the prescriptive. Developers therefore opt to model their buildings to get their building permits with little or no energy savings compared to the base case. Finally, BCO inspections are limited with no repercussions to non-compliant buildings.

3.6 Competence of Local Authorities in Implementing BEEC

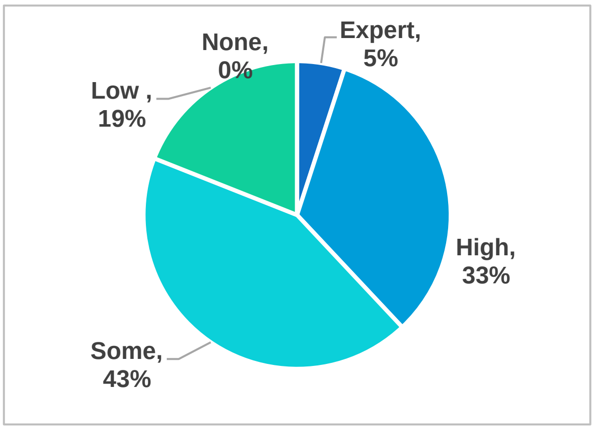
To accurately assess a building's energy efficiency credentials, a minimum level of understanding and competence of the basic principles within the topic are required. Under the existing process, there is no requirement for project developers to submit any information regarding energy efficiency with their building applications. This would imply that knowledge required for implementing a BEEC may be limited within various local authorities. To establish the level of competency a questionnaire survey was conducted among a selection of technical staff from a local authority in February 2017. The results are summarized below.

Twenty-three respondents from the local authority completed the questionnaire, made up of the following technical backgrounds:

Architects	8
Civil engineers	3
Mechanical engineers	2
Electrical engineers	2
Others (urban planners)	8

3.6.1 General Understanding

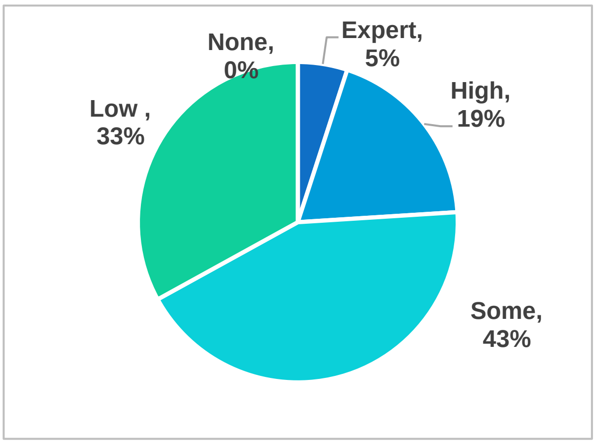
Question 1: *How would you rate your current / general knowledge about energy efficiency in buildings?*



Staff within the local authority believe that they are familiar with the concepts of building energy efficiency. This view was shared across all technical backgrounds with no prevalence from any particular group believing they were stronger compared to others.

Figure 46: Level of competency

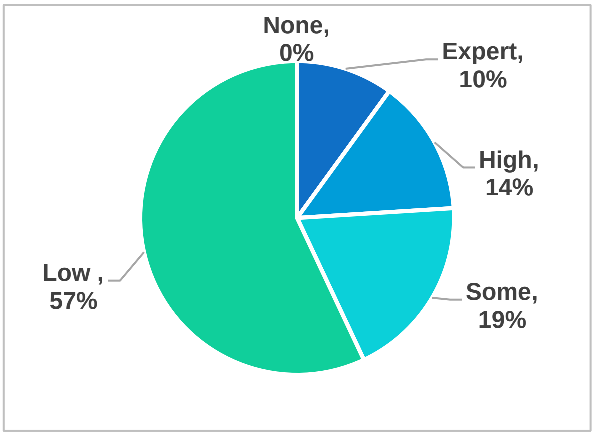
Question 2: *How well would you rate your ability to assess the level of energy efficiency of a building design?*



The groups understanding of energy efficiency gives them the confidence to assess such buildings, however there is a shift towards a lower competency. This suggests that the existing knowledge provides a base level or starting point for training.

Figure 47: Ability to assess energy efficient buildings

Question 3: *The Nigerian building code includes recommendations on green and sustainable building design. How well are you aware of these recommendations?*



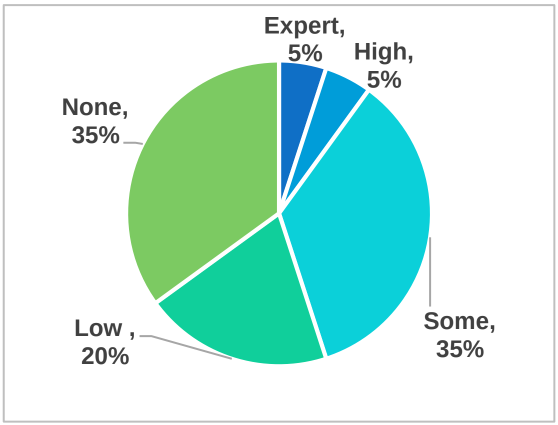
It may be expected that staff have acquired knowledge related to energy efficiency as the Nigerian national building code includes a section on green and sustainable building design. The results indicate that this is not the case. Only few developers are submitting design information that refers to the recommendations on green and sustainable building design. These answers somewhat contradict the answers to the previous question.

Figure 48: Proficiency with green components of existing building code

3.6.2 Technical Competency

The next set of questions were aimed at getting a better understanding of their knowledge of equipment and design features. If staff are expected to undertake compliance checks, then they must have a minimum level of knowledge related to the aspects that need to be appraised.

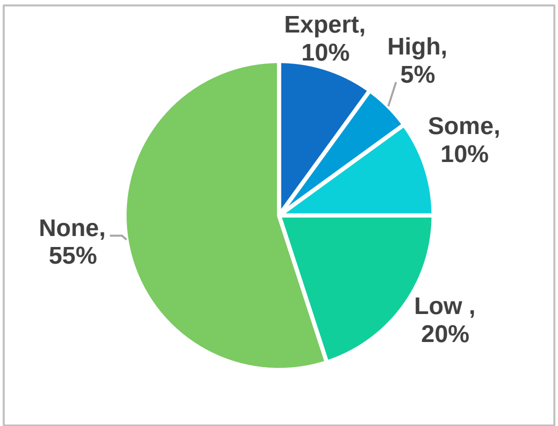
Question 1: *How would you rate your knowledge about lighting power density?*



The results are unambiguous and show that there is a definite requirement for training on this topic.

Figure 49: Lighting power density

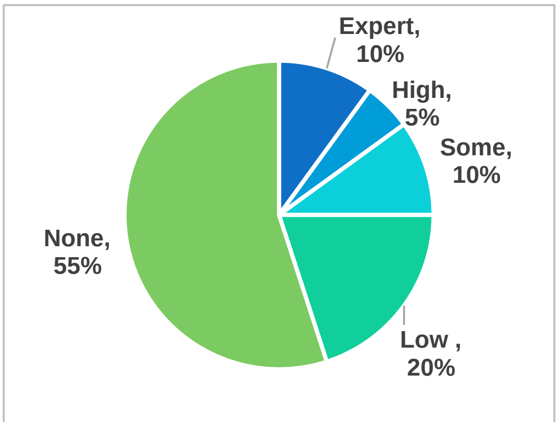
Question 2: *How would you rate your knowledge about performance of air conditioning – specifically coefficient of performance (COP)?*



The level of knowledge with regards to COP of air-conditioning systems has a low score overall. It was engineers that rated their knowledge either as high or as an expert. It can hence be justified that training on this topic would benefit the local authority.

Figure 50: Air-conditioning – Coefficient of Performance (COP)

Question 3: *How would you rate your knowledge about shading coefficient?*



More than half (55%) of the staff at the local authority has responded that they have no knowledge about shading coefficient. As this element is one of the regulated requirements it is clear that the level of knowledge on building envelopes is low and needs to be strengthened. This finding suggests that this would be the case for all passive design features.

Figure 51: Shading coefficient

3.6.3 Final Comments on Questionnaire Findings

The survey did not distinguish between staff that do the desk appraisal of building design and those that are conducting inspections of newly completed buildings. However, as the principles for checking design specifications of building designs and conducting site inspections do not differ much, the same elements covered above apply to site inspections. A final question asked the respondents what training they would deem appropriate.

Table 27: Overview of training needs according to respondents

Content of training courses	Yes (out of 23)
Overall approaches and concepts of energy efficient building design	16
Passive design approach (building orientation, shading, WWR etc.)	14
Building envelope / construction materials, insulation, window types	14
Lighting systems (natural and artificial)	14
Air-conditioning and ventilation	8
Service water installation (hot water)	9
Electrical appliances for households	8
Electrical appliances for office buildings	7
Energy management in buildings	16

The responses show that the greatest need for training relates to passive design elements, and then energy management in buildings. The active design topics such as lighting, AC and other electrical household or office appliances have a lower score. However, based on the responses to the direct question on lighting and AC (Figure 50 and Figure 51), it is concluded that comprehensive training is needed for all the building elements required for compliance with the BEEC – Window to Wall Ratio, shading, lighting, roof insulation, and air-conditioning.

3.7 Implementing Control Procedures for Verification

Before proposing a process, it is necessary to identify project risks or areas which can be easily exploited. Table 28 has been compiled based on experience, research and consultations with Nigerian stakeholders and summarises the most likely risks that this project is likely to face with mitigation actions. Table 29**Error! Reference source not found.** proposes a high-level application process identifying appropriate documentation for verification.

Table 28: Risk matrix and proposed mitigation measures

Risk	Description	Proposed Action to Mitigate Risk
False Information	Installation of products below the minimum requirement to reduce costs (40 mm of roof insulation instead of 50 mm).	Detailed procedures which eliminate ambiguity, and training of the local authority staff.
Product Standards	The code is specific on minimum requirements for installations, i.e. COP values and inverter type AC and K-value for roof insulation. These values are based on international norms and the onus is on manufacturers to demonstrate, through credible and independent information, that their products are compliant.	Training of the local authority staff to capacitate them to interpret product data sheets.
Incentive	The non-financial incentive of an expedited process is being offered to attract participation. Developers may use this to expedite their project, with no intention of compliance, and then pull out of BEEC when they have achieved their objective.	Imposition of a fine or suspension of building permit if developer pulls out of programme after a given time period or after they have failed to correct.
Project Information	The onus lies on the local authority to capture and store project information, this requires well documented processes and systems.	Analysis of the local authority processes to develop new procedure and forms.
Labels	There is a concern that fraudulent labels may be printed and attached to buildings.	Publicly available database of certified projects, project developers found to transgress may be blacklisted.
Lack of Resources – Financial	The programme will require additional input and effort from the local authority. This includes additional tasks, site inspections, training, implementation of new procedures and systems, etc..	Commitment from ministry that funding will be made available.

Table 29: Suggested BEEC application process (Abuja example)

STAGE	ACTION	DOCUMENTATION
Application	1. Developer declares intention to participate and states level of intended complaince 2. Application reviewed – approved or returned for corrections or additional information 3. Building Permit application process expedited	1. BEEC form submitted with building permit Application 2. DoDC records submission on internal database
Construction	1. Developer to comply with prescriptive requirements 2. Evidence submitted to DoDC (invoices, performance sheets, product certification, photographs etc)	1. DoDC to evaluate and capture submitted declarations Acknowledgement of receipt to be sent to developer
Site Inspection	1. DoDC may undertake a site inspection to ascertain that the developer is complying with agreed to prescriptive requirements for example, check thickness of roof insulation. This is an opportunity to provide guidance	1. Findings and outcomes recorded on project application form
Final Declaration	1. On building completion, developer submits outstanding documentation and a final declaration stating that the prescriptive requirements for applied rating have been met	2. DoDC captures information to ensure all requirements have been met. If not, request for additional information. If yes, acknowledgement of receipt
Ex-ante inspection	1. DoDc conducts a final site inspection to confirm compliance. If non-compliant, corrective measures are advised but developer to pay fee (penalty) for next inspection. If compliant, certificate and label issues	1. DoDC updates and closes project on database 2. Project is uploaded on a publicly available website, which states: type of building, address and rating achieved.

3.8 Training Requirements

A review of the existing local authority building application process was conducted to assist with integrating the BEEC into their internal processes. This required the consulting team to sit in and observe the local authority adjudicating a building submission. The process to include BEEC checks into the local authority work stream includes the creation of new forms, developing the various steps to ensure applications are speedily but accurately processed and identifying needs for new equipment, IT programmes (i.e. database) and staff resources.

Based on the results of the survey, review and on previous missions to Abuja, training required for the BEEC will be split into two distinct phases.

3.8.1 Building Physics Training

This will focus on the core concepts of energy efficiency in general and would include inter alia:

- Elements that make up a buildings energy building performance
- How building fabric impacts comfort and energy from AC
- Understanding building and zone energy balances
- Understanding how climate affects energy efficiency
- Understanding how AC works

The initial training on building fabric will equip local authority staff with the necessary background to tackle the next stage of training.

An exam or test can be set at the end of this training with participants being able to move onto the next stage of training only after passing the first stage.

3.8.2 BEEC Specific Training

After training on general concepts, staff will undergo training that pertains to the specific requirements of the BEEC.

- For the prescriptive route to compliance, this will include:
- How to use BEEC calculation sheets
- Recognising correct details pertaining to BEEC on drawings
- Spot checks for all items
- Recognising different types of equipment (i.e. how to tell if a unit is an inverter type or not)
- How to use new forms and procedures to process applications, track progress and keep a database

For the performance route to compliance, training will include the items mentioned above, along with:

- Recognise applicability of software package used
- Understanding the method by which the project complies. I.e. if the project passes because it has lighting that is a significant improvement on the BEEC baseline but has not adhered to the AC or WWR requirements, will the results be acceptable or will the project have to be rejected.

At the end of this training, another exam or test can be undertaken, with staff members only being allowed to process BEEC applications if they hold this minimum qualification.

The training mentioned above can also be provided for professionals working in the industry to ensure they are conversant with the requirements of the BEEC.

This will support the authority with the practical implementation of the BEEC and allow for another level of quality control.

4 Calculations and Tools

As an alternative to the prescriptive route to compliance, a performance route has also been developed. This entails creating simulation models of the proposed developments and comparing the energy performance of the design building to one that meets the minimum code requirements. This method allows a building to deviate from the prescriptive requirements whilst still achieving the overall aim of reducing energy use when compared to a business as usual solution.

The items available for trade-off are listed below:

- Internal lighting
- External wall construction
- Roof construction
- Glazing ratios and shading
- Cooling system

This chapter deals with the investigation of various software products in order to determine the most appropriate ones for use by projects pursuing the performance route to compliance.

Key outcomes for this chapter are listed below:

- Nomination of 5 software tools to be analysed
- Analysis of deviation of results
- Sensitivity analysis of 5 software tools
- Nomination of 3 recommended software tools to be used

Energy analysis software is an essential component of efforts to foster increased energy efficiency in buildings. Choosing the correct tool will be imperative for this project as a software tool will be required for the performance route to compliance. The work done to develop the minimum energy requirements has used state of the art and highly specialized software, however for the mass market this may not be a suitable choice as it will limit the uptake of the building code's performance route to compliance.

Along with the recommendation of tools, a modelling protocol guide has also been developed, this ensures that all buildings follow the same procedures for modelling (electronic Annex 3).

The Software Tool Passive House Planning Package (PHPP) was also analysed but excluded from further consideration due to the following reasons:

Although the research and development over many years which is invested in the PHPP has produced a design standard which accurately resolves building physics and facilitates highly energy efficient built environment outcomes, there are noted limitations to the broad application of the PHPP as a performance based regulatory evaluation tool.

Fundamentally, the PHPP combines the results of detailed analysis conducted using other software, namely the results of detailed 2D heat transfer modelling.

Unlike other performance based evaluation software, this necessitates an additional level of analysis which must be conducted by designers and/or authorities to facilitate accurate input into the PHPP to produce accurate and meaningful results and representations of design initiatives.

The burden of this additional analysis in some developed markets (notably Central Europe) has been mitigated through the development of resources of standard construction details and products which have been pre-certified for application within Passive House projects. This simplifies the application of the Passive House standard and the accuracy of the PHPP. In other markets, the prevalence of such resources and products are likely to be significantly less or non-existent. It is highly likely that the application of the PHPP in less developed design and construction markets would add significantly to the time required to develop a suitable design, and also result in a higher level of skill and understanding of heat transfer and building physics for designers and authorities.

The accuracy of the PHPP to generate robust and reliable outcomes for the application of the Passive House standard is a product of the validity of the calculation methods when all criteria are achieved. This is in large part associated with the airtightness provisions and detailed secondary analysis of thermal bridges, removing significant uncertainty typical of other design evaluation tools. Removing the uncertainty of heat transfer associated with infiltration and thermal bridges enables the application of simple steady-state calculations which produce accurate outcomes. However, should the airtightness and thermal bridge criteria not be achieved or secondary analysis not be undertaken, significant uncertainty is likely to be introduced and inaccuracies in the application of the PHPP.

The PHPP itself, although a Microsoft Excel based tool, is a comprehensive spreadsheet. The many multiple data entry options and required completion of the full spreadsheet in order to generate a result would likely be highly problematic as a tool intended for mass-market uptake as a local building performance based regulation tool. The PHPP necessitates extensive training to educate users both on the underlying building physics principles and the correct use of the tool.

Although simplifications could be developed, including pre-calculated standard construction details or default values for certain variables (such as thermal bridge values), it is unlikely that these would adequately cover the scenarios necessary for a mass market performance based regulatory evaluation tool. Such simplifications would also undermine the accuracy and intent of the PHPP, such that alternative tools may provide the same outcomes with better propensity for mass-market uptake.

Although its origins lie within the residential market of Central Europe, the Passive House standard and the PHPP can theoretically be applied to non-residential building types, the heat balance calculations completed by the PHPP are sufficiently sensitive such that accurate calculation of internal gains associated with non-residential building types would be required, again adding an additional level of analysis complexity to correctly use the PHPP.

4.1 Software Packages

The packages investigated are listed below:

- Designbuilder
- Equest
- HAP
- Matchbox
- Open Studio

Of the five packages, only HAP is used in Nigeria. This represents a significant challenge since it means there is currently limited expertise on modelling in the country. This issue is further compounded by the fact that in general, the more user friendly and intuitive software packages are the most expensive ones. The criteria for evaluation have been simplified to items as per the table below.

Table 30: Sensitivity analysis for various modelling software

Item	Requirement
Weather files/Climatic Inputs	Able to input detailed weather files. Either by request to software vendor or by converting standard weather file formats.
Cost	This is the most important factor to be considered if the modelled route is to be available for the mass market. Cost cannot be a limiting factor.
Ease of use/User interface	Method of input to be intuitive for new users, allowing them to quickly understand how to use the software.
Passive Design	Ability to correctly model passive design elements.
Simulation engine	Accuracy of simulation results and type of simulation engine/calculations.
Outputs	Manner of outputs should be such that it is easy for users to interrogate results or present findings.

4.1.1 DesignBuilder

Cost: EUR 1051 (once off)

This is an advanced integrated software package that can be used for not only energy modelling but also system sizing, daylight modelling and thermal comfort analysis. It is a front end software for EnergyPlus. EnergyPlus is the most advanced and well researched simulation software available worldwide, it has been developed by the United States Department of Energy and is available for free. It does not however have a graphical user interface and many software packages have been developed to be used as a front end for EnergyPlus of which DesignBuilder is one of them.

Method of input: 3D model is drawn based on architect’s drawings. Material properties are added from the software’s database or users can create their own materials.

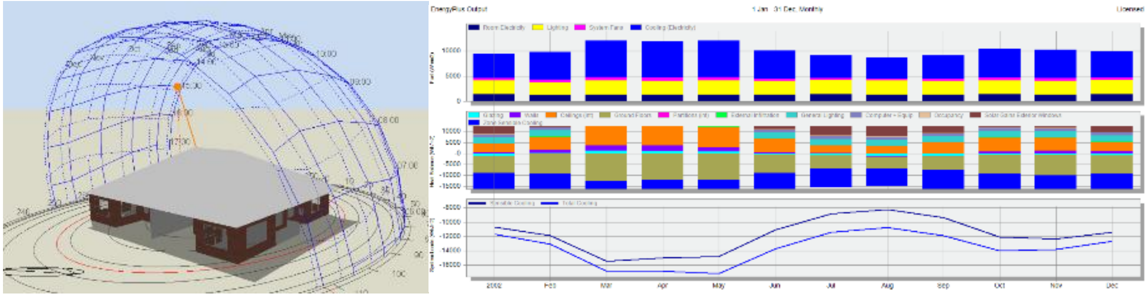


Figure 52: DesignBuilder model image and output example

DesignBuilder/EnergyPlus uses the heat balance method and also performs radiant and convective calculations at each surface. It can therefore model complex building issues like thermal mass effect more accurately. This is currently the most advanced and researched simulation engine. Its only drawback is that EnergyPlus in its native state does not have a user interface and users edit a text file. Any software package that uses EnergyPlus as a simulation engine therefore has access to the best simulation engine possible.

For a BEEC it could be that the software provides significantly more than what is required for compliance.

4.1.2 eQUEST

Cost: Free

eQUEST® is a widely used whole building energy performance design tool. Its wizards, dynamic defaults, interactive graphics, parametric analysis, and rapid execution make eQUEST able to conduct whole-building performance simulation analysis throughout the entire design process, from the earliest conceptual stages to the final stages of design.

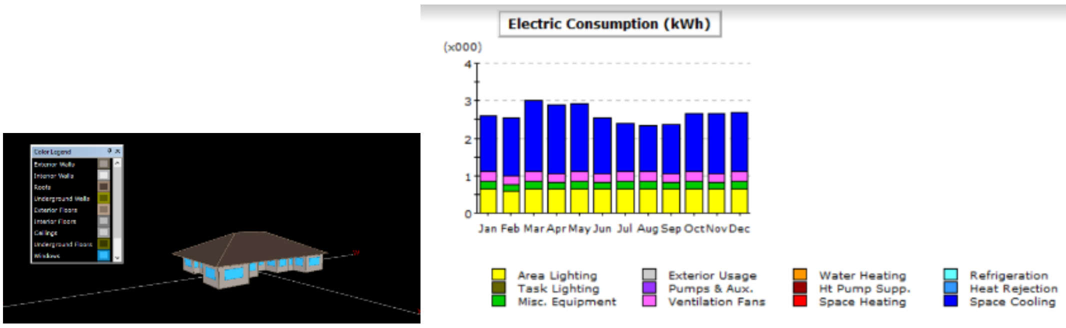


Figure 53: eQUEST model image and example output

The simulation used in eQUEST is called DOE-II.

eQUEST's simulation engine, DOE 2.2, was the first simulation engine developed in the 1970s, many simulation engines developed since have made use of it as a basis for their software (including EnergyPlus). DOE-2.2 uses the transfer function method with custom weighting factors. This method is an approximation of the heat balance method used in EnergyPlus and is less accurate.

In terms of software available for free, eQUEST is a very powerful option for users. It's main drawback is that there is no version that gives metric units. Despite this drawback it is still a very good option for a BEEC.

4.1.3 Hourly Analysis Program (HAP)

Cost: 350 EUR (once-off)

Hourly Analysis Program (HAP) is an energy modelling and AC cooling load calculation program developed by Carrier. It is one of the few software packages currently being used in Abuja.

The software does not have a 3D user interface, information is entered one space at a time using different input sheets.

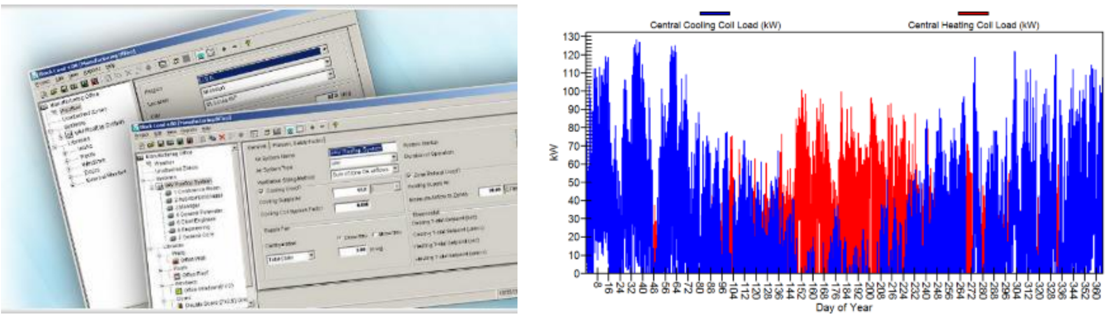


Figure 54: HAP model input and example outputs

HAP uses ASHRAE Transfer Function method as per eQUEST. Whilst the simulation engine is industry standard, the method of input is prone to errors. Furthermore, the outputs do not give the user any kind of feedback to understand the performance of the building.

4.1.4 Matchbox

Cost: 800 EUR (once-off)

Matchbox is an energy calculation tool which offers a basis for communication between design consultants throughout the design process. The software was developed to enable the delivery of low energy buildings, by enabling designers to visualize and track the energy effects of their decisions from the initial stages of design to completion.

The software is an online solution which means simulations are run in the cloud and do not require the user to have a powerful PC for modelling. Method of input is via tabs for various building elements rather than a 3D model.

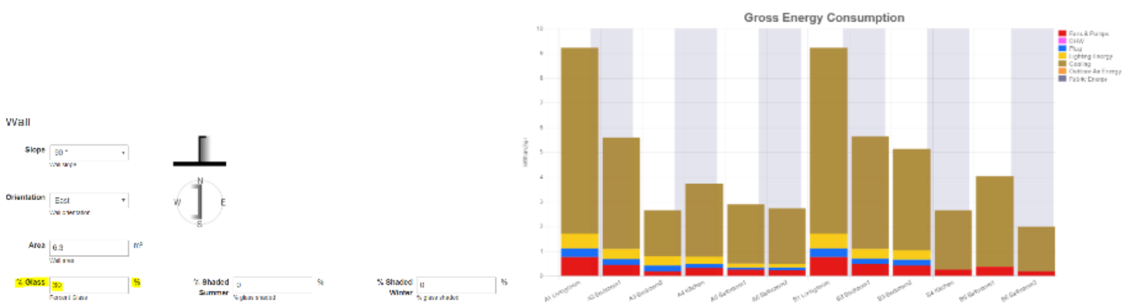


Figure 55: Matchbox inputs and example outputs

The simulation engine uses a bespoke calculation method based on the ASHRAE transfer function.

A unique feature of this software is that because it is online, it is possible to purchase a 'country' or 'state' licence. This means that the government or GIZ can pay for a licence and a large number of professionals, including Development Control will have access to it. This would be an advantage since cost would not be a factor anymore and results can be stored in a central database, allowing clients, development control, donors etc. to have access and be able to check what the submitted performance of buildings.

4.1.5 OpenStudio

This is a free plugin for sketchup that makes use of the EnergyPlus simulation engine. All the benefits of EnergyPlus are available for the user. Since sketchup is also available for free and used by many architects already, the intent was that it would not be a big jump for architects and engineers to start using the plugin for energy modelling.

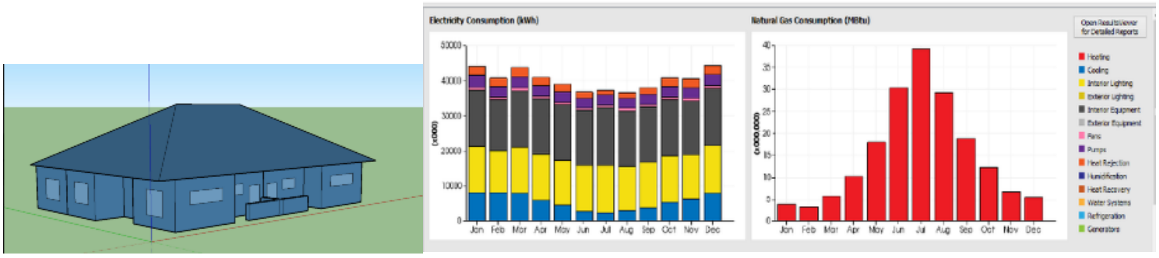


Figure 56: OpenStudio model image and sample outputs

The same simulation engine as DesignBuilder is used. It can only be used for energy calculations though whereas DesignBuilder can be used for daylight modelling. OpenStudio requires a bit of effort to come to terms with but since it is free, it is an excellent option for a BEEC.

4.1.6 Sensitivity Analysis

The software packages were tested by modelling the duplex bungalow used in Chapter 1. Results are shown below. All models were run using the simulation guide provided with the BEEC (electronic Annex 3).

Table 31: Sensitivity analysis for various modelling software

	DesignBuilder		HAP		Equest		Matchbox		OpenStudio	
	BAU	BEEC	BAU	BEEC	BAU	BEEC	BAU	BEEC	BAU	BEEC
Cooling (kWh/m²/year	80	52	160	120	90	65	99	74	74	48
Lighting (kWh/m²/year)	33	15	32	14	33	15	33	15	33	15
Total (kWh/m²/year)	114	67	192	134	123	80	132	89	107	63
% Saving	41%		30%		35%		33%		41%	

The results were as expected given the analysis of input methods and simulation engines presented briefly.

Designbuilder and Open Studio – These use the same simulation engine. Differences in results are due to methods of inputs. DesignBuilder has an easier to use interface for adding geometry to the model.

HAP – HAP is known to overestimate results. This is due to not having many options for inputing shading and not being able to account for thermal mass accurately.

eQUEST – eQUEST results were within expected limits when compared to software that uses EnergyPlus as its simulation engine. Shading can be captured accurately so the only source of error is accounting for thermal mass correctly.

Matchbox – Shading in Matchbox is handled better than in HAP, although since there is no 3D model, complex shading is difficult to include in the model.

4.1.7 Ranking of Solutions

The scale below was used to rank software according to the various criteria:

1 - Poor

2 - Satisfactory

3 - Good

4 - Very Good

5 - Excellent

Table 32: Software comparison table

Criteria	Design Builder	HAP	eQUEST	Matchbox	Open Studio
Weather Inputs	4	4	4	4	4
Cost (1-most expensive, 5-free)	1	4	5	3	5
Ease of use/User interface	4	2	3	3	4
Passive design	4	2	3	4	3
Simulation engine	5	2	4	4	5
Outputs	5	3	5	5	5
Weather Inputs	**23**	**16**	**24**	**23**	**26**

Based on the table above three packages are chosen to be recommended for use in Nigeria:

- OpenStudio
- eQUEST
- Matchbox

Although DesignBuilder and Matchbox have the same score, Matchbox was chosen as one of the recommended packages due to the ability to set up a country wide database of results and licence.

4.1.8 Energy Modelling Guide

A detailed energy modelling guide has been developed and provided as part of this project (electronic Annex 3).

This will ensure that all projects that follow the performance route to compliance will have the same inputs in terms of items listed below:

- Setpoint temperatures
- Schedules of operation
- Reference building construction

5 Conclusion

All the items described above have been used to develop a National Building Energy Efficiency Code that can also be used by any State in Nigeria. This report is to be read in conjunction with all documents provided as part of the scope in the development of this building energy efficiency code. These are listed below:

- Building Energy Efficiency Code
- BEEC calculator spreadsheet and manual
- BEEC energy modelling simulation input protocol guide

•

6 References

[1] Building Energy Efficiency Guideline for Nigeria (BEEG); Federal Ministry of Power, Works and Housing (Housing); June 2016

[2] Nigerian National Building Code 2006

[3] Energy Efficiency in Buildings (EEB) in Selected Sub-Sectors of the Nigerian Building Sector: Development of recommendations for interventions to promote energy efficiency in buildings incl. appendices; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; December 2013

[4] Institutional and Policy Mapping of the Renewable Energy, Energy Efficiency and Rural Electrification Sub-Sectors in Nigeria; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH; November 2013

[5] National Renewable Energy and Energy Efficiency Policy (NREEEP); Ministry of Power, Federal Republic of Nigeria; 2015.04.20

[6] Modernising Building Energy Codes to Secure our Global Energy Future; The IEA Policy Pathway series; International Energy Agency (IEA); 2013

[7] Designing and Implementing Best Practice Building Codes: Insights from Policy Makers; Global Buildings Performance Network (GBPN); July 2014

Abbreviations

AC	Air-conditioning
AMMC	Abuja Metropolitan Management Council
ASHRAE	American Society for Heating Refrigeration and Air-conditioning Energy
BAU	Business As Usual
BEEC	Building Energy Efficiency Code
BMO	Business Membership Organisations
COP	Coefficient of performance
DCM	Development Control Manual
DHW	Domestic Hot Water
DoDC	Department of Development Control
EER	Energy Efficiency Ratio
EU	European Union
FAR	Floor-to-Area density
FCDA	Federal Capital Development Authority
FI	Financial Incentive
FMPWH	Federal Ministry of Power, Works and Housing (Housing)
K	Kelvin
LPD	Lighting Power Density
m^2	Square meter
NESP	Nigerian Energy Support Programme
PHPP	Passive House Planning Package
SANS	South African National Standards
SHGC	Solar Heat Gain Coefficient
SWH	Solar Water Heating
W	Watt
WWR	Window to Wall Ratio

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List of Tables

Annex 1 Results of Parametric Study

The following graphs show some results of the Parametric Study used to develop the benchmark models.

Annex 2 BEEC Calculator

The BEEC Calculator is available only in electronic format.

Annex 3 BEEC Modelling Protocol

The BEEC Modelling Protocol is available only in electronic format.

Energy Saving over Regulated Loads – Duplex Bungalow

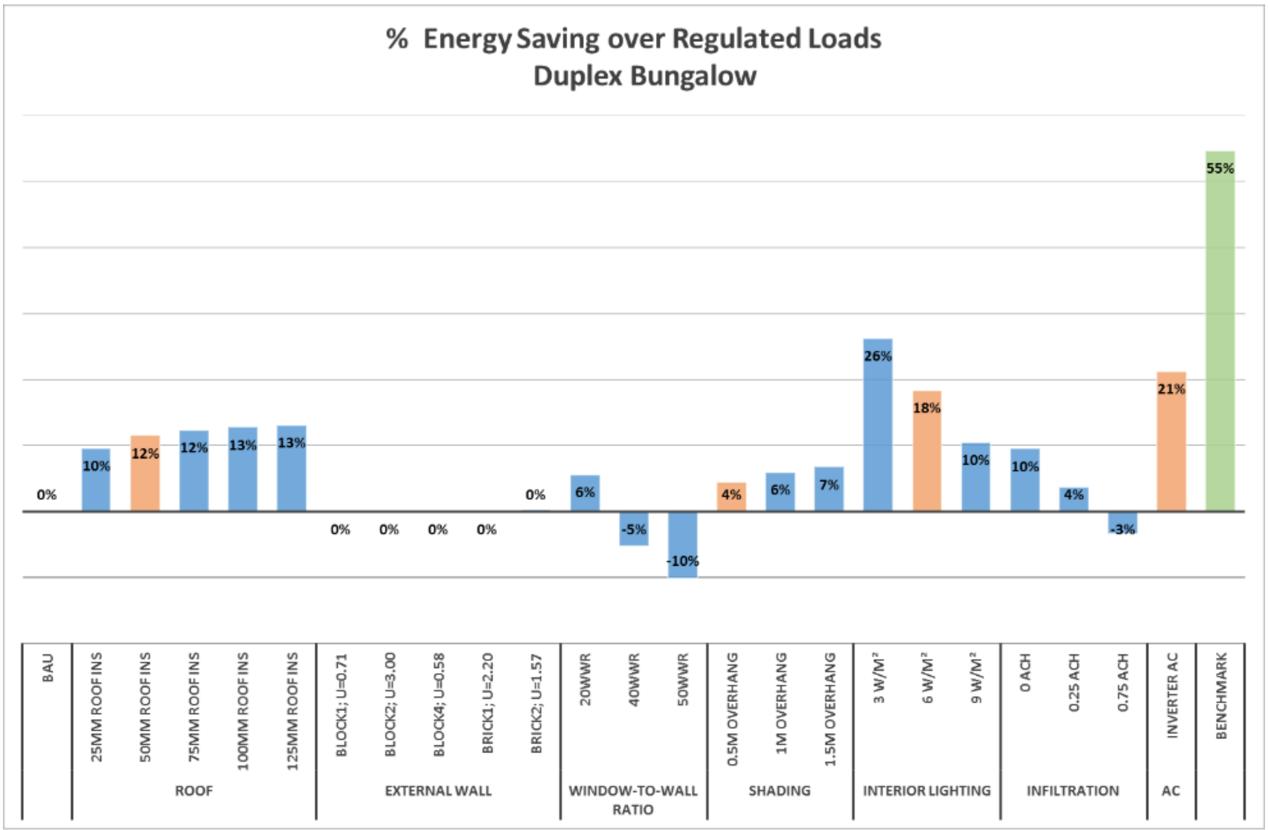

Figure 57: Graph showing energy savings from various interventions – duplex bungalow

The blue bars represent various iterations that were tested but not considered for the benchmark model.

The green bar shows the cumulative impact of all the regulated items on energy saving over the business as usual option.

The orange bars show the items that were chosen for the BEEC benchmarks.

A negative number equals an increase in energy consumption.

The graph shows that a significant annual energy saving can be made by changing from current construction practices to ones compliant with the draft BEEC. In the model a saving of 55 % was reported.

Peak Load Saving over Regulated Loads – Duplex Bungalow

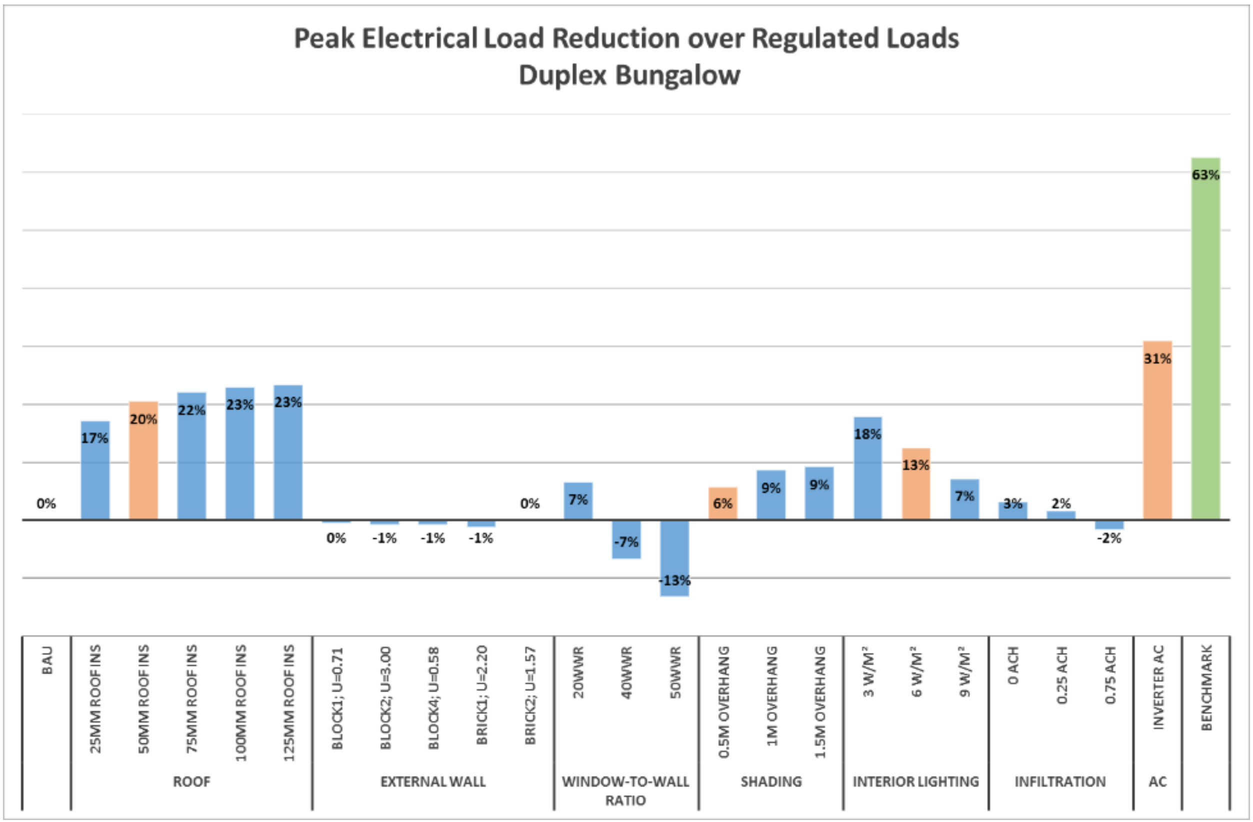

Figure 58: Graph showing peak electrical load savings from various interventions – duplex bungalow

Energy saving and peak load savings are both addressed by the BEEC. A negative number equals an increase.

The green bar shows the cumulative impact of all the regulated items on peak electrical load requirements. The orange bars show the items that were chosen for the BEEC benchmarks.

The graph shows that a significant peak electrical load saving can be made by changing from current construction practices to ones compliant with the draft BEEC. In the model a saving of 63 % was seen.

Peak load saving is very important as it reduces the requirement for electrical infrastructure and can produce capital cost savings from the outset on a project, i.e. smaller generator can be purchased.

Energy Saving over Regulated Loads – Multi Unit Apartment

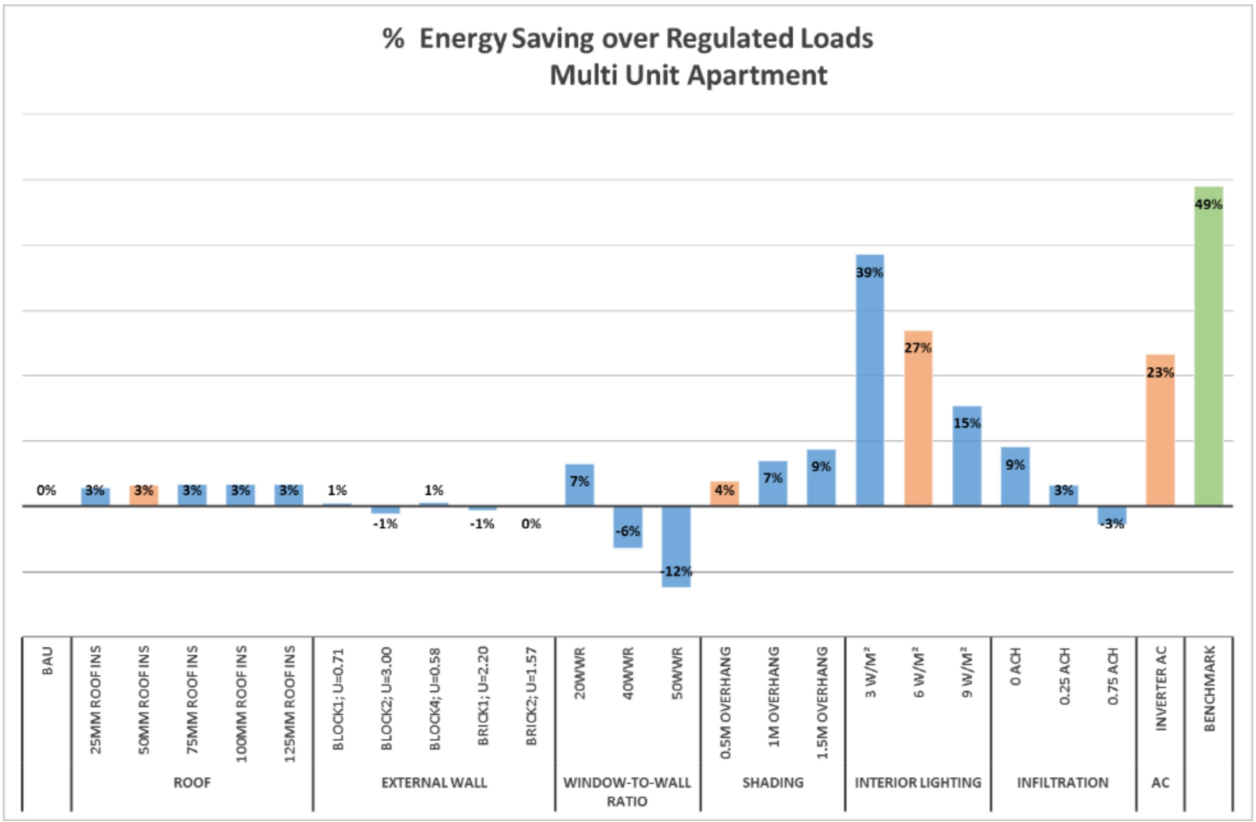

Figure 59 Graph showing energy savings from various interventions – Multi-unit apartment

The blue bars represent various iterations that were tested but not considered for the benchmark model.

The green bar shows the cumulative impact of all the regulated items on energy saving over the business as usual option.

The orange bars show the items that were chosen for the BEEC benchmarks.

A negative number equals an increase in energy consumption.

The graph shows that a significant annual energy saving can be made by changing from current construction practices to ones compliant with the draft BEEC. In the model a saving of 49 % was seen.

The apartments have 3 to 4 floors, therefore savings from roof insulation are less than those of a single storey building.

Peak Load Saving over Regulated Loads – Multi Unit Apartment

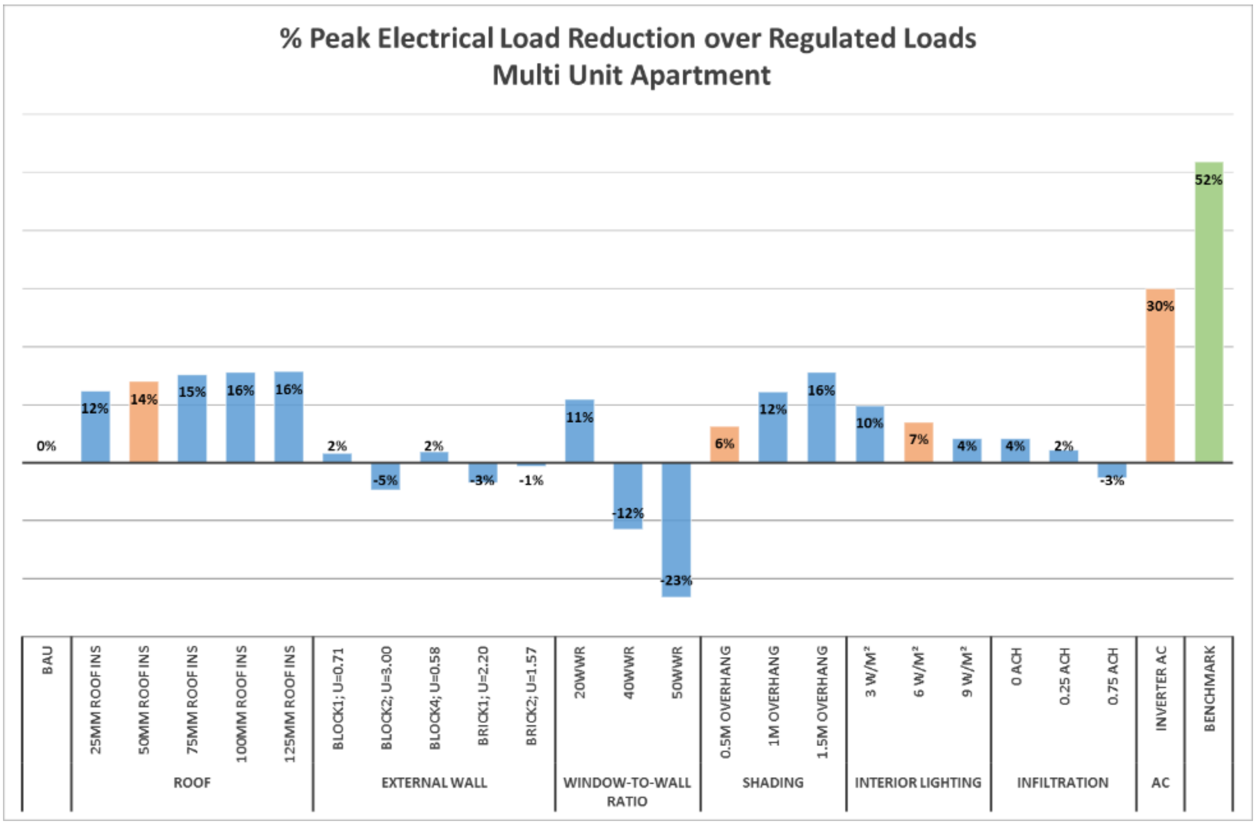

Figure 60: Graph showing peak load savings from various interventions – Multi-unit apartment

Energy saving and peak load savings are both addressed by the BEEC. A negative number equals an increase.

The green bar shows the cumulative impact of all the regulated items on peak electrical load requirements.

The orange bars show the items that were chosen for the BEEC benchmarks.

The graph shows that a significant peak electrical load saving can be made by changing from current construction practices to ones compliant with the draft BEEC. In the model a saving of 52 % was seen.

Peak load saving is very important as it reduces the requirement for electrical infrastructure and can produce capital cost savings from the outset on a project, i.e. smaller generator can be purchased.